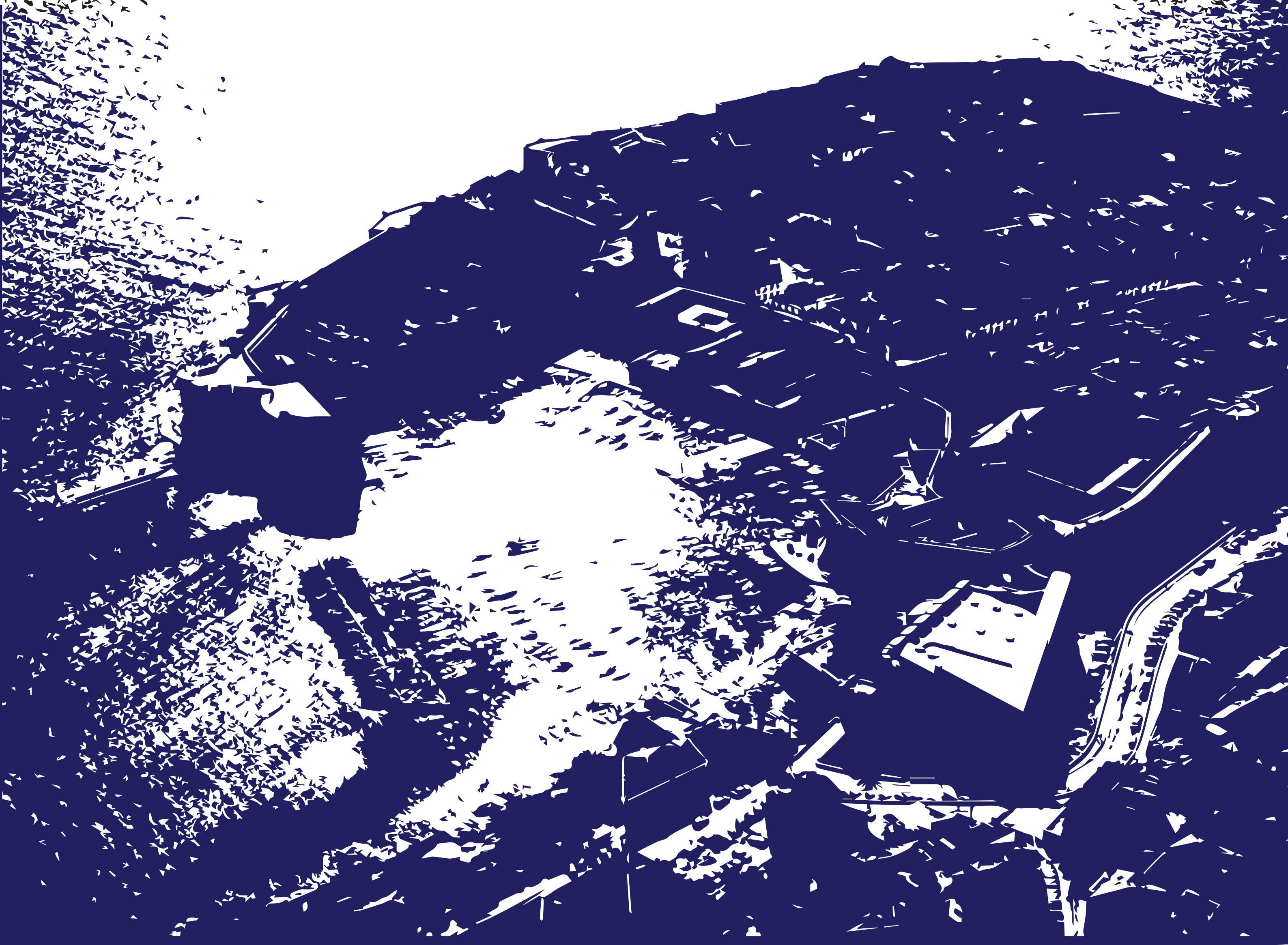

NAŠE MORE 2023

3rd International Conference of Maritime Science & Technology

CONFERENCE PROCEEDINGS

SVEUČILIŠTE
U DUBROVNIKU
UNIVERSITY
OF DUBROVNIK

Dubrovnik, 14 – 16 September 2023

University of Dubrovnik
Maritime Department

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SUSTAINABLE SHIP RECYCLING – CURRENT SITUATION IN INDIAN SUB-CONTINENT

Chavdar Alexandrov
Technical University-Varna, Bulgaria
E-mail: ch.alexandrov@tu-varna.bg

Nikolay Ivanov
Technical University-Varna, Bulgaria
E-mail: n.evgeniev@tu-varna.bg

Iglika Ivanova-Slavova
Technical University-Varna, Bulgaria
E-mail: iglika_iv_slavova@tu-varna.bg

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Abstract

In the last decade, much has been done to improve the ship-breaking worldwide. It has become a necessary trend to recycle as many elements of a vessel's equipment and structure. Nowadays we talk about refurbishing and reusing spare parts, recycling a ship's steel structure and completely recycling a vessel. But such an ambitious endeavor cannot be accomplished without implementing an entirely new approach to the matter. Forming of a ship recycling industry to replace the traditionalship-breakings could prove challenging. The present article aims to present how much the process has evolved and what the main challenges and obstacles are in fully implementing the idea of ship recycling.

Key words: Shipping Industry, ship recycling, Hong Kong Convention, EU RSS

1. INTRODUCTION

With the growing concern for the global warming effect and other climate warnings, the problem with environmental protection is becoming increasingy important by the minute. The protection of marine environment is not less important than the protection of other major wildlife habitats worldwide. And there is a good reason for this, many researches have shown significant decline in quality of life for sea organisms caused by a variety of factors, all of which are the direct result of human activity. The global warming, causing the rise of water temperature, is one problem, but the pollution of sea waters is the other equally troublesome reason for the decline in sea life [2, 3].

One of major contributors to the pollution of the World Ocean is the shipping industry, and in particular, the ship dismantling industry, which takes place directly on the beaches of the Indian Sub-continent, hence called "beaching". In addition to its harmful effect on the environment, beaching is, even though it is one of the major occupations for the residents in the area, extremely dangerous for workers involved in the direct dismantling of vessels.

Looking for a solution to the problems resulting from the way the process is carried out, the IMO adopted in 2009 "The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships" which was developed in collaboration with the International Labor Organization and the "Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal" [4].

The Convention aims to address the problems, arising from ship recycling, and the handling of environmentally hazardous substances, such as but not limited to:

- asbestos and asbestos based materials
- hydrocarbons and other fuel materials
- ozone depleting substances such as cooling agents and some types of aerosols
- heavy metals waste materials containing lead, mercury, as well as other toxic materials

All these dangerous byproducts may be a direct residue form scrapping of ships. All of the addressed concerns focus on the working conditions and state of the environment in many of the recycling facilities around the world [6].

The Hong Kong Convention is a direct result of the "Global Program for Sustainable Ship Recycling".

Launched in 2007, the main objective was to improve worker health and safety and environment in the countries of South Asia that are part of the ship recycling industry.

Figure 1 Gadani Shipreaking site, Pakistan

Source: https://tribune.com.pk/story/1491772/gadani-ship-breaking-yard-among-top-hazardous-workplaces-ntuf

2. A BRIEF DESCRIPTION OF SHIP RECYCLING AS A PROCESS. MAIN SITES FOR DISMANTLING AND RECYCLING OF SHIPS

Ship recycling is essentially the dismantling of obsolete vessels for recycling and disposal, usually on a beach, in dry dock or a pier. This is one of the major industries in South Asia, whose leading countries are India, Bangladesh and Pakistan, and employs hundreds of thousands of workers. It is also a valuable source of steel. In general, the process is sustainable, as more than 95% of the ship's structure and equipment can be recycled [6]:

- steel is usually reworked for use in construction;
- machinery and equipment that are in good condition can be refitted;
- oils and fuels can be reused and if needed recycled.

Ship recycling countries have a major role in the global economy by recycling ships that can no longer be operated. The alternative would be to abandon or sink them.

Let us take a closer look at the particularities that make up the shipbreaking industry in the Indian subcontient.

2.1. India

There are many locations along the coast of India where ship recycling activities are carried out. The most important center is in Alang-Sosiya in the Gujarat Province. The first records of shipbreaking in India show it began in 1912 in Kolkata and Mumbai (Kumar, 2009), with actual commercial ship recycling beginning in the 1980s with the breaking of the MV Kota Tenjong (Misra, 2009b). Not long after, the recycling operations increased in numbers, from the initial 5 ships broken down in Alang in 1982-1983, to 51 ships in 1983-1984, reaching 601 ships in 1991-1992. It should be mentioned that the volume of ships broken down until the late 1990s on Indian coasts was considerably smaller compared to today (see Figure 2), mainly because China was still considered a popular destination for shipbreaking. India joined the ship recycling business in the 1980s, and reached its peak in the late 1990s, processing more than 60% of the world's deadweight tonnage sent for dismantling. Not long after that, India began to lose its market share to Bangladesh and Pakistan due to their more aggressive bidding (Reddy and Manoharan, 2014). In addition, because of the guidelines on shipbreaking, released in 2003 by the Indian Supreme Court, there was an increase in environmental regulations compared to Pakistan and Bangladesh, which served to further undermine India's leading position in the South Asian shipbreaking industry. Shipbreaking in India is mainly monitored and regulated by the Gujarat Maritime Board (GMB), which is also the owner and landlord of the plots used for ship recycling activities.

At the moment, Alang employs 25,000 to 35,000 staff out of the total 40,000 people who directly work in the Indian shipbreaking industry as whole; also, an estimated additional 100,000-300,000 workers are employed in various activities connected to shipbreaking (Reddy and Manoharan, 2014). The Indian ship recycling industry is not only a major employer, but also a leading source of revenues and contributor to India's steel demand: actually, the estimation of shipbreaking activities supply amounts to 7% of the demand. In 2021 an announcement was made by the Indian Finance Minister and the Ports, Shipping and Waterways Minister about a plan to double India's ship recycling capacity by 2024, increasing the country's global shipbreaking market share to 50%. It was estimated that this would create 150,000 new jobs, with the main aim of this plan to 'capture' more ships from Europe and Japan. This is a very ambitious plan, not an easy one to achieve. In reality, the Indian Government is counting on the fact that India has been a member of the Hong Kong Convention since 2019, also HKC being nationally implemented with the 2019 Recycling of Ships Act, and so far about 90 Indian yards have been certified as HKC-compliant by independent certification bodies. A reason why this plan might not achieve the expected results is that, from 2018 onwards, a requirement for European shipowners is in place to demolish their ships only in yards included in EU-approved yards, and so far there are no Indian yards on the European List of Ship Recycling Facilities. Taking this in to consideration, it is unlikely for Indian yards to attract many European ships, unless there is an effort to meet the standards imposed by the European Ship Recycling Regulation (which are more stringent compared to the ones set by the HKC). From the beginning of 2016, cash buyers, shipbreakers' associations and shipowners' associations have tried to 'convince' the EU to include at least some Indian yards in the EU List, but for the time being the European authorities are determined not to lower requirements for issuing EUSRR statements of compliance.

Figure 2 Location of Alang Sosiya

Source: Google Maps

2.2. Bangladesh

Most of shipbreaking activities in Bangladesh are situated in a coastal strip between Sitakunda and Chittagong. The beginnings of the shipbreaking industry in the region were in the early 1960s when, due to a violent storm, the Greek cargo ship MD Alpine became grounded in front of Chittagong (Rabbi and Rahman, 2017). After several failed rescue attempts, it was later sold to and scrapped by the Chittagong Steel House on a nearby beach. That single ship alone was not enough to be the actual beginning of the shipbreaking industry in Bangladesh: there had to be another important event, which was the 1971 war between West and East Pakistan (known as Bangladesh today), with the war leaving many ships damaged and abandoned in the waters of the Bay of Bengal, with access to the port of Chittagong blocked, leaving no choice but to be broken on the local beaches. And lastly, because of China's decision in the 1980s to adopt stricter health and safety controls that made many shipowners to look for other more convenient locations. Over the next years, this transformed the ship recycling from a volatile earning opportunity for a limited number of businessmen into an actual industry demanding the employment of tens of thousands of workers.

Shipbreaking in Bangladesh became an important source of steel and other metals, which are low in supply, as there are no large iron sources in the region, but the demand for steel is high (this need can be partly satisfied by the use of re-rolling mills and steel factories and utilizing scrap metal salvaged from end-of-life vessels). The domestic construction industry uses most of scrap metal obtained through shipbreaking (Sarraf et al., 2010). The percentage of Bangladesh's demand for steel satisfied by shipbreaking is not clear, as it can range from 50% to 80% depending on sources (Sujauddin et al., 2015; Rabbi and Rahman, 2017; Rizvi and Adekola, 2020). In reality, the "small" share of '50% is of vital importance: by estimation of Hoque and Emran (2016), if Bangladesh forced to import all the steel it requires, the cost of about $1.3 billion would be equal to 25% of Bangladesh's 2015 development budget.

The shipbreaking industry is now the second in importance in terms of revenues for the Chittagong Division: actually, the industry pays annually about $120-$150 million in taxes, import duties and other fees (Rabbi and Rahman, 2017). Also, the ship recycling industry in Bangladesh is an important contributor to the job creation, as it is estimated to directly employ around 25,000-30,000 people, and another 250,000 indirectly for various recycling and reselling activities (Hoque and Emran, 2016; Norwegian Maritime Authority, 2021). According to statistics from the International Law and Policy Institute (2016) and to Rabbi and Rahman (2017), the actual number of people directly employed in the shipbreaking industry is between 40,000 and 50,000, across all the 100 registered yards operating in the Sitakunda area. Most of these yards are organized in the Bangladesh Ship Breakers and Recyclers Association.

Figure 3 Location of Chittagong province (marked in red dots)

Source: Google Maps

With time Chittagong has earned its place as one of the major shipbreaking sites, with the help of the Bangladesh Government, by designing it as one of the special economic zones that can foster industrialization (Dewan, 2020). Also, the Bangladeshi ship recycling industry makes use of the lower import customs duties compared to India and Pakistan (Kumar, 2009). As noted by both Kutub et al. (2017) and Dewan (2020), because the local scrapping industry has developed too fast and chaotically, the institutional capacity of monitoring and regulation has failed to keep up the same pace.

2.3. Pakistan

Most of Pakistan's ship recycling activities are located on the 12-km-long stretch of coast near the city of Gadani, in the Balochistan Province (see Figure 4). Before beginning to establish shipbreaking as a steady industry in the early 1950s, Balochistan was no more than a sparsely inhabited backcountry area where mostly small vessels such as barges and fishing boats were recycled. Thanks to the efforts of some of local companies, the shipbreaking area in Gadani made a rapid expansion by the late 1960s. However, the biggest growth of the industry was in the early 1970s when the shipments of steel and iron from newly formed Bangladesh to Pakistan stopped after the 1971 Liberation War. After the local currency was depreciated, Pakistan was forced to look for alternative sources of metals to satisfy its growing domestic demand. In the end, in 1978 the Pakistani Government decided to put in place a set of measures and policies to support the national shipbreaking industry, some of which are the recognition of Gadani beach as a harbor, reduction of import duties, and measures to improve connectivity between the coast of Gadani and the inland areas (Memon and Zarar, 2016). This resulted in Gadani becoming the world's largest shipbreaking area by the 1980s, the employment of more than 30,000 workers and scrapping of the record of 1 million tons a year (Kumar, 2009).

According to statistics from Kumar (2009), by 2009 the yards in Gadani were the source of direct employment of about 5,000 workers, which is considerably less than their counterparts in India and Bangladesh, and also less than 30000 workers that were once employed in the 1980s, during the peak of the Pakistani shipbreaking industry (Sarraf et al., 2010). This difference attributed to the fact that Pakistan has much higher customs duties compared to the rest of the Indian subcontinent, which in turn balances out the lower labor costs. Statistics form the early 1990s show that with the introduction of a 45% customs duty for end-of-life vessels (Sarraf et al., 2010), by the early 2000s most the ship recycling industry in Pakistan had almost completely disappeared. Thanks to lobbying activities carried out by the Pakistan Ship Breakers Association a reduction on taxes and duties was achieved, leading to the industry moderately recovering, but by that time it was already too late: It is because of this Pakistan has yet to be able to catch up to India and Bangladesh. Also because Pakistan frequently experiences power outages due to poor infrastructure, this lowers the productivity of Pakistani scrapyards.

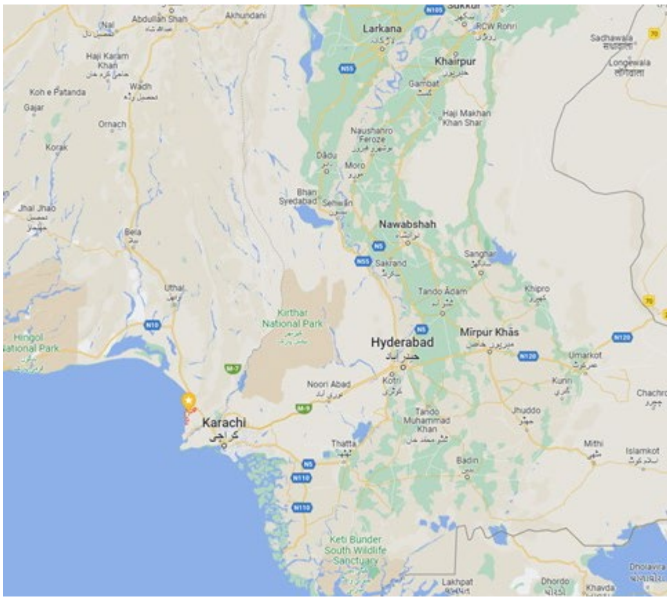

Figure 4 Location of Gadani beach (shown with yellow star)

Source: Google Maps

Despite all the problems, shipbreaking is still one of the largest industries in the Balochistan Province, having employed many locals and also providing a great contribution in tax revenues for the economic development of the region. According to statistics by Memon and Zarar (2016), about 40 plots are operational in Gadani; most of which are privately owned, and the rest is owned and operated by the Balochistan Development Authority (Iqbal and Heidegger, 2013).

However, the international community expresses some concerns, regarding the conditions associated with carrying out the process. The workers' health and safety are not well monitored, workers' injury and illness, sometimes even fatal accidents are commonplace. The environmental protection is not a primary concern, with frequent cases of local air, soil and water pollution. Workers are often not properly briefed that ships can contain highly toxic materials, such as heavy metals, asbestos, PCBs, as well as oils and fuels. As a result, there is limited or no precaution for workers' safety.

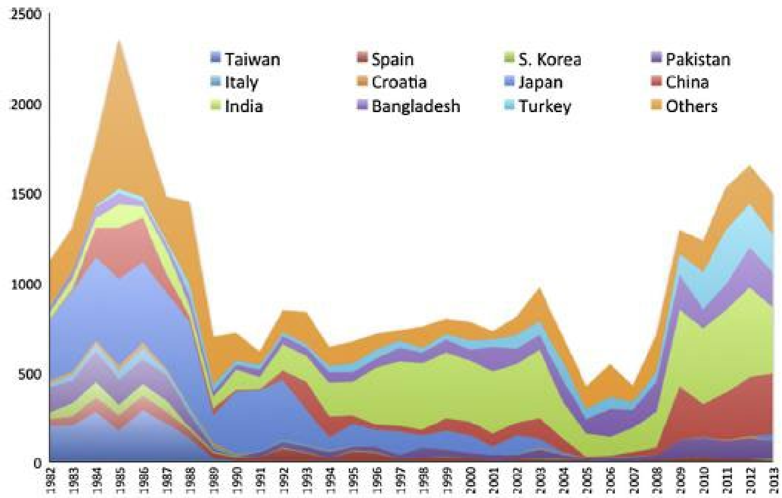

Figure 5 Total historical breaking volumes by region and year (expressed in number of demolished vessels)

Source: Shipbreaking in the Indian subcontinent, Practices, consequences and applicable legislation, Gazzola J, Ca'Foscai University of Venice, 2021

The ship dismantling industry has a key role for the economies in the Indian sub-continent. India, Pakistan and Bangladesh have turned it into a major source of steel for the countries' inner markets with long traditions in the field. Furthermore, dismantling is one of the key employment opportunities for people who live in the areas where this industry is developed. There was a concern that the implementation of the Hong Kong Convention may cause the countries to lose key market shares. In response to the growing concerns, the IMO adopted, in the period between 2011 and 2015, a number of transitional guidelines to help governments adapt their economies' infrastructures and legislation. The Convention requires entire change in the infrastructure of the industry, as well as improvement in labor conditions, which is a time and resource consuming process. Additional stress was caused by the COVID-19 pandemic, which hit the area severely and impaired economic growth not only in recycling sector. The countries found their way out of the crisis and by the first quarter of 2023 their economics are showing signs of recuperation.

Additional concerns are caused by the EU REGULATION FOR SAFE DISMANTLING OF SHIPS (EU RSS), adopted in 2013. It addressed all EU-flagged ships as well as ships from third countries calling at a European port or anchorage of 500 gross tonnage or above. EU SRR prohibits or restricts the use of dangerous materials such as asbestos and ozone-depleting substances on board ships [7]. The Regulation also makes it mandatory for ships to have a certified "Inventory of Hazardous Materials (IHM)" specifying the exact location and approximate number of the materials in question. It basically aims at implementing the Hong Kong convention in the EU legislation earlier than the actual ratification [1, 11].

The main concern for the countries in the Indian sub-continent lies in the EU-regulations on the manner in which EU-flagged vessels are to be dismantled in the end of their operational life. The EU announced a list of ship recycling sites, which the RSS finds acceptable for EU-flagged vessels. This list of EU-approved ship dismantling yards hardly contains locations outside the EU and none in the Indian sub-continent. This restriction gave rise to the shady practice of selling a vessel which is planned for breaking to brokers who would then register her outside EU before sending her to the scrapyard. A Report of BIMCO form the second half of 2022 on the matter points out the need for revision of the EU list of approved scrap yards.

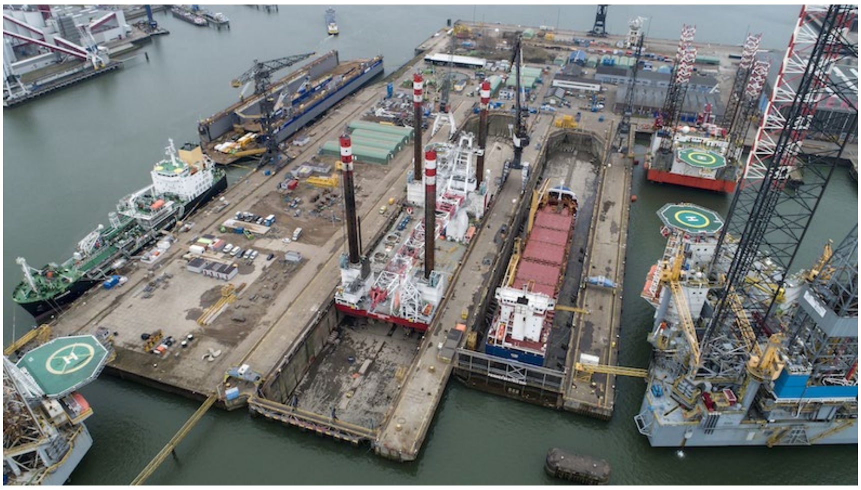

Figure 6 EU compatible recycling plant in the UK

Source: https://lloydslist.maritimeintelligence.informa.com/LL1123066/Waiting-for-Europe-to-bite

3. EFFECT OF THE HONG KONG CONVENTION AND EU-RSS ON THE SHIPPING INDUSTRY

Even though the Hong Kong convention has not entered into force yet, there are all signs that this is a matter of time. But the implementation of a similar document, which aims at such a dramatic transformation of the ship breaking industry will have its significant effects not only on the sector it is aiming at, but also on the entire shipping industry and hence, the entire supply chain planning. All the side effects, both positive and negative, must be carefully considered. With so many questions without an answer, the bold decision of the EU to include de Hong Kong convention's restrictions directly into its own legislation may prove to be a beta testing for what may happen. All the above mentioned newly implemented restrictions in the EU have caused a certain tension in the shipping market, particularly for those owners, who want to get rid of their obsolete EU-flagged vessels. There are many side effects for the environmental restrictions, not only to the EU countries, but also to those, whose scrapyards are not in the list of the EU RSS approved scrapyards.

The first concern, which arises directly from the regulation, is the limited opportunity for owners to scrap their vessels. The limit on their options where to direct their out-of-service craft causes significant delays, and thus increases price of scrapping. With such a volatile industry as shipping, the building up of excessive fleet for an owner who has already commissioned new tonnage, may prove to be catastrophic. That is the reason, in 2018, for The European Community Shipowners' Associations (ECSA) to include additional facilities in the list [4]. Since then, there have been 3 amendments of the list, but the number of approved scrapyards has not changed significantly.

Furthermore, even though the regulations aim at improving working conditions for people employed in this sector, they may be a reason for workers not to be able to practice jobs their families have long traditions to. The EU flagged fleet accounts for about 23-25% of all fleet worldwide, but still it has had its toe on Indian sub-continent shipwrecking sites' business options. In addition, the diminished amount of recyclable steel would mean shortage in the inner steel market, causing a stall in the economic development of the affected countries. A study from 2022 [10] recommends further dialogue between South Asian countries and the EU, suggesting further investment in improvement of available equipment or implementing entirely new practices.

Last, but not the least in importance, is the political factor. The EU is, most of all, a political structure and needs to address all interests of member states. It is clearly a political statement that China has not ratified the Hong Kong Convention yet. With the turbulent and intense political situation in recent years

(Economic crises, COVID-19, Ukrainian crisis) it is not easy to predict how economies will develop, what resource will be available for investments and what further development may be expected. This tension additionally impedes all developmental efforts.

4. CONCLUSION

Certainly, the issue of environmentally safe ship wrecking is growing both in importance and impact. However, the direct implementation of stringent requirements worldwide will not eradicate the environmental issue arising from malicious practices. It will, most likely, pose new, more severe problem, which, as a result, may dissolve all that has been accomplished so far. Further discussion is needed both on domestic and international level, in order to ascertain safe transition to environmentally sound transition. The hope is that the world is heading in the right direction – India has been a side to the Convention since 2019, and both Pakistan and Bangladesh planning to ratify it by the end of 2023.

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METHOD FOR EVALUATION THE ECONOMIC EFFICIENCY DUE TO THE USE OF COMPOUND MARINE DIESEL FUELS

Rositsa Bakalova
Nikola Vaptsarov Naval Academy
Department "Operation and management of maritime transport"
Varna, Bulgaria
E-mail: r.bakalova@nvna.eu

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Abstract

A method is proposed to estimate the economic efficiency due to the use of compounded marine fuels diesel + HFO and fuel treated with An StoTeh technology is proposed. The idea and method of the research are based on the experimental collection of relevant information. It should be noted that they are linked to a specific real object, i.e. a diesel engine, from which it follows that the results are valid for the specific diesel engine of the series and can only be considered in principle for other types of diesel engines. Formally, a comparison of the data on the impact of compounded fuels before and after treatment with An StoTech technology, depending on the load, on the mechanical and environmental characteristics and performance of the marine diesel engine individually is not possible due to the difficulty of achieving the same operating conditions of experimental research, and prevention from uncontrollable disturbances, etc. The method features high noise resistance. It is based on pre-compiled mathematical models of the characteristics and parameters of marine diesel engines when operating with both types of fuels, at different loads as well as on the evaluation of the economic efficiency for research objects, which enables experimental statistical analysis. A real application example is used.

Keywords: economic efficiency, marine diesel fuels, mathematical models, An StoTeh technology

1. A PROBLEM WHEN ASSESSING THE ECONOMIC EFFICIENCY OF COMPOUNDED FUELS

The specific simulation model of an LNG Carrier Ship of the ERS TheSim 5000 simulator for marine engineers, which is used in current practice investigates the impact of compounded fuels on the characteristics and performance of marine diesel engines at different loads. This is particularly relevant today in relation to the EU's environmental restrictions and norms [1,2,3,4,7]. The use of the classical approach to evaluate the performance of diesel engines with the fuels being studied by comparing their performance at different loads is not appropriate in these cases due to the practical impossibility of achieving the same modes of operation and due to random errors. This in turn gives rise to difficulties for economic evaluation of the results of their parameters. Obviously, when comparing data accompanied by measurement noise and the influence of external conditions, there is a need for a method assessing the economic efficiency of compounded diesel fuels, based on their statistical processing in order to eliminate the shortcomings manifested.

This structural model is used in describing the relationship between preselected factors and their responses. A report proposes a technology for conducting research and analysing the results obtained when considering an engine fuel treatment device. The main approach is the experimental analysis and consideration of the engine as an object for identification.

The significance of the considered problems and their accompanying analysis are grounds for formulating the purpose of this work as follows: Method for evaluating the economic efficiency due to the use of compound marine diesel fuels.

2. IDEA AND METHOD OF EXPERIMENTAL-STATISTICAL RESEARCH

The idea and method of the research are based on gathering relevant information experimentally. It should be noted that they are linked to a specific real object, i.e. diesel engine, from which it follows that the results are valid for the specific diesel engine in the series and can only be considered in principle for other types of diesel engines [5,6,8,9,10].

Formally, the comparison of data of the impact of compounded fuels before and after treatment with An Sto Tech technology, depending on the load, on the mechanical and environmental characteristics and performance of the marine diesel engine individually is not possible because there is a difficulty in achieving the same operating conditions of experimental research, and the prevention of uncontrollable disturbance, etc. A natural approach therefore is the use of specially synthesized qualitative mathematical models and deciding on the impact of compounded fuels after analysing their "reactions" to selected test operating signals, characteristic and related to their modes of operation.

Thus, the experimental research procedure is reduced to: a synthesis of qualitative mathematical models of the influence of selected compounded fuels, as well as those fuels treated with An Sto Tech on the studied mechanical properties and environmental parameters, and, on their basis, through comparative analysis to make a motivated decision. This approach eliminates as much as possible the influence of possible uncontrollable random impacts during the experiment and guarantees high quality analysis of the results and decisions made on the nature of their influence. In addition, the synthesized methodology should answer the question under which interval load range of the diesel engine the positive or negative effects of compounded fuels can occur and their treatment on the characteristics of the engine exhaust gases compared to the individual qualities of the gases of the non-compounded fuels.

On the other hand, the main drivers of economies - competitiveness and economic efficiency - have forced a number of productions to be exported. Thus, the great advantage of globalization under the conditions of the pandemic turns out to be dependent on unpredictable external factors and results in a negative impact. Despite the expectations of stabilization of economic development, this fact will have lasting consequences on the dependence between different economies, which can ultimately be considered a negative effect of globalization. As a countermeasure to the above, the great economic potential of the EU should be taken into account, which, combined with optimal management in terms of efficiency, is a reason for optimism. It is important to note the need for more efficient use of modern achievements of economic theory for a precise economic analysis when making managerial decisions. Taking into account a number of economic processes as stochastic processes, an effective approach is the use of mathematical methods and, in particular, mathematical modelling. This approach enables precise economic analysis and the implementation of effective management decisions.

The idea boils down to the compilation of workable, qualitative mathematical dependencies between previously regulated input-output values of economic processes, which are of interest for the purposes of management or decision-making. This is only one side of their usefulness. The developed theory of mathematical modelling includes many types of models and diverse applications.

Mathematical modelling (MM) has developed intensively in recent years in the direction of improving the mathematical theory for obtaining qualitative models, expanding the arsenal of mathematical equations, introducing discrete dynamic models, collecting qualitative information in view of common cases in practice from a relatively small volume of data and above all in adapting the theory to specific tasks. Particular attention is paid to the quality of the data, which are the carriers of information on the studied phenomena, when experimental data and their processing methods are used. It should be noted that the most widely used method for processing experimental data is the method of least squares, which is most easily adopted by researchers, since it boils down to the minimization of the error between the real data and those approximating it mathematical equations. Computationally, this technology is the simplest. It is natural to note that its application is accompanied by a number of assumptions related to its application, which are checked in the process of evaluating the model. The quality of MM depends on their implementation [13,14].

3. GATHERING APPROPRIATE INFORMATION AND ALGORITHM OF THE ECONOMIC APPROACH IN THE EXPERIMENTAL-STATISTICAL RESEARCH

The task is to organize and conduct a targeted, planned experiment with the studied marine diesel engine using compounded and treated fuels, whose parameters are of interest for the purpose of assessing their qualities and obtaining a quality mathematical model. Serious attention should be paid to the accumulation of experimental data. The use of mathematical methods for their processing, especially in the implementation of modelling with the help of matrix analysis can be a problem of computational nature, poorly defined matrices and others. It should be emphasized that the mathematical models used here should be of very good quality. Regression analysis is used as a mathematical apparatus for processing the collected information [11,12].

In the presented research, the created models will serve for the analysis of economic processes, the making of appropriate decisions, which is important for their optimal management. It should be noted that the study of economic tasks with the approach of cybernetics requires a new vision and further development of the application of statistical methods, which is offered in econometrics. Their relationship, from the point of view of philosophy, should be considered as the relation of general versus particular.

The entry of econometric analysis into the practice of the scientific approach in the study of economic phenomena gives good results in extracting their regularities. A need for such information exists for the purpose of making a decision on their optimal management. Solving such a delicate task would not be possible without the synergy of new economic thinking and theory, the development of specialized sections of mathematical statistics, and especially important development of the possibilities: technical, algorithmic and programmatic of digital computing technology. The new type of pragmatic thinking of managers-economists working in a competitive environment has to break with the intuitive approach traditionally used in the recent past or the "trial-error" principle and making an adequately justified decision in the management of economic processes.

This procedure is also performed with An Sto Tech-treated compounded fuel, the result of which is of practical interest. Thus, in practice, we have a pair of mathematical models that take into account the impact of the main compounded fuel and the one processed with An Sto Tech on the results of scientific interest of the diesel engine operation under a certain load mode. It is logical to assume that the "reactions" of both models when exposed to a set of engine-specific operating loads due to the concentration of all information about their impact on them will be clearly reflected only if such an influence exists. When deciding on the degree and quality of significant impact, it is necessary to take into account the error with which the experimental studies were conducted, usually 5%. In the load setting range, where the two processes differ by more than the error of the experiment, it may be appropriate to decide on the significant influence of compounded fuel treated with An Sto Tech on the parameters of the exhaust gas constituents compared to the exhaust gases of the raw compounded fuel.

Therefore, it is clear that as a tool and information for diagnosing the impact of An Sto Tech technology on the mechanical and environmental parameters of the diesel engine is the significant difference in the reactions of the two models, with and without the use of this technology. This should be borne in mind in the statement that follows and the subsequent economic analysis.

The evaluation of economic efficiency

In assessing the economic efficiency of the use of An Sto Tech processing technology, when an appropriate solution has been found, the following three cases are possible, clearly expressed by the nature of the curves of differences in the reactions of models when using or not using the additional treatment, Fig.1.

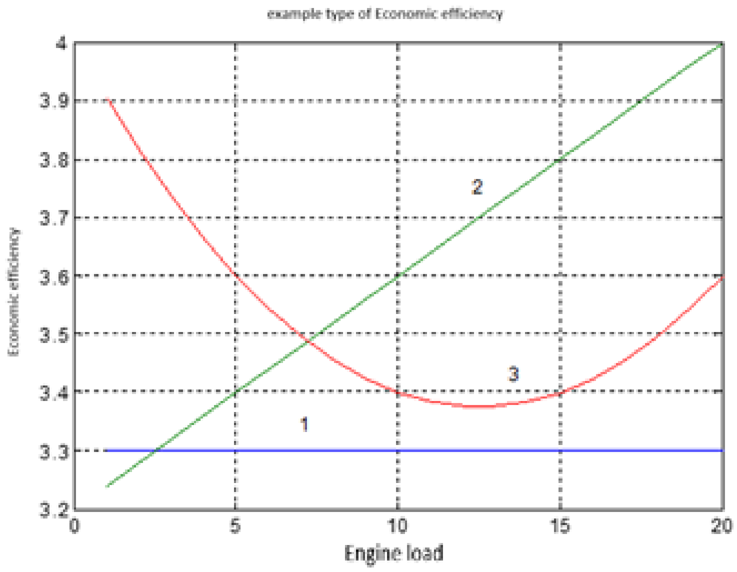

Figure 1 Economic efficiency of the use of An Sto Tech processing technology

A) The marine diesel engine is in constant load mode G1 within the admissible load range (Curve 1). The economic efficiency of An Sto Tech can be determined by the expression

$$IE\ (G1) = (P1\ (G1) - P2\ (G1)).\ \Delta t,$$

Where P1 (G1) and P2 (G1) are values of the considered parameters of the marine diesel engine before and after using An Sto Tech treatment, and Δt is the test time. The difference IE (G1) is a constant value independent of the load G. This case is rare in practice;

B) The marine diesel engine is in a mode of varying load at random (drift due to disturbing external factors) in the range G1 - G2. This interval may be valid for the entire load range. The economic efficiency of An Sto Tech can be determined in a way that depends on the nature of the difference IE(G). The following cases are possible:

B1) The difference IE(G) in the interval G1 - G2 is a linear function (Curve 2).

To determine the economy, the expression IEeconomy = IEmean (G1, G2) * Δt is used. Here IEmean (G1, G2) = (IE (G1) + IE (G2)) / 2.

B2) The difference IE (G) in the interval G1 - G2 is a nonlinear function (Curve 3). This is the most common case. The following is performed:

The average value of economic efficiency in the load range G1-G2 is determined by solving the integral.

$$IE_{mean}(G_1,G_2) = \frac{1}{G2-G1}\int_{G1}^{G2}(P1(G) - P2G))dG$$

Using the average value of IEmean during the time of operation in this interval Δt, the economic efficiency of using the AnStoTech technology in the load range G1 - G2 is determined as follows

$$IEeconomy = IEmean\ (G1, G2) * \Delta t..$$

In case of arbitrary character of the curve IE(G), the section G1-G2 should be reduced to one of the types shown.

Generalized application algorithm

- Carrying out a scientific research and creating high-quality, adequate mathematical models of the characteristics and of the engine parameters, subject to comparison, of the type "cause - effect", using both types of fuels. Experimentally recorded data are used;
- Using adequate mathematical models of the dependences of the engine characteristics on the load G, for fuel 90% DO + 10% HFO, and one treated with An Sto Tech, outputs are generated as a "response of the models" in a selected load range;
- The error between the two reactions is calculated and its significance is determined according to the accuracy of the collected experimental data;
- The difference between the two reactions is considered to be considerable, significant and due to the An Sto Tech-treated fuel if it exceeds the experimental error. Otherwise, it follows that the error between the two reactions is commensurate with the error of the experiment and there is no significant effect of the treated fuel;
- The efficiency of using An Sto Tech, IE economy (G) is determined.

Example of a study of the effect of diesel fuels 90% DO + 10% HFO and 90% DO + 10% HFO treated with An Sto Tech on carbon monoxide CO (ppm). Evaluating the effectiveness of using An Sto Tech.

All tests were performed on a serial marine diesel engine SKL 3NVD24. The mathematical models created by the method of Regression Analysis when recording 10 sets of experimental data and using diesel fuel 90% DO + 10% HFO (CO1) and 90% DO + 10% HFO treated with An Sto Tech (CO2) are given in Table 1 They reflect the statistical relationship of the effect of the load G (kg) on the engine, when using two types of fuel on carbon monoxide CO (ppm).

According to the equations, when the load changes within the range G = [0 2 4 6 8 10 12 14 16 18], which is of research interest, the values for CO1 and CO2 are given as vector rows:
CO1 = [459.2 413.2 418.2 474.0 580.9 738.6 947.4 1207.0 1517.6 1879.1];
CO2 =[301.1 287.8 302.6 345.5 416.5 515.7 643.0 798.4 981.9 1193.5];

The error between the two predicted values CO_e = CO1-CO2 is
CO_e =[158.1086 125.4304 115.5746 128.5412 164.3302 222.9416 304.3754 408.6316 535.7102 685.6112];

The relative error that exists between the two processes in percentages is
CO_e%=(CO_e./CO1)*100,
CO_e% = [34.4330 30.3562 27.6394 27.1158 28.2901 30.1825 32.1291 33.8553 35.3004 36.4862].

The maximum relative error is 36.4862%, at load G = 18 kg.

Provided that the error with which the experimental data are taken is 5%, it can be assumed that the difference CO_e% between the values of carbon monoxide CO1, for fuel 90% DO + 10% HFO and CO2, for fuel 90% DO + 10% HFO treated with An Sto Tech is significantly above this value. Figure 2 shows the predicted values of CO1, CO2 and the difference between them CO_e.

Conclusion: The effect of diesel fuel 90% DO + 10% HFO treated with An Sto Tech on the release of carbon monoxide CO (ppm), during the operation of the diesel engine, compared to the operation on diesel fuel 90% DO + 10% HFO is significantly above the error of experiment and should be considered as significant throughout the load range. The impact of the treated fuel is significantly greater at low and high loads and less at medium loads.

Table 1 Method of Regression Analysis when recording 10 sets of experimental data and using diesel fuel 90% DO + 10% HFO (CO1) and 90% DO + 10% HFO treated with An Sto Tech (CO2)

CO (ppm)						
Model	Adequacy	Standard error SY	Normality check on Jacques-Bera curve	Homoskedasticity according to Glaser's criterion	Pearson's Ryx	DERBIN-WATSON correlation check
$\widehat{CO1} = 459.1777 - 35.7253.G + 6.3672.G^2$	Fem =195.122 F(0.05;2;7)=4.74 **Conclusion: yes**	85.7046	JBem =1.0588 JBт(0.05;2) = 5.99 **Conclusion: normal**	FFem = 1.0862 Ft(0.05;1;8)= 5.32 **Conclusion: yes**	0.99115	d = 1.2454 alfa=5%; dU= 1.32 dL= 0.879 **Conclusion: test is non-conclusive**
$\widehat{CO2} = 301.0691 - 13.6806.G + 3.5144.G^2$	Fem =114.7438 F(0.05;2;7)=4.74 **Conclusion: yes**	60.648	JBem = 0.8147 JBт(0.05;2) = 5.99 **Conclusion: normal**	FFem = 0.3665 Ft(0.05;1;8)= 5.32 **Conclusion: yes**	0.98509	d = 1.0612 alfa=5%; dU= 1.32 dL= 0.879 **Conclusion: test is non-conclusive**

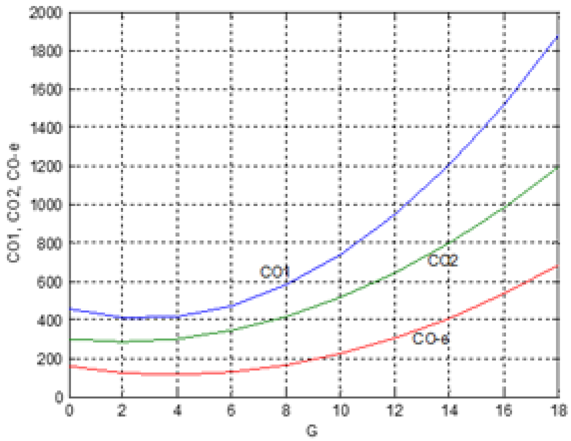

Figure 2 CO1 and CO2, and CO_e

Savings due to the use of An Sto Tech can be realized in the entire range of engine load. The following approach can be used to determine it.

From Fig. 2 it can be seen that the CO_e dependence is nonlinear, therefore the following approach is adopted. It is assumed that due to disturbing factors the load changes in the range G1 - G2. The mean value of carbon monoxide (CO mean) ̂ is determined. After taking into account the model equations and solving the integral, the mean value of the difference (CO mean)̂ in the exhaust gases will be

$$\widehat{CO}mean = \frac{1}{G2 - G1}\int_{G1}^{G2}(\widehat{CO1}(G) - \widehat{CO2}(G)dG=$$

$$=\frac{1}{G2 - G1}[158.1086(G_2-G_1)-11.0224(G_2^2-G_1^2)+0.9509(G_2^3-G_1^3)]$$

Using the average value (CO)̂mean during the operating time in this interval Δt, the savings from carbon monoxide CO (ppm) caused by the use of An Sto Tech technology are determined, i.e. (CO)̂economy = (CO)̂mean * Δt.

For specific values: The solution is shown at a load variation interval G = 10-12 kg. The savings for a period of f 1 hour is

(CO)̂economy= (CO)̂mean*Δt=1/(G2 – G1)[158.1086(G2-G1)-11.0224(G22-G12)+0.9509(G23-G13)]*1 = 261.7435 (ppm)*1.

4. CONCLUSION

A method and algorithm for estimating the economic efficiency of the use of compounded marine diesel fuel + HFO and fuel treated with An Sto Tech technology, based on the use of experimental statistical data analysis and analysis of the difference from the reaction of the obtained mathematical models. According to the generalized algorithm of application on a real object of research - the CO component in the exhaust gases of a marine diesel engine, results were obtained, showing an assessment of the savings resulting from the use of An Sto Tech technology.

The proposed research technology can be used in other cases to assess the economic efficiency of fuels.

Formulation of guidelines for future developments:

1. Further development and improvement of the created method, in order to expand its possibilities for additional research on diesel marine engines, for example, on the influence of hydrogen on economy.
2. The comparison of analytical and experimental-statistical methods for mathematical modelling of ship engine processes.

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CROATIAN COAST GUARD'S ACTIVITIES IN THE MARINE FISHERIES CONTROL

Ivan Carević
Croatia Navy, Split, Croatia
E-mail: icarevic0605@gmail.com

Tomislav Sunko
Croatian Defence Academy "Dr. Franjo Tuđman", Zagreb, Croatia
E-mail: tsunko@morh.hr

Toni Mišković
Marine Electronic Center Ltd. (PCE d.o.o), Split, Croatia
E-mail: toni.miskovic@pce.hr

Marin Delić
Croatia Navy, Split, Croatia
E-mail: deliae@net.hr

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Abstract

For the purpose of preventing increasingly frequent modern threats on the waterways of coastal countries, continuous control and protection of national interests at sea are maintained through implementation of legal provisions and through actions of state administration bodies. The Coast Guard is a body responsible for the implementation and protection of maritime interests of the Republic of Croatia. One of the tasks is to protect marine fisheries in the internal sea waters, territorial sea and in the area of the exclusive economic zone of the Republic of Croatia. The Coast Guard's authorised personnel are qualified and authorised to perform affairs and apply powers of the Coast Guard, which also presumes qualifications for carrying out inspection controls of marine fisheries. The objective of this paper is to look into the productivity of the Coast Guard of the Republic of Croatia analysing the period from 2018 to 2022. Procurement of technical assets in the form of floating assets represents a significant step forward in the increase of operational capabilities of maritime countries, especially for control of marine fisheries. The analysed model of furnishing of the technical equipment of the Coast Guard of the Republic of Croatia can serve as an example for all maritime countries with indented coastlines.

Keywords: Coast Guard of the Republic of Croatia, Control of marine fisheries, Operational capabilities

1. INTRODUCTION

The total length of the coast of the Republic of Croatia on the Adriatic Sea amounts to 1,777 kilometres and comprises the largest part of the eastern Adriatic coast. Not so big aerial distance between the end points in the northern and southern Adriatic Sea amounts to 526 kilometres, and because of a large number of bays and coves the Croatian coast is ranked among the three most indented ones in Europe. The total of 718 islands and islets, 389 rocks and 78 reefs stretch along the indented coastline, so the Republic of Croatia can quite legitimately be called the country of a thousand islands [3].

State bodies authorised for the control and protection of the rights and interests of the Republic of Croatia at sea control the sea area of 31,479 km^2, out of which 12,498 km^2 are internal sea waters and 18,981 km^2 belong to the territorial sea. After establishing the protected ecological fisheries zone and the exclusive economic zone, respectively, this area has been extended by 23,870 km^2. The total of 55,349 km^2 of the sea area imposes a challenge for competent bodies which act on behalf of the Republic of Croatia [7].

Undoubtedly, the above mentioned sea areas represent a great challenge for a small maritime country. For organised and successful implementation of the protection of the sea areas, the essential prerequisite is a clear political decision with clearly defined guidelines for work of the competent state institutions. The Government of the Republic of Croatia with an act on the Coast Guard of the Republic of Croatia (hereinafter referred to as Coast Guard) regulates the implementation and coordination of interdepartmental bodies competent for the control of the sea [11]. Constituting of the Central Coordination for the Control and Protection of the Rights and Interests of the Republic of Croatia at Sea (hereinafter referred to as Central Coordination) was a key element for unique and long-term cooperation of all the competent bodies with determined guidelines for the control of the sea.

For a maritime country a sea area can present a field full of possible dangers such as terrorist or piracy attacks, organised trafficking of people and goods, marine pollution and unlawful fishing. As a basis for the protection the national security at sea the Republic of Croatia organised the Coast Guard, competent for the control and protection of the rights and interests of the Republic of Croatia at sea. On account of increased fisheries efforts and unlawful fishing, especially by foreign fishing boats, the Coast Guard is investing additional efforts in order to achieve set goals in the control of marine fisheries. Due to potential threats, procurement of new technological assets is an essential element of the prevention thereof. After the equipping was carried out, the research focuses on the efficiency of the Coast Guard in the period from 2018 to 2022.

For a relatively young country such as Croatia it is realistic to expect several years of harmonisation of administrative and legal regulations on the basis of acquired knowledge from the work of bodies competent for the sea control. Continuous amending to the Act and developing of ordinances are contributing to an improved system of the protection of the national security at sea. Adequate legal provisions are an essential precondition for reaching the objectives pursued by a coastal country. Along with the advancement of administrative and legal part, it is crucial to have systematic advancement of other elements such as human resources and technological assets. Diversity and innovativeness of potential threats requires constant improvement of all the elements involved in the protection of the national wealth of the Republic of Croatia. New technological solutions, in the form of new floating units with characteristic of faster and more cost-efficient execution of control of the sea assignments, lead to more rational execution of the sea control as opposed to slower and economically less favourable floating vessels. The cooperation between the Ministry of Defence of the Republic of Croatia and the Ministry of Agriculture of the Republic of Croatia can be taken as a good example. The agreement between the Ministries provided new craft intended primarily for the marine fisheries control.

The Central Coordination constantly controls and analyses the security of the sea area under the jurisdiction of the Republic of Croatia, the hierarchically laid out model, from regional units via the Expert Body to the umbrella Central Coordination, aligns the work of all the competent bodies for the marine control. In addition to planning, execution control, planning of monthly, quarterly and annual joint activities, the mentioned bodies also collect data on the grounds of which they base proposals for potential improvements [7].

The Coast Guard, a floating unit within the Croatian Navy, is a military unit whose basic mission is to protect the sovereign rights and implement the jurisdiction of the Republic of Croatia in the exclusive economic zone, continental shelf and at open sea. Regarding the question of controlling the marine fisheries, Coast Guard personnel authorised to carry out fisheries inspections authorities are entitled to perform the control of marine fisheries within the internal sea waters, territorial sea or in the area of the exclusive economic zone [13]. Expert trainings of the Coast Guard personnel authorised to perform marine fisheries inspections are carried out on a yearly basis, in line with the Central Coordination's measures for improving safety and protection of the marine area [7]. The objective of this research is to produce evidence that the Coast Guard has significantly improved in performing the marine fisheries control, particularly after commissioning of the new craft on the basis of the agreement between the Ministry of Defence and the Ministry of Agriculture.

During the research, the collected data were statistically processed, and the conclusions were made on the basis of scientific methods of analysis and synthesis.

This paper deals with the Coast Guard's activities in the marine fisheries control. It is divided into four parts, the introduction states the problem, subject, purpose and objective of the research and states the scientific methods used to demonstrate the scientific hypothesis. The second part shows the Coast Guard as a competent body within the organised structure of the Central Coordination together with the outstanding cooperation between the Ministry of Defence and the Ministry of Agriculture of the Republic of Croatia. The third part analyses the Coast Guard vessels in the implementation of the marine fisheries control through joint actions, on the basis of the annual report of the Central Coordination. Furthermore, the paper analyses activities of the new rubber boats during the execution of joint actions from the moment they were commissioned in the Coast Guard. Finally, the fourth part analyses data on a number of issued inspection minutes and on a number of measures taken related to marine fisheries in Coast Guard's joint or individual controls of vessels in the period from 2018 till 2022.

2. COAST GUARD OF THE REPUBLIC OF CROATIA

Soon after the Republic of Croatia gained its independence, an idea of creating a new maritime-administrative organisation emerged. It took more than a decade before that idea came fully to fruition. Finally, in October 2007, the Croatian Parliament promulgated the Coast Guard Act, which defined the organisation, scope of work, affairs and missions of a new unit within the Croatian Navy [1]. The act entered into force on 1 November 2007 and it was valid until 27 December 2019 when the new Act on the Coast Guard entered into force. It was to expect that the development itself of the Coast Guard would lead to regulations, ordinances and to the new act based on lessons learnt in that period of control and protection of the sea.

The Coast Guard is a floating unit formed of active military personnel subject to military rules. Active military personnel, i.e. members of the Coast Guard are officers, non-commissioned officers, sailors, civil servants and employees posted to vessels or the Headquarters of the Coast Guard. In line with the Coast Guard Act and other relevant legislation, the authorised personnel of the Coast Guard are qualified and authorised to perform affairs and apply powers of the Coast Guard. The commander of the Coast Guard is a Croatian Navy officer appointed and dismissed by the President of the Republic of Croatia, at the Government's proposal. The Coast Guard commander is the chairman of the Expert Body of the Central Coordination for the Control and Protection of the Rights and Interests of the Republic of Croatia at Sea. The Coast Guard Headquarters is in charge of planning and execution of tasks and coordinating cooperation with other bodies competent for the control and protection of the rights and interests of the Republic of Croatia at sea. It is composed of two departments, support department and operations department. The floating part of the unit comprises two divisions. 1st Division of the Coast Guard is stationed in Split whereas 2nd Division of the Coast Guard is stationed in Pula. A separate part, which is under of the operational control of the Coast Guards, is composed of Croatian Air Force aircraft and systems of unmanned aircraft belonging to the Intelligence Regiment of the General Staff of the Croatian Armed Forces [8]. Along with its usual tasks, the Coast Guard also has to maintain its combat readiness. In war conditions, the Coast Guard vessels are responsible for protecting the internal sea waters and for tactical missions of combat and logistic support [4], which requires regular military training in the ports and conducting of military exercises at sea. It is possible to say that the Coast Guard is a polyvalent organisation that will definitely advance in the execution of all its assignments.

2.1. Central Coordination for the Control and Protection of the Rights and Interests of the Republic of Croatia at sea

On the basis of the Coast Guard Act [11], in June 2008, the Government of the Republic of Croatia adopted a regulation on the organisation and work of the Central Coordination, Expert Body and regional coordination units competent for the control of the sea. The Central Coordination is an interdepartmental body in charge of harmonising work of bodies competent for the control and protection of the sea. Representatives of the ministries competent for defence, maritime and internal affairs chair the Central Coordination. Members of the Central Coordination control and analyse a level of safety of the marine surface under the jurisdiction of the Republic of Croatia, give guidelines for development of an annual plan for bodies competent for the control and protection of the sea and they, eventually, adopt it. When necessary, they adopt standard operating procedures for the implementation of the control and protection of the sea, and at the end of a year they also draw up an annual report on the implementation of the defined policy, tasks and regulations on the control and protection of the rights and interests of the Republic of Croatia at sea. The Central Coordination has the Expert Body which is managed by the Coast Guard commander, whereas the other members of the Expert Body are representatives of state administration bodies and other state bodies. The scope of work of the Expert Body includes, inter alia, approval of monthly plans of joint activities of regional coordination units, adoption of quarterly plans of joint activities of regional coordination units, development of an annual plan and proposal thereof to the Central Coordination. They are also to submit the annual plan of joints activities to the Central Coordination. Because of the joint planning and more efficient operative procedures, the regional coordination units are organised at a level of regional self-government units. They act in the area of eight regional self-government units and are harmonised pursuant to the structure of the ministry competent for maritime affairs. The regional coordination units are chaired by the harbour masters of competent harbour master offices. The regional coordination units develop monthly plans of joint activities and reports on their realisation, harmonise the work of the bodies competent for the control and propose the Expert Body improvements in the control and protection of the rights and interests of the Republic of Croatia at sea. The joint activities are performed when the members of the competent bodies get aboard a ship, boat or aircraft for the purpose of performing tasks within their scope of work.

2.2. Coordination between the Ministry of Defence and the Ministry of Agriculture

In July 2019, the Ministry of Defence and the Ministry of Agriculture concluded an agreement on the procurement of two craft for the control of marine fisheries. Through the Operational Programme for Maritime Affairs and Fisheries of the Republic of Croatia, the Ministry of Agriculture procured the craft with the co-financing of funds from the European Union amounting to 70%. After the handover of the craft, the Ministry of Agriculture assumed material and financial responsibility over the craft, whereas a trained crew and logistic support would be provided by the Ministry of Defence and the Croatian Armed Forces. The craft, or to be more precise, the rubber boats, will be used at least 60% of the time for the control of marine fisheries. The rest of time they will be used for search and rescue operations at sea and for the needs of the Croatian Navy, i.e. for the needs of the Coast Guard [5]. In November 2020, the rubber boats were delivered to the Coast Guard group. The first rubber boat named GB-201 "Modrulj 1" was assigned to 2nd Division of the Coast guard in Pula, whereas GB-202 "Modrulj 2" was assigned to 1st Division of the Coast guard in Split. The coordination continued and on the basis of the above-mentioned agreement, two more rubber boats were procured. The remaining rubber boats were assigned to 1st Division of the Coast Guard and handed over in November 2021 (GB-203 "Modrulj 3") and in April 2022 (GB-204 "Modrulj 4" shown in Figure 1). The completed project additionally strengthened the capabilities of the Ministry of Defence through the operational use in the Croatian Navy. In addition to the operations of the control of marine fisheries and search and rescue, the rubber boats are also used as a support to the conduct of interdepartmental and military exercises of the Croatian Navy [9].

Figure 1 The fourth rubber boat GB-204 handed over to the Croatian navy

Source: Morh.hr

Table 1 Specifications of the rubber boat

Specifications of the rubber boat	
Type of craft	Motor boat
Length over all	14,00 m
Beam	4,20 m
Height	4,50 m
Maximum draught	0,70 m
Maximum speed	40 kt
Cruising speed	28 kt
Construction materials	Fiberglass / Kevlar / Hypalon neoprene
Wight of the craft	10.000 kg /11.600 kg
Model and type of engine	2x Caterpillar C 7.1 Marine 510KS
Model and tip of the propulsor	Castoldi Jet TD 284 H.C.T.
Maximum number of people	12 people
Autonomy of the craft	230 NM
Fresh water capacity	300 l
Fuel tanks capacity	1400 l

Source: Morh.hr

3. ANALYSIS OF THE ANNUAL REPORTS ON THE IMPLEMENTATION OF THE DETERMINED POLICY, PLANS AND REGULATIONS RELATED TO THE CONTROL AND PROTECTION OF THE RIGHTS AND INTERESTS OF THE REPUBLIC OF CROATIA AT SEA

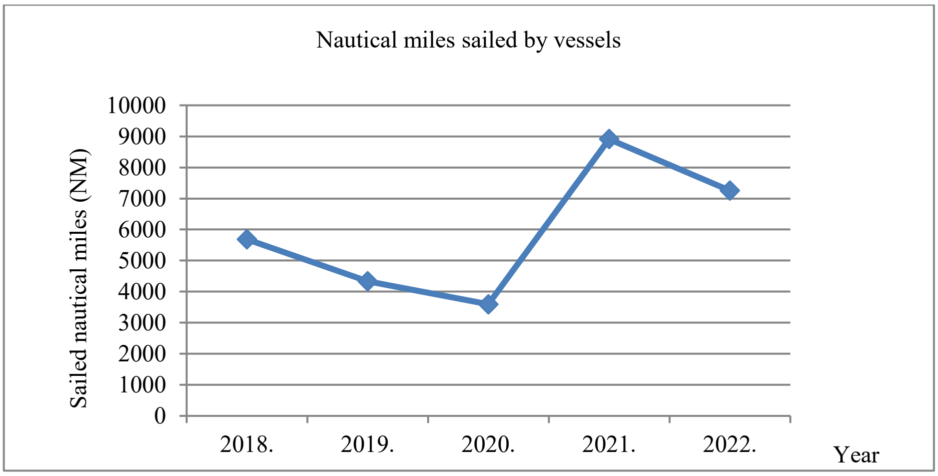
By applying the Coast Guard Act, the Central Coordination develops annual plans on the implementation of joint activities of the interdepartmental bodies for the control and protection of the rights and interests of the Republic of Croatia at sea for each calendar year [13]. The annual report is a faithful representation of how given political instructions, plans and regulations for the purpose of the control and protection of the rights and interests of the Republic of Croatia at sea are carried out. It contains all the assignments where the competent institutions and human resources are involved, presents the accomplished goals, realised joint interdepartmental activities through numerical effects of the conducted assignments, measures taken after perceived irregularities and financial expenses of all those bodies competent for the control and protection of the interests of the Republic of Croatia at sea. The numerical data of joint actions serve as a faithful representation of the functioning of the system, on the account of which, different conclusions can be made as well as judgments, praises and suggestions for further improvements.

The conducted joint actions of the Coast Guard and interdepartmental bodies are statistically processed by analysing the data collected from the Central Coordination's annual report for the years 2018. [12], 2019. [10] , 2020. [6], 2021. [7] and 2022. [2], which are shown in Table 2. This statistical analysis defines the scope of the implementation of the control and protection of the rights and interests of the Republic of Croatia at sea by the Coast Guard.

Table 2 Annual data on the conducted activities of the Coast Guard

Year of conducted activities	2018	2019	2020	2021	2022
Number of Coast Guard personnel involved	226	226	219	224	223
Number of nautical miles sailed by vessels	5,687.50 NM	4,336.9 NM	3,595.9 NM	8,910.58 NM	7,253.50 NM
Number of vessel engine working hours	520.75 h	465.7 h	364.27 h	819.34 h	594.40 h
Vessel fuel consumption (litres)	201,365 l	150,557.50 l	110,555.30 l	124,501.30 l	116,879.49 l
Cost of fuel on vessels / daily allowance (in euros)	213,490.1 €	199,706.3 €	141,393.7 €	144,036.3 €	101,303.5 €

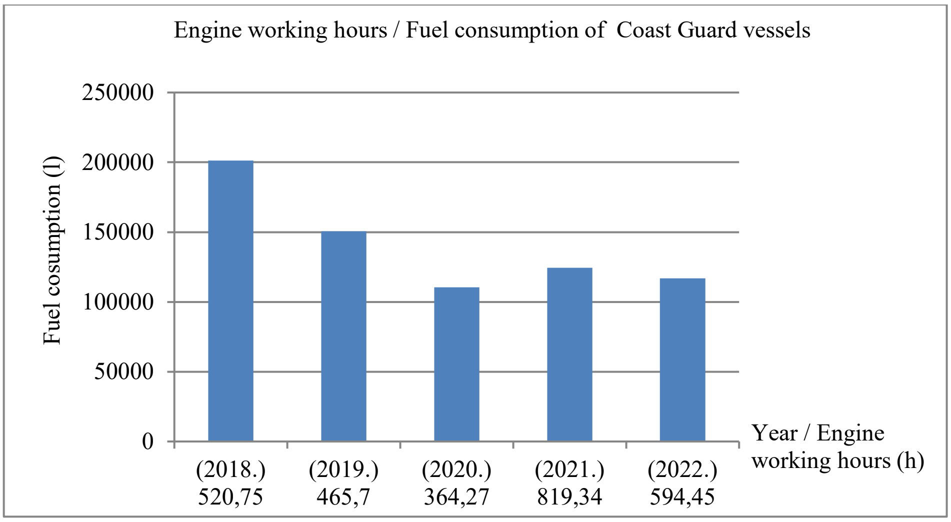
Source: Annual reports of the Central Coordination; The data given by the Croatian Navy



Graph 1 Graphic display of sailed nautical miles by the Coast Guard vessels

Source: Annual reports of the Central Coordination; The data given by the Croatian Navy

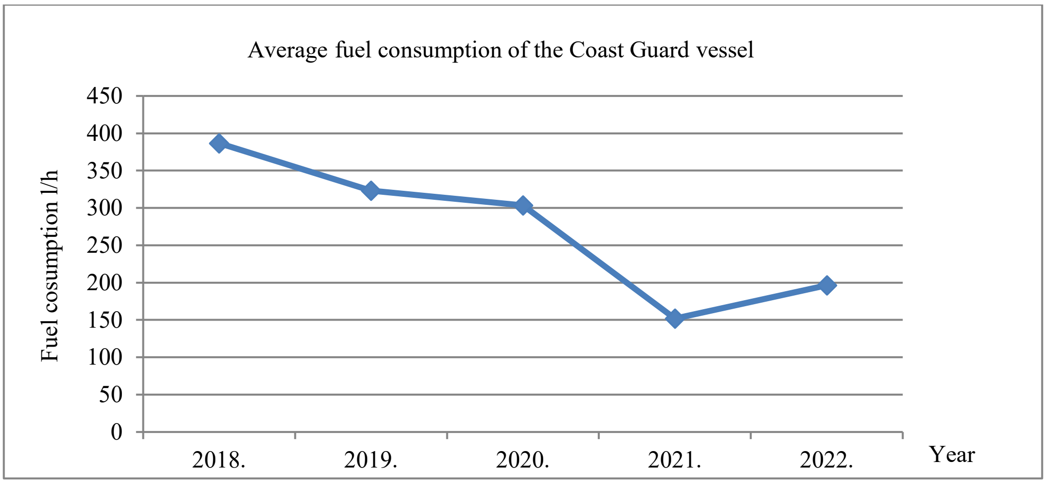
The graph in Graph 1, showing the distance sailed by the Coast Guard vessels, indicates that after 2018, 2019 and 2020 there was a multiple increase in 2021 and 2022. It is an assumption that the attained level will continue to increase in the following years, especially because of the new boats in the Coast Guard.



Graph 2 Graphic display of engine working hours and fuel consumption by the Coast Guard vessels

Source: Annual reports of the Central Coordination; The data given by the Croatian Navy

During 2018, the Coast Guard vessels consumed in the joint actions 201,365 litres of fuel during 520.75 engine working hours, which represents an average consumption of 386.7 litres of fuel per one engine working hour. In 2019 the average consumption of engine working hours amounted to 323.3 litres of fuel, and 303.5 litres of fuel in 2020. A dramatic fuel saving was noticeable in 2021 when the Coast Guard vessels spent 124,501.30 litres of fuel during 819.34 engine working hours, which gives an average of 151.9 litres per one engine working hour. In 2022 the average consumption amounted to 196.60 litres of fuel when 116,879 litres of fuel were spent during 594.45 engine working hours. The obvious conclusion is that the use of the new rubber boats in 2021 and 2022 contributed significantly to the saving of fuel (Graph 3).



Graph 3 Graphic display of average fuel consumption by the Coast Guard vessels

Source: Annual reports of the Central Coordination; The data given by the Croatian Navy

The analysis of the fuel consumption and daily allowances of the personnel (Table 2) indicates that the Coast Guard spent much less funds in the course of the joint actions of the control of the sea. The Central Coordination's annual reports show an obvious decrease in the spending of funds from 2018 to 2022. In 2018, the expenses for the fuel and daily allowances amounted to 213,490.1 EUR, whereas the expenses for 2022 amounted to 101,303.5 EUR. It can be concluded that the number of activities increased, the sailed distance grew larger and the fuel consumption was dramatically reduced, which resulted in the reduction of costs.

3.1. Analysis of the rubber boats' activities during the conduct of joint actions of the bodies competent for the protection of the rights and interest of the Republic of Croatia at sea

In the period from November 2020 to April 2022, the Coast Guard got four rubber boats which after the commissioning started carrying out joint activities of the bodies competent for the control and protection of the rights and interests of the Republic of Croatia at sea [7]. Since the Croatian Navy approved, and the Coast Guard Headquarters submitted the requested data, it is possible to analyse objectively the rubber boats' activities and acquire new insights. This statistical analysis determines a part which the rubber boats carried out in the joint activities of the bodies competent for the control of the sea.

Table 3 Annual data on the conducted activities of the Coast Guard

Year when activities were conducted	2020	2021	2022
Rubber boat	GB-201, GB-202;	GB-201, GB-202, GB-203;	GB-201, GB-202, GB-203, GB-204;
Nautical miles sailed	129.3 NM	3,871.6 NM	3,490.0 NM
Engine working hours	09:20:00 h	343:10:00 h	336:11:00 h
Fuel consumption (litres)	813.0 l	23,576 l	31,316.0 l

Source: The data given by the Croatian Navy

The statistic data show the period from the commissioning of the rubber boats. Hence, the year 2020 can be neglected in the analysis of the numerical data. Table 3 represents the portion out of the total of the joint actions numerical data shown in Table 2. Thus, the distance of 3,871.6 nautical miles the rubber boats sailed in 2021 makes 43.4 % of the total of 8,910,58 nautical miles sailed by all the Coast Guard vessels. In 2022 the rubber boats carried out 48.1 % out of the total of 7,253,50 nautical miles sailed by all the Coast Guard vessels.

The data analysis shows that the average fuel consumption is 81 litres per hour per rubber boat on the basis of the total of 688 engine working hours and 55,705 litres of the consumed fuel. This insight explains the obvious drop in the Coast guards vessels' fuel consumption (Graph 3).

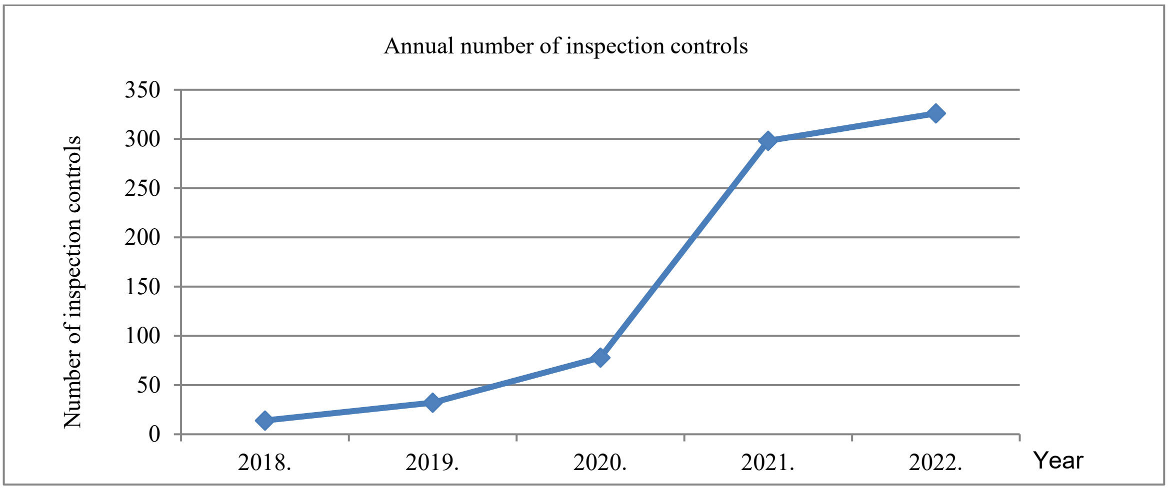
3.2. Data analysis of the number of conducted inspection controls and the measures taken during the Coast Guard vessels' marine fisheries control

The data obtained by the Croatian Navy on a number of the conducted inspection controls of marine fisheries and the measures were analysed and statistically processed. The control of marine fisheries carried out from 2018 to 2022 by all the Coast Guard vessels are displayed in Table 4. The conducted inspection controls occasionally resulted in issued mandatory misdemeanour warrants.

Table 4 Annual data on the conducted inspection controls by the Coast Guard vessels and measures taken

Year of conducted control	2018	2019	2020	2021	2022
Number of inspection controls	14	32	78	298	326
Number of measures taken	2	1	4	60	86

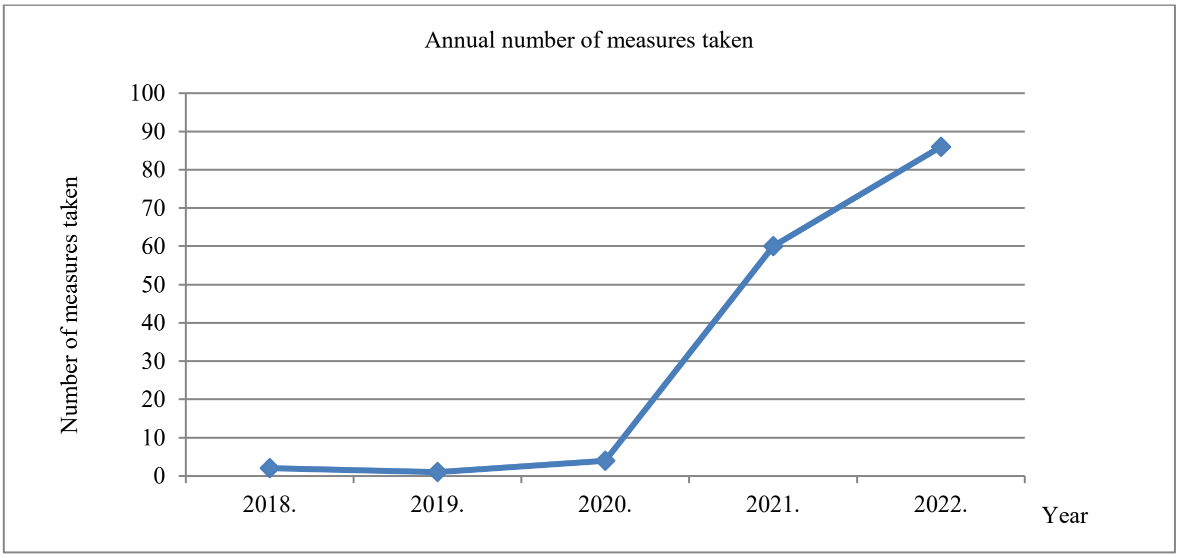
Source: The data given by the Croatian Navy



Graph 4 Graphic display of inspection controls conducted by the Coast Guard vessels

Source: The data given by the Croatian Navy

A number of the inspection controls of marine fisheries in the period from 2018 to 2022, displayed in Table 5, was gradually growing until 2021 when it soared by four times and even 2022 was marked by an increase. It is very likely that a number of the inspection controls in 2023 will be the same or bigger in relation to 2022.



Graph 5 Graphic display of measures taken by the Coast Guard vessels

Source: The data given by the Croatian Navy

From 2018 to 2021 the number of measures by means of misdemeanour warrants was minimal. The fisheries control in 2021 registered 60 corrective measures taken and in 2022 this number was 86. The number of inspection controls along with the measures taken is the most objective indicator of the development of the Coast Guard capabilities. Therefore, a technological step forward through the procurement of the speed boats as well as the high level of training of the Coast Guard personnel deserve the credit for the obvious advancement in the marine fisheries control.

4. CONCLUSION

The sea area, for sure, represents for the Republic of Croatia a strategic priority which is necessary to protect in an appropriate way. The total of 55,349 km2 of the sea area is quite a challenge for the competent state bodies responsible for protecting the rights and interest of the Republic of Croatia at sea. In order to protect the sea area successfully, the basic prerequisites are political guidelines and defining of a organisational model for carrying out assigned tasks. The initial point of the organisational model is the Coast Guard Act with which the Government of the Republic of Croatia, *inter alia*, defined the manner of work of the bodies competent for the control of the sea. Constituting of the Central Coordination for the Control and Protection of the Rights and Interests of the Republic of Croatia at Sea was an important precondition for the future development of the interdepartmental body. Furthermore, in order for the overall system to advance, it was of utmost importance to invest in the training of the human resources and equip the Coast Guard with new equipment intended for the purpose of more rational and more effective sea control. Potential threats in sea areas such as terrorist and piracy operations, marine pollution, organised trafficking of people and goods and unlawful fishing, clearly indicate the need for further equipping with technological assets for combatting these threats.

The Coast Guard has a basic role to protect sovereign rights and to implement the jurisdiction of the Republic of Croatia in the exclusive economic zone, continental shelf and open sea. It can also legally control marine fisheries in the internal sea waters, territorial waters and the exclusive economic zone. For the purpose of accomplishing these tasks and for the advancement of the Coast Guard, it is necessary to refresh the Coast Guard technologically by equipping it with fast and more economical craft intended for the sea control. With respect to this, it is necessary to point out the cooperation between the Ministry of Defence and Ministry of Agriculture of the Republic of Croatia whose agreement enabled the procurement of the craft for the marine fisheries control.

The Central Coordination develops annual reports on the implementation of the joint activities of the interdepartmental bodies competent, for the control and protection of the rights and interests of the Republic of Croatia at sea. Every year the accomplished interdepartmental activities are presented through numerical data, as well as the measures taken after inspection controls and financial indicators of the performance of all the competent ones for the control and protection of the rights and interests of the Republic of Croatia at sea. An analysis of the annual reports can help in making conclusions, judgements and praises on the performance of the competent bodies.

The analysis of the annual reports for the period from 2018 to 2022 defines the intensity of the implementation of the Coast Guard's control and protection of the rights and interests of the Republic of Croatia at sea. While the sailed distance during the sea control was increasing, the fuel consumption was decreasing a great deal which resulted in more efficient and rational performances of the Coast Guard. The analysis of the data on the conducted activities of the new rubber boats stresses the positive impact they had on the Coast Guard. Finally, the number of the conducted inspection controls of marine fisheries and subsequent measures taken are evidence of an exceptional step forward of the Coast Guard. Investing in both indispensable human resources and new floating units with clearly defined characteristics is a key to further development of the Coast Guard.

Acknowledgements: Acknowledgements to the Croatian Navy, which permitted, and to the Coast Guard Headquarters which handed over the key data, because without these it would be impossible to do this research. Document: Conduct of the joint and individual tasks of the craft of the Coast Guard of the Republic of Croatia CLASS: 008-01/23-01/1; No.: 6104-0502-23-2 6 February 2023.

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CONTROL OF SHIP STRENGTH DURING HULL REPAIR

Yordan Denev*
Technical University of Varna, Bulgaria
Shipbuilding Faculty, Naval Architecture and Marine Engineering Department
E-mail: y.denev@tu-varna.bg

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Abstract

In dry docking periods, ship hull repairs are very important; control of her strength and deformation. The paper deals with analyzing the proper cut-outs, the dimensions in the ship's hull during scale repair and section modulus according to bottom and deck. With BV software, MARS 2000 has developed general cargo midships sections models with ten real hull repair scenarios for hull repair. With the help of their section modulus on deck, bottom and hatch coamings, deformation is calculated and analyzed. For every one of the models and scenarios, it is possible to do it when the ship is afloat. The analysis showed that in 40% of cases the section modulus on deck is less than minimal, calculated by classification society rules. This means that during scale hull repair, control of cut- outs, their dimensions and areas in the ship's hull is an important problem. Steel repair without any control leads to hatch coamings deformation, disrupted hatch cover, water tightness, and additional work related to their proper condition.

Keywords: ship hull, repair, section modulus, deformation, strength

1. INTRODUCTION

During her life, the ship passed through different types of inspections and repair. The types of repairs are briefly described in [3]. Ship strength is a topic of study and analyzed by a lot of authors. It is a characteristic which has been proved in the early design process and every time when the ship leaves port or enters the dry dock. This is important in the exploitation process, while the transverse ship strength is important for docking in a dry dock or floating dock.

Much of the scientific research involved in ship strength mainly addresses the longitudinal strength in different hull conditions and ultimate strength. The effect of sudden damage and intensive corrosion on the ultimate ship strength when the ship collides with another vessel is analyzed in [4]. By the finite element analysis, the collision scenarios are presented. Ultimate strength is evaluated by Smith's method and authors investigate how corroded ship structures suffer from ultimate strength and how it should be considered by FEM and Smith's method.

Longitudinal strength with damage due to grounding and collision is studied in [10]. The authors derived analytical equations for residual hull girder strength and verified calculations for a sample ship for a board accident.

Aging ships, corrosion and cracks are the most frequent factors for ship damage. The corrosion-wasted models of different parts of ship hull and construction elements are developed in [7]. The criteria for repair and maintenance of corroded areas and elements to keep ultimate girder strength at satisfactory values are discussed.

The hull girder strength as a result of grounding upon longitudinal bending is studied in [1]. The damage is simply created by removing the elements from the cross-section and the simulation by FEM and Smith's method developed an analysis program. Ultimate strength is imposed on the cross-section and hogging and sagging conditions. Load impact on ship requires transverse strength calculations depending on the ship type, cargo, construction, and environment [8].

Many of the articles are focused on longitudinal ship strength because it is set in classification societies rules. Different authors analyzed ultimate strength in different scenarios and environmental conditions. Transverse strength is an important characteristic when the ship is in docking and repairing periods. In these periods of intensive plates and frame corrosion, deformation or dents are necessary for scale steel hull repairs. The same applies to retrofitting a ship, for example, from a tanker to a bulk carrier. Uncontrollable cutting and welding lead to additional steel working, mostly on general cargo ships with one hold. When this is done, the control of cut-outs and dimensions is preferable in the preliminary and the repair phase.

2. PROBLEMS APPEARED DURING STEEL HULL REPAIR

Problems that appear during hull repair are mainly in hatch coaming deformation. This deformation leads to water tightness reducing and water ingress in the cargo hold when the ship encounters bad weather. The deformation is caused mainly by bending moments and appears in the bottom structure and additional equipment on board the ship (Fig.1). The methods for fast and simple calculations of forces applied to ship hulls during docking periods have been developed [9].

The model is used for general cargo ship with DWT 5000 tons with one cargo hold. The ship's main dimensions are L=88.96m, B=16.00m, D=9.17m with unrestricted sailing area. In the conceptual design of the ship, 7% of Lmax for the length of forepeak part and 23% of engine room length are used.

The length of cargo hold is 70% Lmax. Frame and primary support frame spacing is consistent with the ship type and possibilities for container cargo. Taking into account this exploitation condition, the frame spacing in the forward part is 700mm, in cargo hold 700mm and in engine room 700mm. In this analysis, the merchant ship life cycle is normally about 30 years and the ship hull is treated as 25 years old with partly intensive corrosion in plate construction elements.

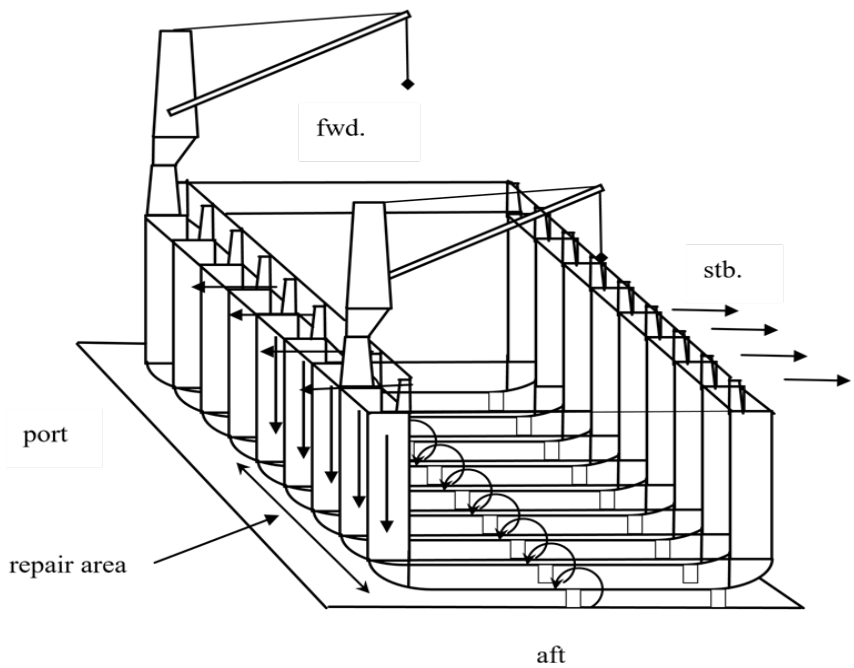

Figure1 Forces and moments applied in ship hull during repair [5]

This uncontrollable process leads to opening (move to side) or closing (move to cargo hold) of hatch coamings, Fig. 2.

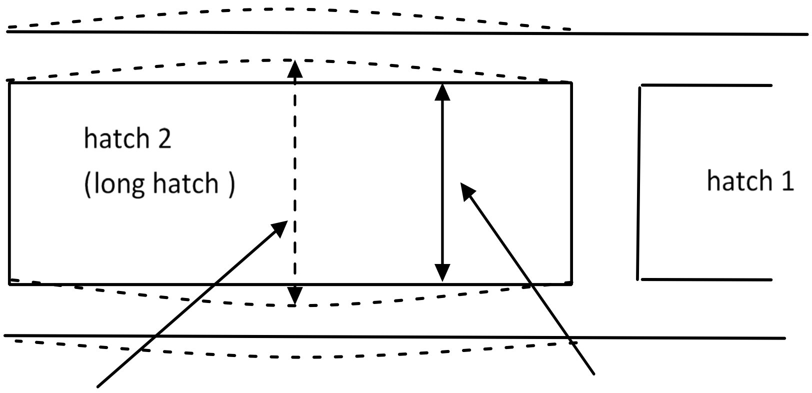

Figure 2 Hatch coaming opening [5]

Returning the hatch coamings in their proper position is connected with additional waste and time. In case of larger deformation, an additional part from coaming stool is cut and welded (Fig.3) or just a part of coaming stool is cut and welded (Fig.4). The problem of this type appears mainly in ships with long hatch coamings and this confirms the control and analysis of repair work in the ship hull during steel repairs.

Figure 3 Return hatch coamings by the cut and welded additional part from coamings stool [5]

Figure 4 Return hatch coamings by cutting and welding of coamings stool [5]

3. THE ANALYSIS OF SHIP STRENGTH DURING HULL REPAIR

Analysis of ship strength during hull repair is evaluated by modeling of the ship's midsection and applying different scenarios. The models were developed on BV software MARS 2000. The model is used for general cargo ship with DWT 5000.

The analyzed criteria for ship strength during hull repair were section modulus and deck and bottom and neutral axe position. The minimal required section modulus at deck and bottom are calculated for this ship [2].

$$W_{bottom} = \frac{I_{y-n50}}{z_n}, m^3 \tag{1}$$

$$W_{deck} = \frac{I_{y-n50}}{V_D} \tag{2}$$

Where: W_{bottom}- section modulus at bottom, m3; W_{deck}- section modulus at deck, m3; Iy-n_{50} net inertia moment, m4; V_D- distance to neutral axe, m; z_n- Z- coordinate of the neutral axe, m.

The required minimal section modulus at deck is 1.03m^3 and for bottom is 1.33 m^3, neutral axe position is at 3.44m above the base line.

The calculated current values of every one of the variants are compared with the minimum calculated by classification societies' rules calculations. The applied repair scenarios that are closely applicable in the ship repair practice are shown in Table1.

Table1 Applicable scenarios

	W_1 bottom, m^3	W_1 deck, m^3	N_{axix} position ab. BL, m	Repaired area dimension		Repaired area location
				L,m	B,m	
1	3.29	1.89	3.35	1.00	12.00	Shear strake
2	3.23	1.82	3.31	1.50	12.00	Shear strake
3	3.42	1.5	3.5	1.45	12.00	Shear strake and double bottom
4	2.61	1.5	3.35	3.00	10.00	Shear strake
5	2.2	1.56	3.81	1.95	10.00	Bottom
6	1.86	1.01	3.38	3.50	10.00	Bottom and inner side
7	1.73	1.28	3.78	6.30	10.00	Double bottom
8	1.72	0.98	3.35	3.50	12.00	Double bottom, inner side and deck beam
9	1.51	1.02	3.71	1.45	10.00	Deck and bottom
10	2.08	0.99	2.96	3.70	10.00	Inner side

Where:

- W_1 bottom- current section modulus at bottom, m^3;
- W_1 deck- current section modulus at deck, m^3;
- N_{axix}- current position of neutral axe, m;

In Table 1 with red color, the section modulus on deck are shown, which are less than necessary, calculated by the classification society rules. In 40% of scenarios, the section modulus according to deck is less than minimal required, calculated by rules. In the case number eight, the reduction of section modulus is bigger than in others, it is about 6%, while in the case numbers six and nine it is about 2%. These values confirm that it is not preferable to do repairs in these areas together, but this is not kept because the repairing time is relatively short.

When the ship is in dry docking, the weight forces applied to her construction are normally distributed along the hull, with magnitude varying due to weight in this area of the hull. The keel blocks react in the place where the hull touches the keel blocks and act vice versa with weight forces. Based on keel block reaction in the repaired section, the bending moment occurs. The distribution of bending moments is shown in Fig.5. Its maximum value is at points for neutral axe, in hatch coamings and main deck. The value of the bending moment on the main deck and hatch coaming is negative, while in bottom and double bottom it is positive.

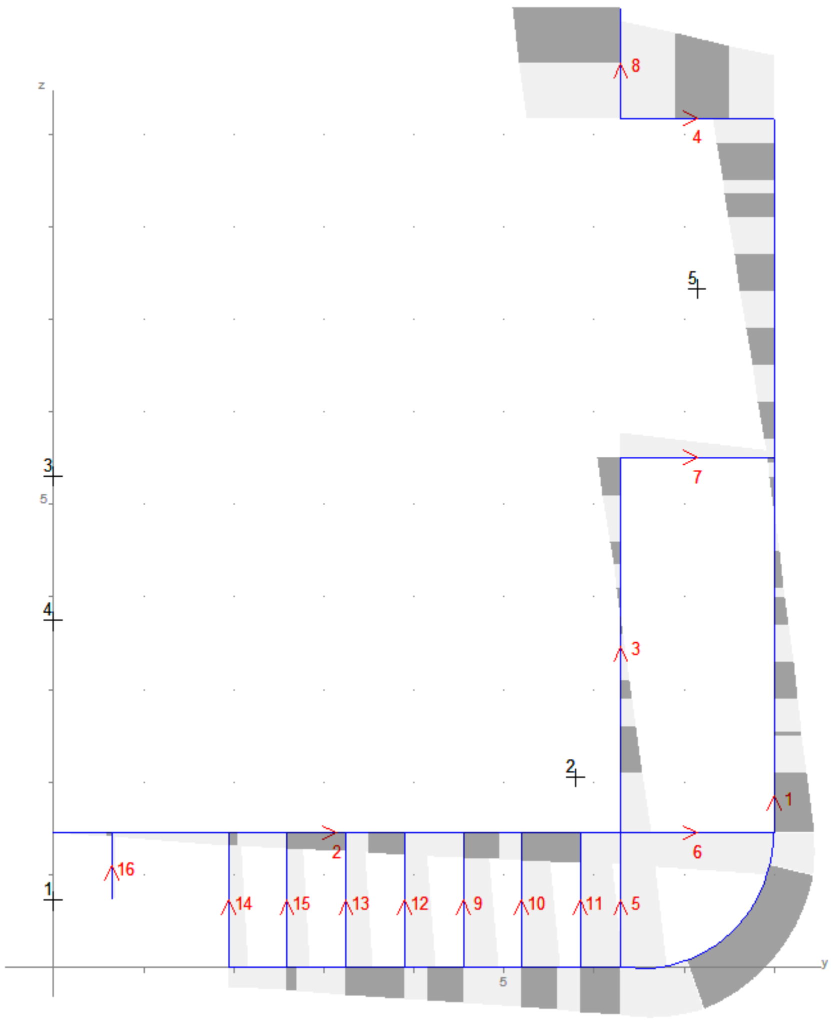

Figure 5 Bending moment distribution in case of repair in bottom and inner side

Normal stress distribution in plate hull elements and frames is shown in Fig.6. The maximum values are near to the main deck and the minimum are in the neutral axe position and mainly in the double bottom and lower part of the side and inner side of shell construction. The normal stress values far away from neutral axe are about permissible for shipbuilding steel and section.

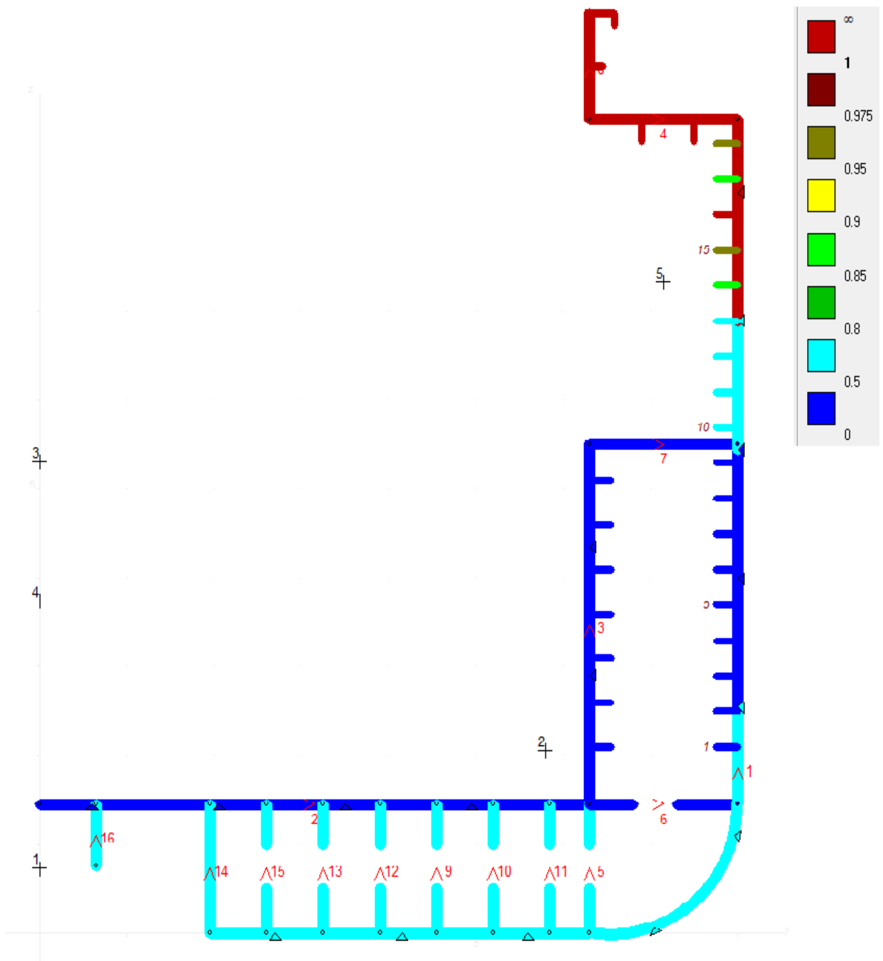

Figure 6 Normal stresses distribution in ship midsection

4. CONCLUSIONS

To analyze the strength of a ship during steel repair, 10 models are developed with applied repair scenarios. The midship section development process is admitted that the ship is 25 years old. The analysis shows that:

- In 40% of scenarios, section modulus according to deck is less than minimal, calculated by rules. In the case number eight, the reduction of section modulus is bigger than in others, it is about 6%; while in the case numbers six and nine it is about 2%.
- Section modulus at bottom is not affected according to the repair scheme;
- The values of bending moment at hatch coamings in cases with exceeded section modulus are about -2.2 N/mm^2 and normal stresses exceeded permissible values by 2.5 times.
- Neutral axe position did not vary closely, from 3.44m in the normal condition of the ship's hull to 2.96m for a repaired section with inner side repair.
- With proper control of steel repair and areas in the ship's hull, additional cutting and welding work and repair delays.

The future study will analyse the developed scenarios like the stress concentrator and its impacts on the hull girder strength.

Acknowledgement

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INTERACTION BETWEEN MANAGEMENT UNITS OF SHIPPING COMPANIES VIA BLOCKCHAIN TECHNOLOGY

Dimitar Dimitrakiev
Nikola Vaptsarov Naval Academy, Bulgaria
E-mail: dimitar.dimitrakiev@nvna.eu

Ognyan Kostadinov
Nikola Vaptsarov Naval Academy, Bulgaria
E-mail: o.kostadinov@nvna.eu

Christiana Atanasova
Nikola Vaptsarov Naval Academy, Bulgaria
E-mail: k.atanasova@nvna.eu

UDK654.07:656.61
347.79:656.61

Abstract

The operation of the marine merchant fleet and the technical maintenance of the ships are activities that require the participation of specialists with different specialties. These activities are internationally regulated, therefore international standards have been introduced. Shipping control is carried out at several levels - starting with the International Maritime Organization (IMO) and ending with Port State Control (PSC). In this regard, all shipping companies have management structures in place that conform to industry regulations. Management responsibilities are distributed within shipping companies, outsourcing is also used. At the top of the "pyramid" for management are the company managers, and below them, in terms of ship management, are Commercial Ship Managers/Operators, Technical Managers, Designated Persons Ashore, Company Security Officers, and Personnel Managers. A hierarchical system of interaction is introduced between all units of management. Management is based on the International Safety Code (ISM Code), which has been mandatory since 2002 for all ships over 500 GT (gross tons). Thanks to the development of private maritime law and maritime commercial practices, the overall management of maritime merchant vessels can be distributed among multiple responsible companies located in different countries. This poses a potential risk of compromising the safety and security of shipping. It is a fact that organizations with high motivation for growth and cost-effective operational efficiency are always trying to bring new technologies into their operations. These organizations are very sensitive to change and are value driven. Blockchain technology is revolutionizing supply chain logistics. Digital currencies are already a method of buying products and trading goods. This in turn simplifies and improves maritime and global supply chains. But how could it promote the interaction between management units in maritime shipping companies? The authors offer an answer in this paper by presenting an overview of the possibilities of Blockchain technology in maritime shipping companies.

Keywords: shipping company, management, maritime transport contracts

1. INTRODUCTION

Shipping companies have several sectors and areas in the management of the merchant fleet that are changing in terms of the organization of their operations. Shipowners decide how to organize the different lines of work in the companies. A part of the activities of the companies is embedded in the work of any kind of commercial company [3,5], therefore it is not considered in this publication. The main part of the activity, which refers to the direct production activity of the shipping companies, is regulated by maritime conventions and rules of the IMO. Thanks to long years of operation and general regulations in water transport, the shipping industry applies uniform internationally accepted practices in the management of the marine merchant fleet, which are usually used by shipowners with some differences [17,7].

Blockchain technology has significant potential to transform the industry. The benefits of using the technology by shipping companies are numerous. Some of them are:

- Compliance with regulations: The maritime industry is heavily regulated, and blockchain technology can help to ensure compliance with these regulations by providing a secure and transparent way of sharing information.
- Cost savings: By reducing transaction costs and improving efficiency, blockchain technology can help to save costs for companies in the maritime industry.
- Improved supply chain management: Blockchain technology can provide a real-time view of the entire supply chain, enabling better supply chain management and reducing the risk of disruptions or delays.
- Increased trust: Blockchain technology can improve trust between stakeholders by providing a secure and transparent way of sharing information and conducting transactions.

In this regard, the article analyses the main reasons for the implementation of blockchain technology in the maritime industry as a tool for effective interaction between management units of shipping companies.

2. SECTORS AND DIRECTIONS IN THE MANAGEMENT OF MARINE COMMERCIAL SHIPS

In relation to the management of the merchant marine fleet, the companies maintain the following two management sectors, with a total of seven directions:

- Commercial fleet management
  - Operations
  - Commercial activity (Chartering)
- Technical management of the fleet
  - Technical support (Maintenance)
  - Safety of shipping
  - Security of shipping
  - Personnel
  - Supply of fuels and materials

Trade in maritime transport services takes place on the freight market. In principle, there are two types of contracts for the provision of maritime transport services: contracts for the carriage of goods and contracts for hiring a ship to transport goods for the charterer or third parties [18]. In this connection, different standard contracts are used, which can be used separately, as well as in combination, as a chain of charters (Charter Party Chain). This provides a legal opportunity for maritime entrepreneurs who have chartered a ship to enter into a subsequent contract for the carriage of foreign cargo without actually being shipowners. The management of the ships can be carried out by the shipowner's office or marine contractors operating a chartered vessel or a mixed form of management is used. In the time charters, it may be agreed that the vessel will be manned or unmanned, which is essential to its management. In principle, in crewed ship charters, the technical management of the ship remains with the shipowner, and the commercial management passes to the charterer. When the vessel is bareboat chartered, then the technical and commercial management passes to the charterer. In turn, the charterer in these terms can appoint its crew and carry out the technical management of the vessel, after which there is an option to sublet the vessel with the crew to another charterer who takes over the commercial management of the vessel [4].

One of the strategic decisions that shipowners make is what fleet operation and maintenance contract system to use individually for each of the ships in the fleet. Both in theory and practice, one of the following contract or chain of contract solutions is possible:

- The shipowner carries out the technical maintenance of the ship, including hiring the crew, and operates the ship as a carrier (Voyage Chartering).
- The shipowner carries out the technical maintenance of the ship, including hiring the crew, but hire the ship with the crew, i.e. the charterer (the time charterer) operates the ship as a carrier transporting its goods and cargo (Time Charter).
- The shipowner hire the ship without a crew, i.e. the lessee (bareboat charterer) undertakes the operation and technical maintenance of the vessel, including hiring the crew and:
    - trades in its name and on its account, transporting its own and foreign cargoes from the market or
    - sublet the vessel to a time charter, i.e. technical management remains in the bareboat charterer and commercial management passes to the time charterer [9].

3. INTERNATIONAL REGULATIONS RELATED TO THE MANAGEMENT OF THE COMMERCIAL FLEET

The main conventions and codes governing the management of the commercial fleet are:

- The 1972 International Convention for the Safety of Life at Sea [11]

The Convention is a foundational document in global merchant shipping. Its main purpose is to set minimum standards for the construction, equipment, and operation of ships compatible with their safety [6]. Based on this convention, numerous international acts related to the safety of shipping and environmental protection have been adopted.

- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)

The Convention was ratified by Decision No. 192 of the Bureau of the Council of Ministers on 22 December 1981. In force from 28 April 1984 [16], The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) was concluded in 1978 between the countries - parties to the IMO (International Maritime Organization - UN agency responsible for the international regulatory framework for maritime transport).

The Convention addresses the requirements for the training of seafarers (mainly members of the command staff) and the corresponding certification. The STCW Convention was significantly amended in 1995. The Convention has been integrated into European Union law with Directive 94/58 on the minimum level of training for seafarers [2]. In reality, EU maritime safety rules are largely aligned with international rules.

- Maritime Labor Convention [10]

The Maritime Labor Convention lays down the minimum requirements for almost all aspects of the working conditions in the employment of seafarers, the norms of working time and rest, accommodation conditions and facilities for recovery and recreation, the supply of food and water, safe and healthy working conditions, medical service, welfare, and social security (Maritime Labor Convention, 2006).

- International Maritime Safety Code (ISM Code) [8]

The Code requires formal procedures for all activities related to the safe management and operation of the ship, both in the offices ashore and on board the vessel. In the same way as in other "quality systems", the procedures must be fully documented. These should be tailored substantially to the requirements of the individual company, the types of vessels it operates, and even the trade routes it uses. When a safety management system is approved for the first time, the company is issued with a Document of Compliance for the entire system and after each ship is audited and approved, it is issued with a Safety Management Certificate (SMC) (ISM Code, 2010).

- The International Ship and Port Facility Security Code (ISPS Code) [12]

Adopted by Resolution 2 of the Conference of Contracting Governments to the International Convention for the Safety of Life at Sea of 1974 on December 12, 2002. In force for the Republic of Bulgaria since July 1, 2004 (Ministry of Transport, 2020) The International Maritime Organization (IMO) states that "The International Ship and Port Security Code (ISPS Code) is a comprehensive set of measures to improve the security of ships and port facilities developed in response to perceived threats to ships and port facilities following the 9/11 attacks in the United States." (ISPS Code, 2022).

Concerning the above, shipping companies are required to have the following positions:

- "Ship Operator" - Operational work connected with the fleet is continuous. Even small companies that cannot maintain a sufficient staff on shore, thanks to modern means of communication, manage to ensure continuous duty (so-called home duty). The operations department is the company's liaison with ship masters and shore services. Most information is sent and received between ship and shore through the operations department.
- "Designated Person Ashore" - (DPA) - according to the requirements of the International Convention for the Safety of Life at Sea of 1972 (ISM Code)
- "Security officer" - (Company security officer - CSO) - according to the requirements of the International Ship and Port Facility Security Code (ISPS), which is part of the SOLAS Convention
- "Ship maintenance engineer" (Superintendent) - according to the requirements of the SOLAS Convention
- "Officer for safe working conditions and labor contracts" (MLC officer) - according to the requirements of the International Maritime Labor Convention 2006
- "Crew Manager / Personnel" - Very often, the recruitment of the crew, and the appointment of the crew is carried out by another commercial company performing the functions of Crew Managers. For this purpose, they should have insurance (P&I cover) to guarantee the wages and repatriation of the crew.

Many ship owners prefer to transfer other auxiliary activities of the company to external companies (outsourcing). Usually, the maintenance of the radio-navigation equipment is carried out by an external organization and, more rarely, this is also done for the maintenance of the ship's machinery and mechanisms.

The management structure of the commercial fleet is divided into 2 pillars as is shown in Figure 1.

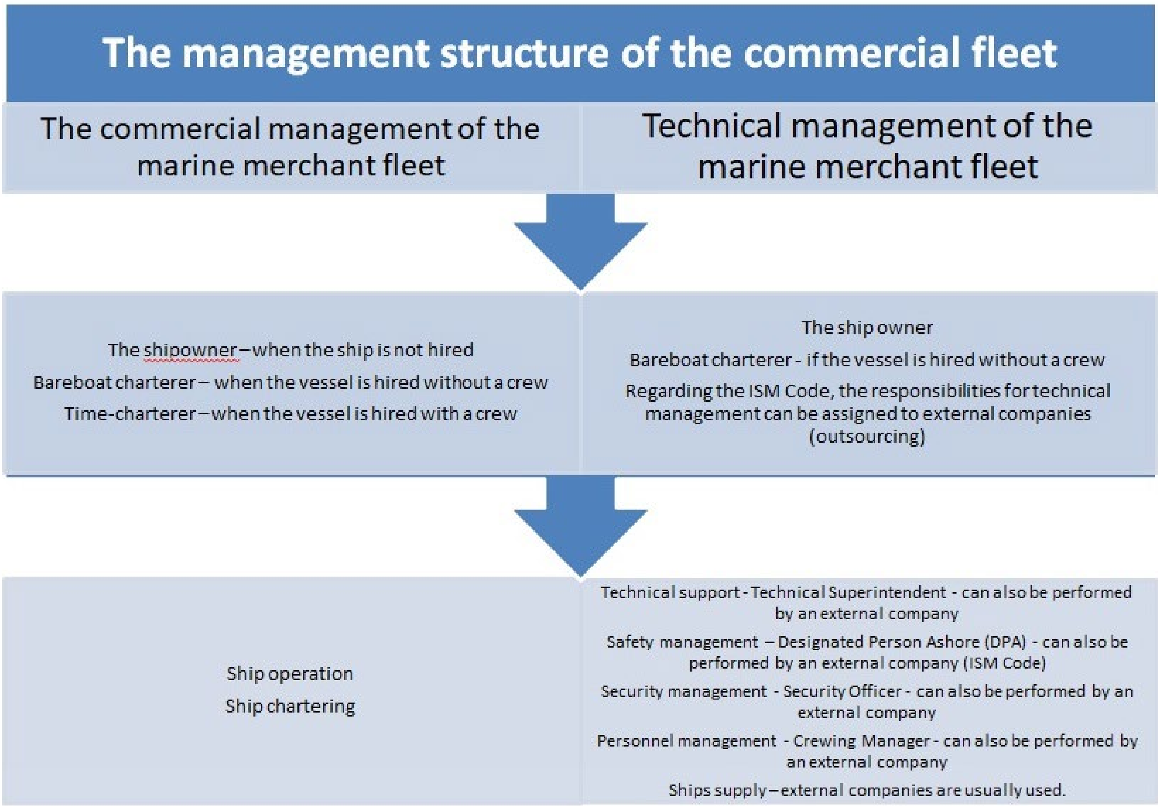

Figure 1 The management structure of the commercial fleet divided into 2 pillars

4. INTERACTION BETWEEN THE MANAGEMENT UNITS OF THE MERCHANT MARINE FLEET VIA BLOCKCHAIN

The management structure of shipping companies can be built only within the company, but in practice, it is accepted that part of the work is carried out by external shipping companies. In terms of commercial ship management, shipowners' choices are dictated by their expectation of the future state of the market and their view of market risk allocation. When the shipowner expects the market to deteriorate, then they prefer to charter their ships and vice versa. In terms of fleet technical management, shipowners' decisions are primarily dictated by their assessment of which form of management will work best for them. The transfer of ISM Code management to an external company has its advantages as well as disadvantages, i.e. this is a matter of discretion on the part of shipowners. When all the management units are part of the shipowner's company, then the interaction between them is the easiest.

However, when the management units are not part of the shipowner's company, then the interaction between them hides difficulties. In this case, new technologies appear.

Blockchain is a relatively young revolutionary technology and is gaining popularity after the success of cryptocurrency. However, most of the facts about Blockchain are either exaggerated, misinterpreted, little known, or still unknown. According to a 2018 PricewaterhouseCoopers (PwC), survey of 600 global executives, 84% of executives were actively engaged in Blockchain. According to another global Blockchain study in 2018 by Deloitte, it found that Blockchain works in supply chain usage 53%, IoT 51%, digital identity 50%, digital records 44%, digital currency 40%, payments 30%, and voting 12%. Blockchain will generate $176 billion in new business value by 2025. This will grow to $3.1 trillion by 2030. Blockchain value generation in 2030 is greater than the individual gross domestic product (GDP) of France (2 .6 trillion), the United Kingdom (2.6 trillion), and India (2.4 trillion) [14] in 2017. In recent times, giant companies have increased their interest in shipping and logistics and are transferring their technology to the maritime industry.

Major companies, including ocean carriers CMA CGM, COSCO SHIPPING Lines, Evergreen Marine, OOCL, and Yang Ming; terminal operators DP World, Hutchison Ports, PSA International Pte Ltd, and Shanghai International Port; and software solutions provider CargoSmart, are working together on a project for an open digital platform based on Blockchain [1]. Technology has hit the shipping industry in a particular way, as many shipping companies look forward to making information flow smoother between business categories and making trade-related office procedures faster and more efficient [13,15]. Although there are several challenges to implementing the technology, taking into account industry standards meeting regulatory expectations, as well as the emergence of a leading blockchain technology platform, shipping industry participants must be prepared for Blockchain technology as it takes the market and companies must be ready to take advantage of this game-changing actor. In the new category created, hybrid Blockchain, any of the three types of Blockchain, namely public, private, or community/consortium, can be combined. A Blockchain platform can be configured in multi modes using Hybrid Blockchain. The new platforms will thus connect stakeholders including carriers, terminal operators, customs agencies, freight forwarders, and logistics service providers to enable co-innovation and digital transformation in the supply chain. Therefore, the model would also apply to the interaction between the management units of any shipping company.

5. CONCLUSION

In conclusion, blockchain technology could transform the maritime industry by increasing transparency, improving efficiency, and reducing costs. This technology can provide a secure and tamper-proof system for the sharing of information between the management units of shipping companies, enabling better collaboration and communication. By eliminating intermediaries and automating many processes, Blockchain technology can also help to reduce transaction costs and improve supply chain management. As shipping companies continue to face increasing competition and regulatory pressures, the implementation of Blockchain technology can provide a competitive advantage and help to ensure compliance with regulations. Overall, the interaction between management units of shipping companies via Blockchain technology can lead to improved operational efficiency and a more secure and transparent supply chain.

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CHALLENGES TO THE EDUCATION OF MARITIME PROFESSIONALS BASED ON DIGITAL PLATFORMS

Svetlana Dimitrakieva
Nikola Vaptsarov Naval Academy
Operation and Management of maritime transport Department
Varna, Bulgaria
E-mail: s.dimitrakieva@nvna.eu

Bogdana Dimitrova
Nikola Vaptsarov Naval Academy
Operation and Management of maritime transport Department
Varna, Bulgaria
E-mail: b.dimitrova@nvna.eu

UDK 378: 656.61
004.774

Abstract

One of the most crucial foundational elements for effective and safe shipping might be considered the calibres of the maritime education system. The training of maritime professionals is undergoing a digital revolution, and with the introduction of artificial intelligence and rising levels of automation on the horizon, the rapid rate of change and innovation is anticipated to continue. These modifications offer several chances for innovation and enhancements to the current platforms, but they also create a number of difficulties for university-level maritime education. The article will examine the relationship between the use of traditional and digital learning management systems in the instructional process of maritime higher education institutions. The existing state of the education system, which should be receptive to contemporary trends, contributed to the need to find new digital tools, but it was not the only one. The COVID-19 epidemic also made things worse. In this article, we will conduct a comparative analysis, chosen as the primary research tool, making it possible to compare the online and offline ways in which higher maritime education institutions implement their educational programs. Additionally, we look at the purpose, structure, results, and success factors of maritime education. We pay close attention to the primary benefits and drawbacks of online learning platforms.

Keywords: maritime, education, training, digital platforms

1. INTRODUCTION

All forms of instruction, training, and education, in general, have served as both a result of and a catalyst for the industrial revolution. The new century provided innovations, difficulties, and increased expectations to both mankind as a whole and to each person, forcing the educational systems to adapt. This adaptation and the introduction of innovations have always needed a lot of time and effort due to the inherent inertia in educational systems, frequently through conflicts and confrontations between the old and the new.

In the past, the dominant approach in maritime education has been the acquisition of skills through vocational training in a real-world environment. This method places a strong emphasis on the value of "firsthand" or practical abilities that may be applied to carry out daily tasks aboard. Such educational programs for maritime trainees involved a set amount of time spent as an apprentice on board ships learning from and absorbing the knowledge of more seasoned colleagues. In modern practices, digital learning platforms and simulator-based training are utilized in conjunction to enable seafarers and maritime professionals to develop some of the prerequisite skills for their positions.

The development of seafarer competencies requires a certain sort of education. New and different options for maritime simulations and simulators have also been made possible by emerging technologies like virtual reality, augmented reality, and mixed reality. A new generation and category of simulators and simulation-based experiences for professional education, training, and operations have been made possible by the increasing technological advancements and readiness of these systems. These experiences are more affordable, immersive, portable, and accessible than traditional configurations. The introduction and integration of these technologies, in particular, into maritime industry operations, education, and training, opens up new opportunities for supporting operators and operations both on land and at sea.

2. DIGITAL PLATFORM-BASED EDUCATION

To address the difficulties of the digital age, education is crucial, and maritime education is no different. Institutions of maritime education and training face additional difficulties because of the limitations on physical training activities. [1]

The right time has come for using technological innovation and training design to make simulator training more available to students using all available media (such as desktop, virtual reality, full-mission, and cloud-based simulators), with or without the students' and instructors' actual physical presence at the simulator training facilities.

Slow growth and development are a result of people's preference to become familiar with what they do rather than step outside of it. Many people in education are afraid of failing and reluctant to learn new techniques or skills if they must adapt to innovative technology or culture. The maritime sector is going through a paradigm shift as it adapts to an environment that is constantly changing due to digitalization and decarbonization. To provide training and retraining that is applicable to practice, maritime education and training must develop.

As is well known, the International Convention on Standards of Training, Certification, and Watch-keeping for Seafarers (STCW), regulates the use of simulators. The International Maritime Organization (IMO) has approved the use of simulators to replace the infrastructure of a traditional "firsthand" approach, in which students take theoretical classes and have hands-on experience with real lifeboats, davits, and equipment. This is allowed if trainees can continue to show that they have attained the competencies listed in the STCW tables referring to this training.

Although using VR (virtual reality), AR (augmented reality), and MR (mixed reality) head-mounted display technologies for professional training and operations is not a novel idea, their rapid development and widespread use now make this possible. This post will not go into great detail about these technologies.

3. MODES OF IMPLEMENTATION OF THE EDUCATIONAL PROCESS

It is undeniable that nowadays in the educational process, there is an interconnection between the learning management systems (LMS) used in traditional and digital environments. E-learning and traditional face-to-face learning are the most significant learning processes, and students pursuing their first degree at higher education institutions, both state and private, around the world, are practicing them. This was stated by Razeeth et al. (2019) even before the start of the pandemic in 2019. [12]. Both methods of instruction are used by the majority of educational institutions.

Higher maritime education uses a virtual learning environment that includes systems for collaboration, integration, information, communication, development, and career orientation. This type of digital education is carried out through networks, mobile phones, and multimedia. Every student in higher education has uncertainty when using or learning in a digital environment without this (Nurassyl Kerimbayev, 2016).

Until a few years ago, most college students and instructors across the globe believed that traditional learning management systems and close-up, one-on-one instruction methods were effective for fostering social skills like correspondence, relationships, and identity. A maritime education student can benefit from traditional education's engagement, motivation, accessibility, organization, and so forth. This leads to direct communication between teacher and students in higher education, which allows students to develop their group work activities and promptly clear any doubts they have about particular subjects, setting them apart from digital-based learning.

The following keywords best describe future-educated maritime workers: diversity, personal accomplishments, societal ideals, and challenge readiness. [2] These principles and objectives are the focus of contemporary educational systems. While traditional education takes place in a classroom, universities are increasingly incorporating technology into their curricula today. The trainer is still the main information source in face-to-face instruction situations, though.

3.1. Learning experience process

Any interaction, program, course, or other experience in which learning occurs is referred to as a learning experience, regardless of whether it takes place in a traditional academic setting or a non-traditional one. Rather than focusing on the setting or structure of an educational contact, learning experiences can instead be used to emphasize or reinforce the main purpose of the engagement.

When comparing the learning experiences offered by traditional and digital learning management systems, it can be said that formality can be the basis for learning interventions in traditional LMS, whereas formality, informality, and sociality can all be present in learning interventions in digital LMS.

In a first-type LMS, the end-user tools are the browse catalogue, simple search, and email notification. However, a digital LMS has more user tools, such as faceted search, individual development pane, dynamic recommendations, learning paths, learner and manager dashboards, email and text notifications, ratings and reviews, badges, and leader boards, to name a few.

The word "learning experience" is being used by educators more frequently, which reflects broader pedagogical and technical changes in the planning and delivery of student education. It represents an effort to modernize ideas about how, when, and places where learning does and can occur. For instance, new digital platform-based technologies have increased and diversified the number of ways that students can interact with and learn from teachers. All of this is on top of any learning-related independence they may have. Teachers and students can communicate by email, chat, or video chat, and online course management systems can be used to store and share course materials. To learn independently, students can also use software, apps, and instructional games.

The correct mix of educational opportunities can prepare children for success throughout their lives. Teachers can drastically change how students interact with digitally based maritime platforms by providing them with effective learning opportunities and tactics.

With the correct tools, students can approach subjects with a growth mindset, enabling them to perceive things from a well-rounded viewpoint. Nowadays, it is crucial to teach subjects using multiple senses in order to give real value to education.

3.1.1. Blended learning

With the development of digital technologies, higher education institutions saw a change in basic assumptions in education in the twenty-first century. It is generally acknowledged that Internet networks are employed as learning platforms that are widely dispersed, more adaptable, easily available, and, most importantly, permanently open. This is due to the ongoing improvements in the quality and scope of e-learning content delivery.

The blended learning approach is a brand-new, rapidly developing method of instruction that has been embraced by many schools and universities. To ensure fewer interruptions to teaching and learning activities, most higher education institutions have adopted the new learning system. On the other hand, the work of switching from teaching in physical classrooms to virtual classrooms to ensure successful contact with the students is equally difficult for the instructors [7].

The four components of learning content include creation, management, publication, and delivery of digital content.

Table 1 Learning Content

	Content authoring	Content management	Content publishing	Digital content delivery
Traditional LMS	Simple course builder, rapid authoring tools, sophisticated and structured authoring for courses, presentations, printed guides, job aids, web pages and Flash	Versioning, workflow, and review tools	Print and web output templates/formats	Packaged SCORM/AICC or *.pdf
Digital LMS	Granular learning content separated from presentation for rapid assembly and reuse across any output format or audience	Online collaboration, versioning, workflow, and review tools	Print, responsive web (HTML5/CSS3), and mobile output templates/ formats	Learning Object Repository (LOR) serves multiple formats for many systems and devices

Source: https://elearningindustry.com/

E-learning content, according to Kumar et al. (2021), includes any document, presentation, audio, or video file that can be utilized to offer e-learning. As study material or lectures, this includes PowerPoint presentations, manuals, reports, white papers, charts and graphs, videos, illustrations, case studies, infographics, problem-solution scenarios, simulations, screen captures, animated GIFs, checklists, e-books, articles, blog posts, interviews, etc. It also includes assignments, projects, test questions, a question-answer bank, and practice exercises. They place a strong emphasis on independent learning, with no instructor-led instruction at all. Learning content and digital content are the two main components that make up digitally based education. Learning content refers to information that is concisely and effectively provided to pupils and that is factual and in-depth. The internet, satellite TV, radio, and storage media like compact discs, hard disks, pen drives, etc. are the main electronic channels used to distribute the material. [11]

3.1.2. Administration learning

LMS, including learner profiles, content, needs management, and the LMS itself, are all managed by learning administrators.

With learning administration is possible to:

- Control the organization, sources, and content of online courses. You can set up third-party course providers, create a server, and import your own content into it. A content structure can also be defined, including tests for learners;

- Identify the learning requirements of the specific organization and create a system to provide and monitor what employees are learning as a requirements management process;
- Manage learner profiles: user data imported into training to manage learner training;
- Maintain the LMS's alignment with the organization as it expands, establishes new organizational structures, modifies policies that have an impact on global settings, incorporates new countries, defines new roles, etc.

The learning administration can be separated into three groups: User and Group administration, Course Administration, and Reporting and analyses.

Table 2 Learning Administration

	User and Group administration	Course administration	Reporting and analyses
Traditional LMS	Manage Users and Groups	Course Enrolment, Completion Rules, Classroom Management	Completion Tracking, Test Scores
Digital LMS	Single Sign-On (SSO), integrated with HR system	Course Enrolment, Learning Paths, Classroom Management, Competency Management, Certification Management	Centralized Learning Record Store (LRS) for reporting and analytics, Completion Tracking, Test Scores, Question Analytics, Informal Learning Activities, Social Learning Activities, Content Effectiveness

Source: https://elearningindustry.com/

3.2. Online and offline modes process

Any mode of instruction depends on the learner's thirst for knowledge, the instructor's ability to transmit that knowledge, and their combined competence. Several online tools improved the teaching-learning process during the Covid-19 pandemic. Mobile learning, mobile voice, digital reality, other digital platforms, and other interactive multimedia networks have all emerged as a result of the Internet and wireless communication technology's rapid advancement. Traditional education would be replaced by using the ease of use and popularity of the Internet to use digital teaching resources and achieve the goal of competitiveness. Because of this, extensive research is being done on digital learning to provide better transmission performance and widespread adoption.

Also in an article published in 2012, Sebastian et al. regarded digital learning as the learning mode the most rapidly developed in past years as well as the learning mainstream in the future. In addition, it was rapidly developed because it broke through traditional teaching modes and presented various strengths. [13]

To enhance the educational process, Sharma et al. generalized the following findings: Since peer-to-peer interactions in offline classes are superior to those in online classes, they are preferred. Students can learn outside of the classroom by using reading materials, PowerPoint presentations, and videos shared by topic teachers. Collaborative online technologies are preferred for problem-solving over in-person interactions. Most students prefer to study from the video lectures given by the same lecturers who handle the theoretical and lab experimentation topics. During interactive sessions held in class or during group discussions, many students choose to voice their opinions. When offline classes cannot be held, online classes are preferred. Online classrooms are the finest substitute for off-line classes, particularly in instances like the pandemic since they enable students to adhere to safety procedures [14].

Only when the system functions are extensive and varied, close to the perception of the users, and draw students to log in to the system for learning, can the effectiveness of teaching be increased.

Sharma et al. concluded by saying that learning is a dynamic phenomenon that has continuously changed over time. So, the methodology chosen will determine how effective learning is. They believe that the pedagogy or technique should be based on the skill sets that students should be expected to learn. The only thing we know for sure is that the pandemic in 2019 provided us the chance to use and evaluate a variety of online teaching and evaluation technologies across various digital platforms. The parties involved in this situation include the school's officials, teachers, and students. [14]

3.2.1. Distance education

There are many definitions of distance education, as Silber et al. noted at the beginning to their article:

- In a distance education system, most of the teacher-student communication takes place virtually.
- Using instructional technologies and mail services, teachers and students from various places engage in learning and teaching activities through distance education.

The term "distance education" describes any initiatives made to deliver instruction to students who are in different time zones and locations than the teachers using written materials or technological communication methods.

Radio, television, telephone, and computers were used to improve distance learning practices, which were initially correspondences. These days, distant education is pursued by using audio and visual interaction mediums along with video conferencing systems in addition to the tools and presentation systems, such as multi-media presentation systems or digital-based platforms. [16] Even though online learning is thought to be the way of the future in terms of education, it will never be able to completely replace traditional learning in its entirety.

3.2.2. Offline education

The original learning method that allowed students to regularly interact in person with their instructors and fellow students is known as offline education. It is the conventional alternative to online education. Offline learning is independent of technical concerns and provides a good opportunity for students to create and maintain a regular schedule. Additionally, offline instruction enables teachers to watch their students' actions and responses and give appropriate feedback. Therefore, despite how sophisticated online education becomes, offline education will always be crucial for students' development.

When teaching offline, subject matter, timing, creating, controlling, and grading exams, and classroom management and other things should be determined. Still, important factors are the teaching approach, classroom management techniques, and interpersonal abilities. Conversely, classroom-based instruction is rigid. Typically, teachers are unable to select when they work. Once the schedule is created, it can be very challenging to change it. The lecturer will not be able to provide your students with the same level of individualized care that an online instructor can. Teachers must be more inventive and imaginative in the offline mode, or traditional classroom, to deliver lessons and hold students' attention. Additionally, the duties of an online teacher are primarily restricted to lesson planning, instruction, and feedback.

According to the findings of a study conducted by Sharma et al., most students would still like to travel to university to attend offline lectures even in a bad condition where commuting seems like a burden. Although many students would still prefer online lectures on such days, this demonstrates their preference to attend offline lectures. According to the findings, 48% of students prefer inclement weather offline lectures, 46% prefer online lectures, and only 6% of students appear unsure. There are many opportunities to socialize and meet new people when taking lessons offline. The pupils are always fascinated by their ardent desire to interact with their peers to learn and discover new things together. Additionally, they can meet with their teachers to discuss both academic and extracurricular issues. [14].

4. BENEFITS AND DRAWBACKS OF DIGITAL LEARNING PLATFORMS

The completion of seagoing practices, the low level of maritime English language teaching, the lack of academic staff in maritime institutions, low-level equipment with high-tech simulators, and specialized digital platforms are just some of the issues that maritime higher education institutions face.

When intelligent mobile devices become more common in modern society, the Internet overcomes the boundaries of time and space and becomes a ubiquitous learning tool, according to Lin et al.'s analysis of the effects of digital learning on learning motivation and learning outcome. The main challenges facing today's information technology-integrated education are designing educational activities for digital learning and applying technology tools flexibly. According to the study's findings, learning motivation has significantly more positive effects on learning outcomes than traditional teaching does, and it also appears to have remarkably positive effects on learning gains in learning outcomes. Digital learning also exhibits better positive effects on learning outcomes than traditional teaching. To create useful teaching techniques for teaching effectiveness, it is anticipated that they would integrate with existing teaching trends and make use of the benefits of digital learning [9].

Because the content would not change with media or standards, students could easily use digital learning platforms to learn and overcome time and space constraints for thorough learning and successful graduation. Learning motivation enables students to get ready for learning and would improve focus and assimilation of added information. The ability to get two degrees concurrently is a huge benefit of digital education systems. While enrolled in a traditional course, a student has the option of pursuing another degree program at the same university or elsewhere. This is one of the key benefits of the digital learning process, which provides higher education students with knowledge in a variety of levels of subjects [8].

The benefits of digital over traditional learning were categorized into nine key areas by Miyoshi et al.: digital learning materials and adjusted learning schedule, learning without issues, rich network resources, interactive learning, increase in learning interests, complete records of learners' learning histories, concurrent new technology learning, effective accumulation of knowledge, and last but not least, lower teaching costs [10]. Regardless of their ability, learners in traditional teaching received the same teaching schedule and lesson plans, according to their scientific publication. In order to obtain a customized learning outcome, the curriculum was designed, and teaching materials were produced for digital learning. Learners could freely choose from a variety of courses and teaching materials based on their level and preferences [17].

With the help of the instructors' online interaction platform, students can learn without issues and without being constrained by time and space, unlike in traditional learning [5]. They can choose the time and place for online learning and are not under any time or space-related pressure. The knowledge and resources available on the Internet are so extensive and varied that students can find material by just performing a keyword search. The effectiveness of network resources would be applied through digital learning when digital-based platforms were able to organize pertinent resources for students' use or connection, and instructors could acquire richer information outside of the teaching materials in the curriculum to improve the learning effect [4].

Hockly et al. noted that interactive learning was self-learning, and that more media (pictures, music, or images) should be included in the creation of teaching materials than in traditional ones to produce more visually appealing and engaging teaching materials. Additionally, interactive features like chat rooms and discussions would be offered by digital education platforms to encourage more two-way communication between students and teachers as well as among learners [3]. Increasing student interest in learning is crucial. To improve learning efficiency and encourage learners' consistency, Kaklamanou et al. observed that information technology and the presentation of diverse media could make instruction more vivid and dynamic [6].

For instructors to comprehend students' learning circumstances, an effective digital education platform should be able to thoroughly record students' learning histories. On the other hand, the pupils were able to understand the level or learning objective for improvement and adaptability. To improve students' abilities to use information technology, Shin et al. emphasized that digital learning entails teaching students new computer and network technologies as well as specialized knowledge [15].

All online teaching resources and students' learning histories might be thoroughly and methodically recorded using the digital learning mode. Through the use of a digital education platform, instructors could efficiently organize and compile the contents of their lesson plans before quickly delivering them to their students [5]. This would allow for efficient information management and gradual accumulation of knowledge for the students.

When discussing the benefits and drawbacks of digital education platforms, the decrease in teaching expenses is also a crucial point. In order to allow for recurrent use of the finished teaching materials, the teaching material contents used in a digital teaching platform were stored as digital files. In other words, the instructional materials prepared by the teachers before the courses allowed students to use them frequently and learn. The costs associated with teaching increased because traditional methods required all students to assemble for lessons at the same time and place.

We can also point out the benefits that education delivered through digital channels has for students with disabilities who are unable to participate in class activities. This kind of feature can be used by a student, and even if they have difficulties, there may be a way for them to get knowledge in a certain subject. As a result, this approach aids reluctant students who are enthusiastic about their studies. One of the excellent chances offered by e-learning to students in higher education is this one. This type of functionality cannot be provided through traditional learning; there is no need to have the same concept repeated for other students, and each student needs to be able to repeat a particular learning management system on their own [12].

The drawbacks of digital learning platforms for instructors and students are diminishing with time. When it comes to learning motivation, digital platforms simply deal with imparting knowledge. However, in conventional learning, a teacher can inspire students in real time to deal with issues that address the social skills problems they are experiencing in e-learning activities. The digital learning method does not support helping less knowledgeable students with exercises, but in classroom activities, a student can ask teachers and other classmates for help and continue.

5. CONCLUSION

The efficiency of digital platforms has improved proportionally with the advancement of technology. For aspiring seafarers and maritime professionals, this has a wide range of benefits. The goal is to have the experts ready and make sure they work well together in situations that are really demanding. One of the main benefits is that it offers a safe environment where trainees can practice their job functions in front of instructors while not fearing any negative consequences that could have serious financial repercussions in the real world.

It is crucial to examine the information and skills that various educational institutions provide to their graduates to predict employment chances in the maritime industry. Although the requirements regarding training methodologies in maritime education are detailed in the International Convention on Watch-keeping and Standards of Training and Certification of Seafarers (STCW) and higher maritime education institutions comply, there are still a number of difficulties in the design of maritime education programmes.

To assess the prospects of graduates for employment in the maritime sector, it is crucial to consider the knowledge and capabilities that different educational institutions teach their students. The best maritime education institutions and programmes follow the criteria set out in the recognised regulations and, despite this, there are still a number of challenges facing maritime education that will not stop being subject to improvement.

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INTERNATIONAL OFFICIAL LANGUAGE OF MARINE INDUSTRY AND EDUCATION OF SEAFARERS

Lia Dragojević
University of Dubrovnik
E-mail: lia@unidu.hr

UDK 656.61:811.111

Abstract

Seafarers require special attention in Croatian tertiary-level education institutions. Our schools have a long tradition and an excellent worldwide reputation. The first Nautical School in Dubrovnik was founded in 1852. The importance of Maritime English globally in the education of seafarers has been discussed because it is considered to be a contributing factor to the safety of human lives at sea. This paper deals with the features of Maritime English nowadays and compares the language of the Syllabus of the Nautical School of Dubrovnik from 1881/82 and the one from the Nautical Department of The University of Dubrovnik from 2019/20. The phenomenon of EMI (English Medium Instruction) has been explained as a new concept both in European and world universities.

Keywords: Nautical Studies, Maritime English, English Medium Instruction

1. INTRODUCTION

Croatian maritime education institutions have a long tradition in the education of seafarers. Dubrovnik has always had a special role, due to its tradition, history, and geographical position. In 2019. it was celebrated the centennial of the scientific journal „Naše more" and the 60th anniversary of the university-level education of seafarers in Dubrovnik. It is interesting to analyze what was the language of education of our seafarers over a hundred-year-long period.

It should be mentioned that seafarers hadn't had an adequate maritime education, before the foundation of the Nautical School in 1852. Skills and knowledge necessary for the seafarer aboard the vessel for a long period had been forwarded from the older to the younger ones. Only the Captain i. e. Master Mariner had to master the skills of handling the vessel, manoeuvering, nautical calculations, meteorology, astronomy, geography, and maritime law. Those young men were educated by their fathers, grandfathers, or by privately paid experienced experts in the area.[1]

The reorganization of maritime education had been caused by the development of the steamship industry and the elimination of sailing vessels as a means of transportation. It happened around 1875.

The Syllabus of the Nautical School of Dubrovnik dating back to 1881/82 showed that the education for seafarers at that time lasted for three years. There were 13 different subjects for three classes of a total of 22 pupils.[2] Interestingly, at the same time, the introduction of the subject *English Language* occurred. It was for the first time that the English language entered the education system of the territory which is now The Republic of Croatia. The authorized English language professors didn't exist at that time, therefore the teaching

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process was taken over by Đuro Margetić, Master Mariner.[3] He had acquired skills in speaking, understanding, and writing in a foreign language i.e. English during his voyages serving aboard merchant vessels in the territorial waters of The United States of America. He was also later assisted in teaching by Nikola Zar and Paolo Radimiri.[4]

The language of education of seafarers on the eastern part of the Adriatic Coast during the 19th century was thoroughly elaborated in the book *Hrvatsko pomorsko nazivlje* by Diana Stolac, published in 1998. The official language of the education of seafarers at that time was Italian. Bakar Nautical School also introduced the Croatian language (subject - Hrvatski jezik) in 1871. as obligatory. From 1882. onwards, in all Nautical Schools on the Adriatic, the Croatian language was introduced, but professional subjects continued to be taught in the Italian language.[5] Today, about 150 years later, the situation has considerably changed. Although Croatian is the official language of education in The Republic of Croatia, English has become a very important element in Nautical Schools, as found in The Syllabus of Nautical Studies - Maritime Department of The University of Dubrovnik.[6]

2. LANGAUGE OF EDUCATION OF SEAFARERS IN THE 19TH CENTURY

Nautical Schools were the first schools in our country to have introduced in their curricula English language as an obligatory subject. The teaching process was caused by extended maritime and commercial activities. The aim had been to teach a specialized language i.e. Maritime English from the very beginning of its introduction in the system of education.

Lecturing of Maritime English in the nineteenth century couldn't be confined to qualified English language professors, because at that time, the school for our profession was not existent. Moreover, the necessity to teach English in Nautical Schools on our coast developed an interest in the English language in our Croatian culture.

Nautical School professors of that time published some manuals. Those books were thoroughly analyzed in M.A. theses by Tonka Carić. Her thesis was completed at the Inter-University Centre of Dubrovnik in 1989. This very valuable work was burnt in the library of the Centre during the Serbo-Montenegrin attack on Dubrovnik in 1991. A complete library of 2300 books in American Studies (Fulbright donation) was burnt.[7]

The author of this paper found another copy of Tonka Carić thesis in the library of the Maritime Faculty in 1999 during the study visit to The University of Rijeka. The adapted version of Carić thesis was published as a book in Belgrade in 1998. Her text follows the history of teaching English at maritime high school institutions.

2.1. First Manuals for Teaching English

Teaching English at Nautical Schools on the Adriatic Sea (especially at Bakar Nautical School) meant also the publication of manuals for that purpose.[8] The books were the following:

1. Aleksandar Lochmer (1889) Gramatika engleskog jezika za školu i samouke = English Language Grammar for School and Self-Education

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[8] Carić, Tonka (1989) *Engleski jezik u nastavi u našem pomorskom školstvu*, M. A. thesis, University of Zagreb: Inter University Centre of Dubrovnik

2. Aleksandar Lochmer (1899) Engleska čitanka sa zbirkom engleskih trgovačkih listova za mlade pomorce i za školu s obilnim hrvatskim tumačem = English Reader with a Collection of Commercial Papers for Young Seafarers and School with an Extensive Croatian Glossary
3. Milan Drvodelić (1927) Engleska gramatika za trgovačke i njima slične škole te za samouke = English Grammar for Commercial and Similar Schools and for Self-Education
4. Svetozar Savić (1937) Englesko privatno i poslovno dopisivanje = English Private and Business Correspondence
5. Jelena Kolin Đukić (1947) Engleska čitanka za pomorce = English Reader for Seafarers
6. Milan Milinović, Marijan Urbany, Vera Urbany (1962) English for Seamen = Engleski za pomorce
7. Katica Jelinić Babić (1968) An English Course for Nautical Schools = Tečaj engleskoga jezika za Nautičke škole

Further research into Maritime English manuals of today is described in the papers, publications, and e-sources by Boris Pritchard.[9]

It is worth mentioning that Aleksandar Lochmer himself was the first founder of the Department of English of The University of Zagreb in 1899. He was not an English language professor but a historian and geographer but he perfected his linguistic knowledge during his travels in England and America. Milan Drvodelić also was not an English language professor but graduated in Croatian, Greek, and Latin from The Faculty of Philosophy of The University of Zagreb. Later, he completed eight semesters of English language kept by Aleksandar Lochmer.[10]

3. IMPORTANCE OF MARITIME ENGLISH

The English language has long been *the lingua franca* of seafaring because the multilingual environment had required one working language. That is not the language of common people, but a specialized language for specific purposes (ESP). According to Cole and Trenker (2004), there are 341 million people, who use English as a first language, and around 300 million use it as a second language.[11] They state that in 105 countries around 50% of the world's total, it has official or special status. At the same time, David Crystal (1997) calculated that one in five of the world's population speaks English „competently" and that, one in three, is exposed to it daily.[12] Great Britain as an insular country, had always had ambitions to spread its trade worldwide. As the dominating partner, they would then expect the local inhabitants to communicate in English if they wished to do business with British vessels. Fred Weeks, the first president of The International Maritime English Conference (IMEC) suggested in 2004 that „this probably formed the basis of the pre-eminent usage of English language Bills of Lading and Charter Parties."

The expansion of the English language was dramatic, especially after The Second World War, due to British-American scientific and technological progress and dominant trade and commerce which influenced all other aspects of life.

In 2013. Anna Bocanegra-Valle in her book *The Encyclopedia of Applied Linguistics* defined Maritime English in the following paragraph:

> Maritime English Terminology and phraseology pose a real challenge due to their specialization and unfamiliarity: Passengers sleep in *cabins* and meals are cooked in the *galley*; a ship does not have walls but *bulkheads*; smoke comes out of a funnel, not a chimney; objects are not positioned left or right but on the *port* or *starboard sides*; ships *make headway*, *sternway*, or *leeway* when they move forwards,

[9] www.IMLA/IMEC visited December 2020 Cole, Clive and Trenker, Peter (2004) *Whither Maritime English*? In Retrospect and Prospect; International Maritime English Committee (16 IMLA/IMEC) p. 22-34.
[10] www.ffzg.hr Vidan, Ivo: *Povijest Odsjeka za anglistiku* Filozofskoga fakulteta Sveučilišta u Zagrebu, visited December 2019
[11] Cole, Clive and Trenker, Peter (2004) *Whither Maritime English*? In Retrospect and Prospect; International Maritime English Committee (16 IMLA/IMEC) p. 22-34.
[12] Crystal, David (1997) *The Cambridge Encyclopedia of Language*, Cambridge: Cambridge University Press

backward, or sideways through the water; and when underway they may be *overhauled*, not overtaken, by faster craft. Orders such as *Single up to a back spring forward*, *Put engines slow ahead*, *Rudder hard-a-port*, *Slack away on the breastline until the stern is clear of berth* or *Let go fore and aft*, require not only good professionals but competent Maritime English speakers if a ship is to be handled efficiently. Noteworthy is the peculiarity of ships to have feminine grammatical gender for seafarers (an in-service mariner would always call a ship *she*), which remains one of the most distinctive features of the English language as currently used at sea. Maritime English subsumes five different subvarieties according to the specific purpose they serve within the maritime context: English for navigation and maritime communications, English for maritime commerce, English for maritime law, English for marine engineering, and English for shipbuilding. [13]

4. MARITIME DEPARTMENT OF THE UNIVERSITY OF DUBROVNIK

If a young student wants to enroll at the Maritime Department of The University of Dubrovnik she/he will check the Web page of our institution. At first glance, it is evident that the syllabus of the Maritime Department - Nautical Studies contains numerous maritime-related subjects. *Maritime English* is the first on the list, being the official working language of the marine industry. Then it follows *Mathemathics*, *Watchkeeping*, *Survey and Safety*, *Organization of the Work and Management*, *Computing*, *Maritime Law*, and *Physical Education*. These are the subjects of the winter semester of the first year. The summer semester syllabus contains *Maritime English 2*, *Mathematics 2*, *Environmental Protection of Sea and Environment*, *Collision Regulations*, *Safety at Sea*, *Medicine for Seafarers*, *Cargoes in Waterborne Traffic*, and *Physical Education 2*. These are only subjects of the first year. Our Nautical Department also offers subjects that are indispensable for Nautical Studies, so the students coming from other special schools (other than Nautical) are offered tailored-made courses named: *Knowledge of the Ship and the Cargo*, *Basic Navigation*, and *Mariners' Skills*.[14]

Will we find that obligatory literature is written in English? Is English used as a medium of instruction for seafarers nowadays at Nautical Department in Dubrovnik? The short survey will show an outline of the literature and at the same time the languages of the manuals and books recommended for studying maritime-related subjects. The international nature of the marine industry as well as the mobility of students within the European Union and worldwide nowadays require courses to be held in English.

4.1. Syllabus – First-Year Nautical Department

The syllabus of the first-year Nautical Department of The University of Dubrovnik reveals to us that eighteen (18) subjects are offered to the student at an academic level. The names of the subjects are written in Croatian, but the literature for the courses (obligatory and elective) contains a lot of titles written in English.

4.1.1. Languages of References

Logically, Courses *Maritime English 1 and 2* contain four (4) publications written in English. *Watchkeeping, Survey, and Safety* require five (5) obligatory publications to be covered for the learning outcomes. *Organization of the Work and Management* requires complete literature which is written in English i.e. eight (8) publications. The Course *Physical Education 1 and 2* under the number 3 requires one American publication published in English. Since the education of seafarers in Croatia is regulated by international conventions, therefore special Course *Knowledge of the Ship and the Cargo* quotes four (4) references written in English. *Environmental Protection Course* is based on the content of two (2) references written in English. The Course *Basic Navigation* which focuses on finding a ship's position, safety and stability contains four (4) references originally published in English. Then follows the Course *Mariners' Skills* with the citations of four (4) references published in English.

[13] Bocanegra-Valle, Anna (2013) *The Encyclopedia of Applied Linguistics*, Edited by Carol A. Chapelle, Blackwell Publishing Ltd.
[14] www.unidu.hr *Nastavni plan i program* Studij Nautika Pomorski Odjel Sveučilišta u Dubrovniku 2019./20. visited December 2020

The total number of references in English quoted in the First Year Syllabus is forthy one (41). On the other hand, there have been quoted 55 (fifty-five) references that are written in our mother tongue - Croatian. The conclusion could be that there is no literature available translated from English into Croatian for the subject matter. Therefore, the professors use texts in English and adapt their lectures respectively. The Croatian system of education has prepared the professors of the Maritime Department to teach in English. In addition, they have also the experience of serving aboard foreign shipping companies and they are fluent in English. It is supposed also that the students have an adequate level of knowledge of English to be able to acquire the contents of the subjects.

4.2. Research into the Knowledge of Students' Vocabulary

To obtain reliable, measurable data and results, modest research was carried out among the students of the first year of the Nautical Department in 2018. The research aimed to reveal the level of students' knowledge of English maritime-related terminology and design the lectures to their needs. It was lexical research in which students established 13 translational equivalents in Croatian for 9 English nouns denoting crew members. The nouns were: *shipmate, captain, sailor, mate, harpooneer, mariner, pilot, seaman, commander.* The results showed that they understand very well the terms and know exactly the homonyms, synonyms, and antonyms. In translation, they tended to use Anglicisms instead of standard Croatian equivalents. Sometimes, it was easier for them to understand by translating into colloquial expressions of f.e. Lastovo, Lopud, Pelješac, Šipan, Konavle, Mljet, Korčula, Mokošica, etc. Frequently, they better understood English than their mother tongue - standard Croatian. They were conscious that to be competitive in an international market means to be equipped with good competence in English. Therefore, they are highly motivated to learn it even better.

4.3. English Medium Instruction

It is well-known that now universities compete at a global level.This is one of the reasons why English is used increasingly as the medium of education in universities across the world. The „Bologna Process“ was an agreement signed originally in 1999, now involving 45 countries aimed at harmonizing university education within Europe. The standardization of higher education is intended both to make the movement of students easier within Europe and to make European higher education more attractive for non-European candidates. Although the use of English in teaching is not mentioned in the Bologna Process, its use has been encouraged. Thus candidates could carry out all, or part of their undergraduate or postgraduate study in another country. In 2003-04 an estimated 1500 Master's programs were offered in English in countries where English is not the first language.[15]

Oxford professors Jessica G. Briggs, Julie Dearden, and Ernesto Macaro in 2018 surveyed the teachers of EMI and they concluded that EMI is beneficial to advancing students' English but they consider that EMI would affect academic content.[16]

An interesting survey was carried out by two professors from The Faculty of Philosophy of Rijeka University. It was discovered that the teachers of English considered the following advantages of instruction in English: heightened international visibility, enhanced international cooperation, increased mobility, and improved competitiveness. The challenges of instruction in English included a lack of English proficiency as a central concern, which would harm the acquisition and production of academic knowledge and lead to a reduction in course coverage. Students' insufficient language skills would impact their ability to comprehend the material and thus adversely affect test results.

[15] Graddol, David (2007) *English Next*, Why global English may mean the end of English as a Foreign Language“ London: The English Company (UK) Ltd. & British Council

[16] Jessica G. Briggs, Julie Dearden, Ernesto Macaro (2018) *English medium instruction*: *Comparing teacher beliefs in secondary and tertiary education*, Studies in Second Language Learning and Teaching

5. CONCLUSION

To compete at an international level as a seafarer, means to have excellent competences in English. Maritime School of Dubrovnik introduced English as a subject in 1852. It was taught by Master Mariner Gjuro Margetić. The professors of Bakar Nautical School founded the Department of English Language and Literature of The Faculty of Philosophy of The University of Zagreb. Although the official language of The Republic of Croatia is Croatian, English has become an important element in teaching maritime-related subjects. It is evident in the analysis of The Syllabus of Nautical Studies of The University of Dubrovnik 2019/20 that in the First year Course Outlines there were found 41 references written in English. Both teachers and students consider it necessary. In the future, it would be interesting to see the development of the usage of the English language in our schools. Today, Master Studies in Europe as well as worldwide have introduced English Medium Instruction to attract foreign students and to be competitive and recognized worldwide.

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ANALYSIS OF SHIPS AND BOATS ACCIDENTS ON THE CROATIAN PART OF THE ADRIATIC SEA

Stipe Galić
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: sgalic@pfst.hr

Zvonimir Lušić
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: zlusic@pfst.hr

Mate Vukić
Harbour Master's Office Split
Split, Croatia
E-mail: mvukicmv@gmail.com

UDK 656.085:338.48-44(262.3)
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Abstract

Maritime traffic on the east coast of the Adriatic Sea has increased significantly in the last ten years, and as a result, the number of collisions, groundings, other accidents and incidents has also increased. The growth of nautical tourism and the general increase in the number of recreational vessels have a significant share in the overall increase of maritime traffic, both in the total number and in the ratio of the number of residents per vessel. Due to the expansion of nautical tourism and the fact that the traffic of nautical vessels is most intense during the summer months, most accidents occur in the summer season. In this paper, the dependence of the number of accidents on changes in the state of maritime traffic will be determined, and the main causes of their occurrence and potential measures to reduce the risk of accidents will be analysed. The paper also gives an overview of the impact of the COVID-19 measures on the volume of maritime traffic and nautical tourism in the Republic of Croatia, taking into account the epidemiological measures that restricted the movement of people, and thus travel.

Keywords: Ship traffic, nautical tourism, ship accidents and incidents, COVID-19.

1. INTRODUCTION

The traffic of ships on the eastern coast of the Adriatic Sea increases every year, so the probability of collisions, groundings and other types of accidents increases accordingly. There is a large traffic of boats and yachts, small cruise ships, passenger ships and large cruise ships during the summer months, and the reason for this is the continuous development and offer of nautical tourism in the Republic of Croatia [1].

Accidents involving smaller vessels that occur especially in the peak of the tourist season are not negligible, as their number is not small. Some accidents involving smaller vessels (yachts, sailboats, speedboats, boats and personal watercraft) also lead to the loss of human life.

Also, such small vessels, which appear as part of nautical tourism, with their number hinder the traffic of large ships, which can cause catastrophic consequences for human life and the marine environment by running aground or colliding. Also, a large number of such small vessels, which appear as part of nautical tourism, can cause the grounding or collision of large ships with their traffic interference, which can cause catastrophic consequences for human life and the marine environment.

Regardless of the measures taken to increase the safety of navigation in the part of the Adriatic Sea under the jurisdiction of the Republic of Croatia, accidents and incidents involving large and small vessels continue to occur. The aim of this work is to investigate and analyse maritime transport on the eastern coast of the Adriatic with an insight into the impact of vessels from nautical tourism through the issues of maritime transport and the resulting accidents and incidents.

2. MARITIME TRAFFIC AND NAUTICAL TOURISM

Today in the Republic of Croatia, tourism has become one of the most important branches of the economy and accounts for one fifth of the Croatian economy [2]. The Republic of Croatia has recorded an intensive development of tourism in the last twenty years. In accordance with the general development of tourism, selective tourism, which includes nautical tourism, is also developing. Selective tourism is defined as the organization of various forms of tourism aligned with the natural and social values of the local community that enable guests and hosts to enjoy positive and valuable interactions of mutual experience [3].

Nautical tourism in the Republic of Croatia is on the rise, and is an increasingly important factor in tourism. However, with its expansion, the maritime traffic of boats, yachts and other vessels also increases, especially in the summer season.

Croatia is a maritime country with a long history and tradition of seafaring and tourism. The natural basis for the development of nautical tourism is the Adriatic Sea with its indented coastline.

It should be noted that the Republic of Croatia has an indented coastline of 6,176 km, of which 4,398 km belong to the island coast, with a total of 1,244 islands, islets and rocks, of which 50 are inhabited, so it is very important to have a good connection between the islands and the mainland [4]. Especially during the summer season, a greater number of ferry lines are introduced for users with vehicles, but also fast-ship lines such as catamarans that are used to connect the islands with the mainland and between islands. Some lines operate throughout the year, but precisely because of the increase in tourism in the Republic of Croatia, the number of lines and the amount of tours per day greatly increase in the summer months [5].

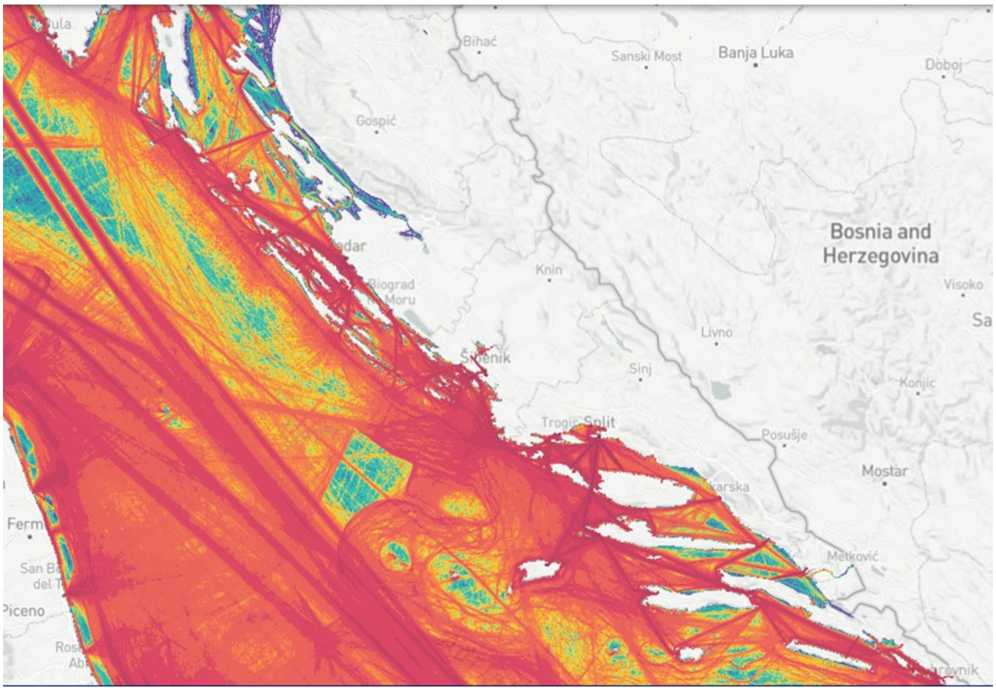


Figure 1 Traffic density of vessels equipped with AIS devices on the eastern coast of the Adriatic in 2020/2021.

Source: [6]

From Figure 1, which shows the density of maritime traffic through 2020/2021 on the eastern coast of the Adriatic, it can be concluded that the densest ship traffic is in the approach to ports and routes of cargo ships, but also in the connections between islands, where ferries and mini cruisers make a big contribution, as well as yachts and smaller vessels during the summer season.

Namely, local ferries and catamarans connect the most important ports with most of the islands, while international shipping lines are connected exclusively to Italy. Thus, in addition to cargo ships, cruise ships, small cruise ships, mega yachts, yachts, large and small sailboats, and recreational vessels, maritime traffic on the eastern coast of the Adriatic also consists of ferries, catamarans and hydrofoils.

Figure 2 Presentation of the positions of built ports and marinas in the eastern part of the Adriatic in the Republic of Croatia in 2023

Source: [6]

Nautical tourism at sea must be based on contents related to tourist and recreational sea navigation in order to function as an economic activity. More important factors of nautical tourism are transport and communal infrastructure of ports and marinas, anchorages, production of tourist boats and equipment, and boat rental (charter). For this reason, the construction of ports and marinas along the east coast of the Adriatic constitutes one of the main infrastructural factors in the development of nautical tourism in the Republic of Croatia (Figure 2).

3. CAPACITIES OF MARITIME TRAFFIC AND NAUTICAL TOURISM

In 2022, maritime traffic recorded a recovery after the decline caused by the COVID-19 pandemic (Table 1). In 2022, 10.4% more ships arrived at sea ports in the Republic of Croatia than in 2021. In Croatian ports, 23.8% more passengers embarked and disembarked in 2022 than in 2021, but that is still 4.9% less than in 2019. However, the total turnover of goods in seaports in 2022 increased by 9.1% compared to the same period in 2021, and looking back 6 years ago, the amount of turnover of goods by sea transport is increasing (Table 1).

Table 1 Traffic of ships, passengers and goods from 2017 to 2022

	Unit of	2017.	2018.	2019.	2020.	2021.	2022.
		I. – XII.	I. – XII.	I. – XII.	I. – XII.	I. – XII.	I. – XII.
Arrival of ships	No.	338.603	353.720	359.223	249.012	310.434	342.752
Traffic of passengers	No.	32.523.000	33.974.000	35.576.000	18.787.000	27.323.000	33.834.000
Traffic of goods	tonnes	20.798.000	21.573.000	20.580.000	21.410.000	21.644.000	23.607.000

Source: [7]

The development of nautical tourism is measured by the ratio of the number of residents per vessel. In total maritime traffic, in addition to cargo ships, large cruise ships, and ferries, there are other vessels tied to nautical tourism and contribute to the density of traffic at sea, especially in the peak of the tourist season in the Republic of Croatia. Vessels in nautical tourism are divided into [8]:

- vessels up to 5 meters – are vessels that are used for a short stay on the water within local limits. Maintenance costs are low and require a simple infrastructure. Such vessels can be: personal watercraft, kayaks, rafts, small sailboats, speedboats and other similar vessels.
- vessels from 5 to 15 meters - represent the interest of the port of nautical tourism. They can be on sails and/or on a motor. Such vessels can be: sailboats, speedboats, boats and boats for pleasure and excursions, etc.
- vessels over 15 meters - include luxury sailing or motor ships, which have at least one permanent captain.

According to the research by the Croatian Bureau of Statistics for 2021, 206 ports of nautical tourism on the Croatian coast are covered, namely 85 marinas (of which 21 are dry marinas), 83 anchorages, 15 moorings and 23 disposal facilities for vessels. The total water area is 4.643.877 m2 with 18.942 berths [9].

Table 2 Port capacity of nautical tourism in 2018 - 2021

	BERHTS			
VESSEL LENGTH:	2018.	2019.	2020.	2021.
up to 6 m	597	674	755	1049
6 - 8 m	1247	1246	1271	1532
8 - 10 m	2736	2840	2676	2440
10 - 12 m	4434	4511	4620	4666
12 - 15 m	4862	5116	5290	5848
15 - 20 m	2699	2984	3078	2455
over 20 m	699	808	935	952
TOTAL	17274	18179	18625	18942

Source: [9]

The average total capacity occupancy of berths in 2021 in nautical tourism ports was 62.9%, berths in the sea 70.3% and berths on land 41.1% [9]. However, what can be seen from the nautical tourism port capacity data 2018 - 2021 is that regardless of the COVID-19 measures in 2020 and 2021, the number of berths in 2021 gradually increased compared to previous years (Table 2).

In 2021 there is a sudden increase of 72.8% in the number of vessels compared to 2020. The reason for such an increase in 2021 is that in 2020 epidemiological measures were taken against the spread of the COVID-19 pandemic.

According to the type of vessel in transit, for which a mooring in the sea was used, the most were sailing boats 61.6%, followed by motor yachts 31.4%, and other vessels 7.0% [9].

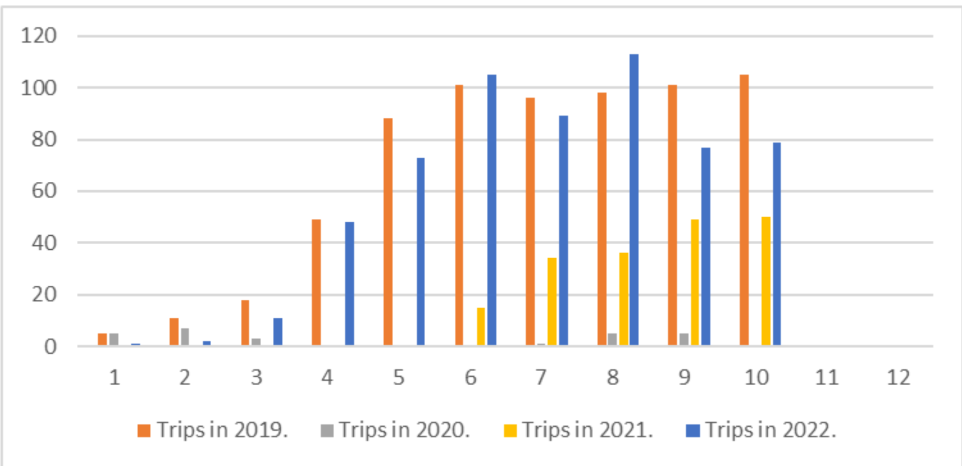
According to the length of the vessels, for which the mooring in the sea was used, most vessels were between 12 and 15 meters LOA (36.9% of the total number of vessels), followed by vessels between 10 and 12 meters LOA (which makes up 28.0% of total number of vessels).

If we compare the number of vessels in 2021 with 2019, when thepandemic has not broken out, an increase of 2.5% in the number of vessels can be observed [9].

The number of vessels on a permanent mooring is higher by 3.4% in 2021 compared to 2020. According to the type of vessels at permanent mooring at sea in 2021, there were: motor yachts 48.0%, sailing boats 46.8%, and other vessels 5.2% [9].

In addition to the aforementioned traffic of nautical tourism vessels, there are also international large cruise ships as a special category related to maritime traffic and nautical tourism, which appear mostly from late spring to early autumn. The increase in the traffic of international large cruise ships in the eastern part of the Adriatic is noticeable in 2022 compared to 2020 and 2021.

The reason for this is that during 2020 and 2021, the COVID-19 measures were introduced, which as a result, restricted cruising of large international cruiser ships in the eastern part of the Adriatic Sea. Thus, it can be seen that in the first ten months of 2022, the number of trips made by international cruise ships increased by 414 trips, and the number of days spent in ports increased by 767 days compared to the same period in 2021. After the reduction of the COVID-19 measures in 2022, the turnover of international cruise ships in 2022 almost reached the data from 2019 (Graph 1). If we compare the data of the first ten months in 2022 compared to 2019, the number of trips by international cruise ships decreased by 11.0%, and the number of days international cruise ships spent in ports decreased by 5.1%. [10].



Graph 1 International cruise ships in the Republic of Croatia by month from 2019 to 2022

Source: https://podaci.dzs.hr/2022/hr/29522

4. ACCIDENTS AND INCIDENTS ON THE EAST COAST OF THE ADRIATIC

A maritime accident is an event or sequence of events that results in [11]:

- death or injury to a person caused by or related to the performance or operation of the vessel, or
- loss of a person from a vessel caused by or related to its exploitation or operation, or
- loss of the vessel or its abandonment, or
- substantial damage to the vessel, or
- grounding or disabling of a vessel or its participation in a collision, or
- damage to maritime infrastructure facilities caused by or related to the operation of the vessel, or
- damage to the maritime environment caused by damage to the vessel, which is caused by or is related to its operation.

A marine accident can be very serious or serious. A very serious marine accident involves the total loss of a vessel, death or serious damage caused by or in connection with its operation. A serious marine accident is a marine accident not classified as a very serious marine accident, which includes: fire, explosion, collision, grounding, impact, storm damage, ice damage, hull cracking or suspected hull defect or other similar damage that has as a result:

- impossibility of operation of the main engines, major damage to the superstructure, serious damage to the structure, which makes the navigable object unable to continue sailing,
- pollution of the marine environment, and/or
- breakdown/damage requiring towing or shore assistance.

A maritime incident is an event related to the operation of a vessel, which is not classified as a maritime accident, and which endangered or could endanger the safety of the vessel, persons on the vessel or other persons, as well as the sea and the marine environment [11].

Maritime accidents and accidents of ships, yachts and boats that occur on the eastern coast of the Adriatic can be mainly divided into: collision, grounding, fire and explosion, water intrusion, sinking, impact by a vessel and pollution of the marine environment (Table 3).

According to the statistical data of SAR actions in the Republic of Croatia, in 2021, due to various maritime accidents and incidents, a total of 610 search and rescue interventions were undertaken at sea. This is almost three times more than 10 years ago (Graph 2). The drop-in interventions in 2020 can be attributed to the COVID-19 pandemic. However, in 2021, the numbers rise close to those in 2018 and 2019. The reason for the increase in SAR interventions compared to the last 10 years lies in the expansion of nautical tourism, i.e. the increase in the traffic of ships, boats and yachts, and from this comes a higher probability of an accident at sea (Graph 2).

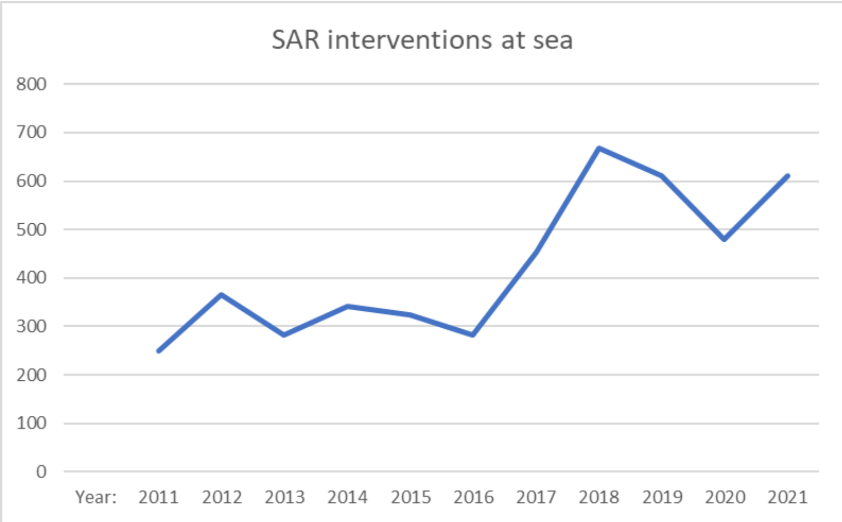
Table 3 Maritime accidents and incidents on the eastern coast of the Adriatic

Statistical data of SAR actions in Croatia per year						
	From 01.01.2016 to 31.12.2016	From 01.01.2017 to 31.12.2017	From 01.01.2018 to 31.12.2018	From 01.01.2019 to 31.12.2019	From 01.01.2020 to 31.12.2020	From 01.01.2021 to 31.12.2021
SUBJECT:						
Grounding	32	51	61	55	44	34
Unseaworthy (engine failure, rudder failure, lack of fuel)	52	59	83	56	42	51
Medical transport, interventions, advice	71	138	205	223	177	231
Scuba divers with air cylinder	4	4	6	6	5	5
Scuba divers	6	2	5	5	8	8
Sinking	3	12	13	23	20	18
Capsizing the ship	3	4	5	5	1	5
Man overboard	7	17	31	16	15	17
Ship collision	7	19	30	15	12	17
Strike	4	10	8	12	4	9
Flooding	8	13	19	18	6	7
Delay to destination	7	18	14	15	14	11
Other (red rockets, assists, etc.)	33	32	119	114	92	126
False alarm	23	18	128	104	57	57
Fire	3	18	19	8	11	27
Swimmers	9	23	23	19	13	15
Surfers	10	16	28	22	16	29
Saved person	831	765	1080	1155	428	733
Missing person	0	6	1	1	0	0
Injured person	16	51	42	29	16	33
Death of a person (including natural death)	24 (0)	40 (7)	34 (3)	27 (0)	28 (0)	28 (0)
Rescued vessel: ship	22	12	19	14	10	13
Rescued vessel: boat	136	111	166	133	92	110
Rescued vessel: yacht		22	31	28	15	12
Vessels saved: other	9	29	20	21	14	15
Number of SAR interventions - only by captain's vessels	13	268	272	307	228	308
Number of SAR interventions - by captain's vessels and other participants	141	621	669	612	480	610
Number of SAR interventions – only by vessels of other participants	127	353	218	139	118	133

Source: Adapted by the author according to available data from the Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, https://mmpi.gov.hr/

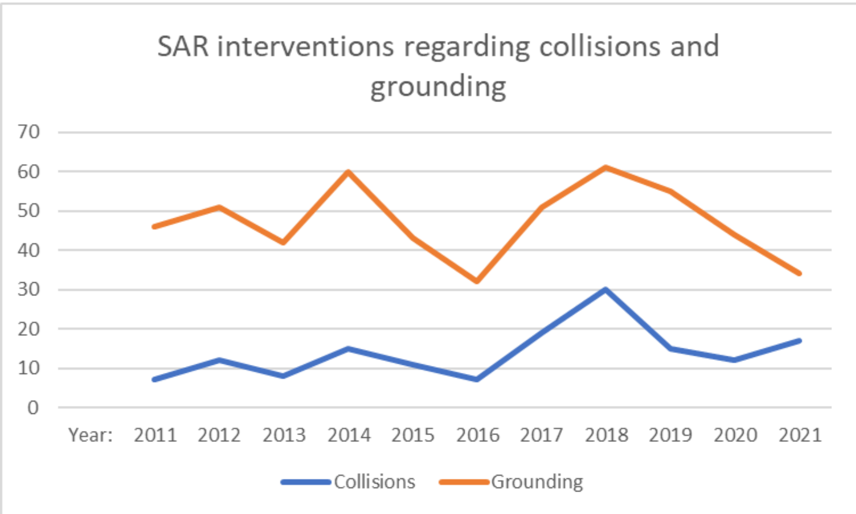
The causes of collisions and groundings in the Adriatic can be divided into two groups: human and technical. What can be seen, according to the available statistical data in the last 10 years, is that vessel collisions on the eastern coast of the Adriatic tend to increase (Graph 3).

In the last ten years, the largest increase in interventions at sea related to ship groundings has been recorded, with a slight downward trend in 2019.



Graph 2 SAR interventions at sea in the last ten years

Source: Adapted by the author according to available data from the Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, https://mmpi.gov.hr/



Graph 3 SAR interventions at sea in the last ten years regarding collision and grounding

Source: Adapted by the author according to available data from the Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, https://mmpi.gov.hr/

5. RECOMMENDED SAFETY MEASURES AND STRATEGIC GOALS

Everyone at sea should always bear in mindthat the sea is a dangerous environment. Crew on cargo ships must be trained and capable to keep their environment safe, but this alsoapplies to sailors on yachts and smaller vessels. When shipboard accidents occur, it takes time for help to arrive, especially if the accident has occurred in rough weather conditions and/or far from shore. Many accidents are caused by negligence and a large part of maritime accidents can be attributed to human error [12].

Situations on cargo and passenger ships that can cause accidents are the most common: lack of sleep, inexperience, insufficient training, relationships between crew and/or passengers, use of drugs and/or alcohol, carelessness in decision-making, pressures and stress on duty. The situation is similar with smaller vessels [13].

Below is an analysis of the causes of accidents and incidents on the Adriatic and corresponding recommendations for increasing safety and reducing risk:

- Alcohol is a factor that disrupts the ability to reason and make decisions, it also affects motor functions. This factor belongs to the first five factors in the total number of reported accidents [14].
- Unadjusted speed - this factor has fatal consequences for the ship, especially if the ship's speed is not adjusted to the environment and weather conditions. In the strait of Split (*hrv. Splitska vrata*), for example, which has no traffic separation scheme, there is a high volume of traffic during the summer season, and large ships need to adjust their speed, especially considering that small vessels interfere with the traffic of large ships [15].
- Grounding - is a factor whose number increases every year in the eastern part of the Adriatic during the high season of tourism. Ship groundings account for about one third of commercial groundings in the global maritime industry [16]. It is a type of accident where the ship's hull hits the seabed, causing damage to the ship's hull and intrusion of water. It can be caused by an unintentional deviation from the course, or when the ship's draft and speed are not adjusted to a safe distance from the coast. It follows from this that there are two types of grounding: The first type of grounding is the most common and occurs while the vessel is moving using its own propulsion. It mainly occurs due to errors in updating navigational charts, errors in passage planning, etc. The second type of grounding is rarer and occurs when a vessel drifts towards the coast. This type of grounding occurs after failure of the engine, rudder and other mechanical failures on the vessel [17]. This type of accident also leads to pollution of the marine environment by spilling ship's fuel or some liquid cargo that the ship is transporting [16].
- Man overboard. It represents an event that happens unexpectedly and can be very dangerous, but also fatal for human life, especially in difficult weather conditions. On cargo and passenger ships, experienced crews know how to act in such situations. However, amateur crews panic in such situations, especially if it happens during bad sailing conditions, and then deaths occur. For this reason, the responsible captain and skipper on smaller vessels and sailboats should familiarize the crew with the procedure in a man overboard situation. If a sailor is operating a boat or sailboat by himself, he must have an emergency engine shutdown rope or a modern electronic replacement, that shuts down the engine if someone falls overboard, and/or a personal locator beacon.
- Running out of fuel - can lead to second type of grounding, caused by drifting or capsize in smaller vessels, if the weather conditions are difficult. It mostly happens when a sailor does not know the consumption of the boat in all sailing modes, when he plans the trip incorrectly, miscalculates his position or forgets to fill the fuel tank due to carelessness.

- Sinking - occurs due to the penetration of water into the ship. The reason for the penetration may be the impact of the ship against the reef, the collision of the ship, etc. In such situations, the place of water penetration must first be isolated, if possible, in order to prevent flooding of other ship spaces. In the case of smaller vessels and sailboats, the bilge pumps should be turned on at the same time. There are also various pastes available today that prevent the penetration of water into the boat.
- Fire on board – is a very common accident that can lead to the loss of human life and the loss of both large and small vessels. Although fire is rare on pleasure boats, a sailor on such vessels should be very careful. On large ships, it is necessary to check fire extinguishing equipment and carry out crew training in case such a situation occurs.
- Ignoring weather conditions – is very important in passage planning for large ships on international voyages. In the case of smaller recreational vessels in the coastal area, in addition to radio stations and VHF devices, if there is a mobile signal it is possible to receive weather forecast data using a mobile device. On the eastern coast of the Adriatic, this is especially important during the summer months, when short storms occur (*hrv. Jugo, Lebić*), their consequences can be dangerous for smaller vessels that are at sea.
- Proper watchkeeping in navigation – is also one of the factors that result in a collision and/or grounding. It happens when a person completely relies on autopilot and does not observe the situation around him. Situations like this occur mainly on pleasure craft, where the autopilot is turned on and it is considered that all matters in navigation have been resolved. Sailors should pay special attention when sailing at night, because then accidents and incidents occur more often on the Adriatic [18]. It is mandatory to keep watch during navigation, observe the surrounding situation and not obstruct the navigation of cargo and passenger ships.
- Safety equipment – for large ships, this part is maintained in accordance with SOLAS and STCW conventions. While with small vessels and sailboats, some sailors know how to ignore safety equipment, such as not wearing a life jacket and pyrotechnic means for signalling in case of an accident [14].

Table 4 shows that the volume of maritime traffic is related to profit and earnings, be it by transporting cargo (in container or liquid form) or passengers, and regardless of the type of voyage and vessel.

The growth of maritime transport should be coordinated with safety, but also with the preservation of the marine environment. From the aforementioned SWOT analysis, it is evident that great attention should be given to traffic control of both large and small ships, especially in the peak season when nautical tourism vessels are most present on the eastern coast of the Adriatic.

Table 4 SWOT analysis of maritime traffic safety on the eastern coast of the Adriatic

STRENGTH	WEAKNESSES	POSSIBILITIES	THREATS
- Greater traffic of cargo ships, greater traffic of goods, greater monetary income for commercial ports in the Republic of Croatia.	- Increase in traffic, higher probability of collisions, groundings and other types of accidents. - The navigation safety system needs to be improved.	- By increasing the traffic of cargo ships, the earnings for the ports also increase. - Operation of the SAR service in the event of an accident. - VTS service for traffic control.	- Loss of human life in the midst of an accident, - In the event of an accident, rupture of a ship's hull or rupture of a fuel tank, catastrophic ecological consequences can occur for the marine environment, especially for closed seas such as the Adriatic Sea.
- Greater traffic of foreign cruise ships, greater financial income for ports and tourist destinations in the Republic of Croatia.	- Increase in traffic, higher probability of collisions, groundings and other types of accidents. - A pandemic like COVID-19 can affect the reduction of this type of traffic. - Seasonal character	- By visiting these types of ships, it contributes to earnings for ports, tourist places and cities. - Operation of the SAR service in the event of an accident. - VTS service for traffic control.	- Environmental pollution of the sea with ballast water from cruise ships. - Damage to the marine environment caused by grounding or collision. - Bacteriological contamination
- The expansion of nautical tourism attracts more foreign sailors who will spend their time on the shores of the Adriatic and thereby bring financial income to the Republic of Croatia.	- The increase in the traffic of these types of vessels increases the risk of collisions, groundings and other accidents that this type of tourist causes. - Failure to maintain safety equipment - Ignoring weather conditions - Seasonal character - Obstructing the navigation of large ships in canals - Proper watch keeping - Supervision of sports and pleasure boats and fishing boats. - A pandemic like COVID-19 can affect the reduction of this type of traffic.	- Coastal indentation, the connection and complementarity of the island and coastal strip are good for the construction of various types of tourist ports and other nautical-tourism capacities. - SAR service in the Republic of Croatia that will come to help in various situations at sea. - VTS service for monitoring, management and organization of all maritime traffic.	- Collisions, groundings, mob, various accidents caused by inappropriate vessel speed and sailing close to the coast, etc. - Pollution of the sea with oil and its derivatives, - Bacteriological contamination, - Pollution of the sea with various wastes and impurities, - Destruction of fish and aquatic wealth, especially shellfish, - Devastation and degradation of the landscape and environment for use of facilities in nautical tourism, - Occupation of the sea, beaches and other maritime assets. - In narrow channels or straits, such vessels obstruct the traffic of large ships, which can lead to their collision or grounding.

Source: Author

It is also necessary to protect the marine environment from the impact of large and small vessels. In addition to maritime legal regulations, adequate supervision and corresponding sanctioning measures are crucial.

In order to prevent the devastation and degradation of the landscape due to the construction and use of facilities in nautical tourism, great attention must be paid to planning the construction of nautical tourism facilities for vessels.

Stricter supervision of ships in ports and greater supervision of smaller vessels are necessary, especially in navigation.

The search and rescue system at sea needs to be improved with additional material and human resources, especially in the summer season.

The Republic of Croatia can also introduce additional measures such as: additional navigational regulation measures for smaller vessels, declaration of special protected areas in some parts of the Adriatic, extension of mandatory pilotage for larger vessels, etc.

6. CONCLUSION

Through the analysis of maritime traffic in the eastern part of the Adriatic, it was established that maritime traffic is constantly increasing. This especially applies to nautical tourism, where the number of cruise ships, boats, yachts and other pleasure vessels increases during the summer months. Although it is obvious that the COVID-19 pandemic affected the decrease in traffic in nautical tourism, its cessation clearly shows that this type of tourism will remain in the world's tourist offer for a long time, and therefore the number of pleasure boats will increase. Nautical tourism has great potential for the economy of the Republic of Croatia, but it is closely related to the level of construction of the nautical infrastructure and the density of maritime traffic, from which potential maritime accidents and incidents arise. Considering that the number of sailors in nautical tourism ports is increasing every year, it is obvious that nautical tourism is of increasing importance in the Republic of Croatia, and thus the need to increase the safety of navigation is also growing. Although the competent authority for the safety of navigation in the Republic of Croatia is well organized, every year there are more and more accidents at sea. The most common reason for this is the human factor, such as: inadequate skills of the skipper in practical navigation, recklessness, alcohol, disregard for weather conditions, inappropriate speed near the coast, etc. Such mistakes can lead to collisions, groundings, and loss of human life. In addition, nautical tourism vessels can interfere with the regular navigation of cargo ships, large ferries, so accidents of such large ships can lead to tragedies, loss of human life and can be catastrophic for the marine environment. For this reason, it is necessary to invest in safety, and above all in training and education of all participants in maritime traffic. Also, stricter monitoring of ships in ports and more intensive monitoring of smaller vessels is needed. Greater connection and coordination of the SAR can be more effective, and in this segment, the improvement of the SAR system with material and human resources is necessary, especially during the summer months.

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AUTONOMOUS ASPECTS FROM THE CAPTAIN PERSPECTIVE

Heikki Koivisto
Satakunta University of Applied Sciences
Rauma, Finland
E-mail: heikki.koivisto@samk.fi

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Abstract

The maritime industry is again radically changing because of new information technology introduced in ship operations and new, more stringent requirements for economy, environment and safety imposed by the society. The research and development have come closer to normal operations, autonomous shipping as a good example of this. M/S YARA BIRKELAND, a 120 TEU open top container ship, fully battery powered solution, prepared for autonomous and unmanned operation. For the first phase of the project a detachable bridge with equipment for manoeuvring and navigation has been implemented. When the ship is ready for autonomous operation this module will be removed. This concept works as this ship is planned as a part of logistics chain and sailing only at sheltered Norwegian waters. IMO decided to look at the regulation of autonomous ships. IMO's Strategic Plan (2018-2023) has a key Strategic Direction to "Integrate new and advancing technologies in the regulatory framework". The scoping exercise was seen as a starting point that would touch on an extensive range of issues, including the human element, safety, security, liability and compensation for damage, interactions with ports, pilotage, responses to incidents and protection of the marine environment. IMO agreed to the development of a non-mandatory goal-based maritime Autonomous Surface Ships (MASS) Code, which will become effective from the year 2025, as an interim measure prior to the adoption of a mandatory code, expected to enter force on 2028. This paper will look deeper into the building of a new building autonomous ship and her operation.

Keywords: Autonomous ships, MASS, building of a new building ship

1. INTRODUCTION

Class notation E0 was introduced in 1970's. Engineers worked only day shifts and from 17:00 one of the engineers was on stand-by. Every engineer had an alarm panel in their cabin and stand-by engineer was the first calling point. If he/she did not respond to the alarm in question next step was alarming all engineers. Similar alarm panel was in the officer messroom, gym, sauna (on Finnish ships) and on the bridge. As engineers had at that time unlimited amount of overtime, this alarm panel became active twice a night, normally at 22:00 and 07:00 ensuring two hours of overtime to the stand – by engineer. In 1990's Engine Control Room (ECR) was situated on some ships on the bridge so that engineers came to bridge to see what the reason of the alarm is. Soon this experiment was forgotten. Nowadays there are similar monitoring stations on the bridge and in ECR. It is quite logical that engineers orient to ECR as the problem may be found closer to that area than the bridge. Autonomous shipping has been attractive topic for some time. Digitalisation, easy research money, recruitment difficulties for sea personnel are just some driving boosters.

2. M/S YARA BIRKELAND

Different autonomous projects and tests like SVAN (Safer Vessel with Autonomous Navigation) [1], AAWA program [2] and SISU, world's first remotely controlled tug was published, there was one very interesting concept of M/S YARA BIRKELAND. First time ever was the boosting thing, when action like this is happening, but nevertheless good things for the future are found (figure 1).

M/S YARA BIRKELAND (Figure 2) is a very realistic example of the world's first autonomous and zero-emission container vessel. Norway is a maritime nation having a sea border of continental 15,626 nautical miles and including islands 51,748 nautical miles, and has the world's sixth largest merchant fleet, with 1,412 Norwegian-owned merchant vessels, and having an important role in the IMO [5].

Yara International ASA (Yara) is a Norwegian-based company which is the world's largest producer of nitrogenous mineral fertilizer [4].

Kongsberg is an international technology group headquartered in Norway, that supplies high-technology systems to customers in the merchant marine, defence, aerospace, offshore oil and gas industries, and renewable and utilities industries [6]. Kongsberg develops and delivers of all essential technologies at M/S YARA BIRKELAND. This applies to the sensors and integration required for remote and autonomous operations, as well as electrical propulsion, battery, and control systems.

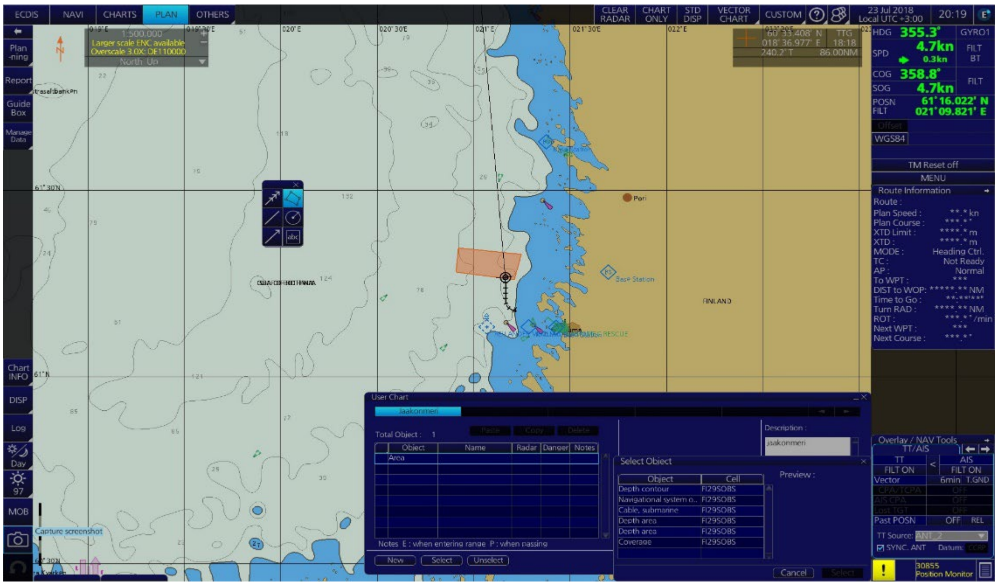

Figure 1 M/S HAMMERHUS entering, during her sea trials, the first time into the autonomous vessel testing area called Jaakonmeri, dedicated only for these autonomous tests according to the decision made by the council of Eurajoki, Finland

Source: Author's photo

DNV is the world's largest classification society, providing services for 13,175 vessels and mobile offshore units (MOUs) amounting to 265.4 million GT, which represents a global market share of 21% [7]. All needed maritime stakeholders working together with this project started to sail in spring 2022 and planned to last for two years before making final decisions for fully autonomous operations.

There was a reduction of the emission and not only the world first autonomous vessel concept but also removing 40,000 diesel-powered truck journeys every year and reduce NOx (Nitrogen oxide) and CO2 emissions, improve road safety, reduce road dust formation, and traffic noise. M/S YARA BIRKELAND transports mineral fertilizer from Yara's production plant in Porsgrunn, Norway to the regional export port in Brevik (Figure 3).

Figure 2 M/S YARA BIRKELAND on route from Porsgrunn to Brevik

Source: Photo by Alexander Holden

Main particulars of M/S YARA BIRKELAND are shown in table 1.

Table 1 M/S YARA BIRKELAND main particulars

Characteristic	Indicator
LOA, m	80
Beam, m	15
Depth, m	12
Draught (full), m	6
Eco speed, knots	6-7
Max speed, knots	15
Capacity: Cargo capacity, TEU Deadweight, tons	 120 3200
Propulsion Azipull pods, kW Tunnel thrusters, kW	 2 x 900 2 x 700
Batteries capacity, MWh	6,8

Source: MarineTraffic.com

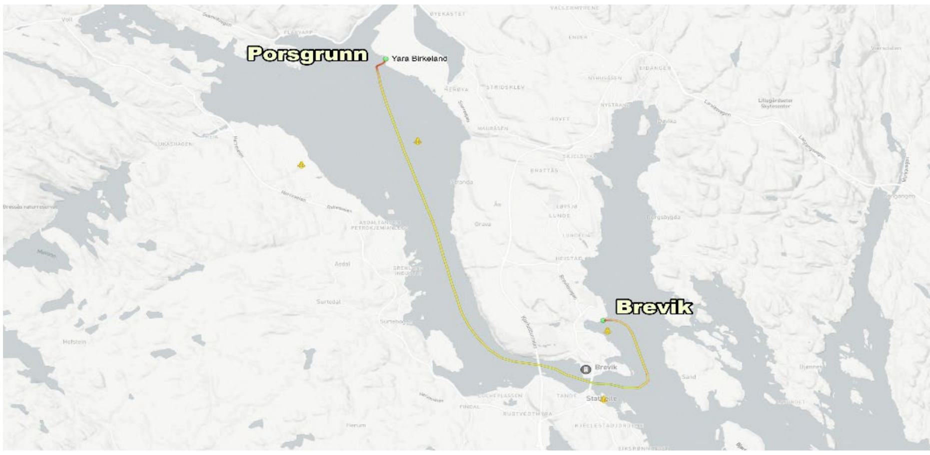

Figure 3 M/S YARA BIRKELAND route from Porsgrunn to Brevik on 3.5.2023 ATD 06:45, ATD 07:32

Source: MarineTraffic.com

3. BUILDING AN AUTONOMOUS SHIP

Is building an autonomous ship much more expensive than building similar manned ship? M/S YARA BIRKELAND has batteries with a capacity of 6.8 MWh and two azipull pods 900 kW each. Two tunnel thrusters 700 kW are assisting in berthing and unberthing. This is a good concept for the Porsgrunn – Brevik route, length of 7 miles. For the coming autonomous operation for example the bridge is movable so it can be shifted to another new building ship when autonomous is fully accepted by all parties. If we think the price of a new building ship, taking the specification list and determine example price 100, so planning to build an autonomous ship for a longer voyage still needs the planning and drawings, main engines, hull, air condition for instruments and computers, generators, emergency generator, gear control system, emergency shutdowns, dual fuel MDO/LNG, propulsion switchboard, main switchboard, emergency switchboard, transformers, propulsion motors, steering gear system, stabilizers, CPP system, shaft lines, tunnel thruster motors, tunnel thrusters, shore connection switchboards, UPS units, battery chargers, sprinkler system, SMS, fire pumps, watertight doors, fire dampers, HVAC system, engine room ventilation, bilge system, remote controlled valves, flooding alarm sensors, gas detection system, navigation system, PA and GA systems, loading computer (NAPA), deck machinery, tank and draught remote sounding system, heeling system, ballast system, fuel oil transfer system, fuel consumption optimizing system, fresh water generator, grey and black water treatment, sewage treatment, air system for starting, service and control, water systems, waste heat recovery, engine pre-heating, classification, key and sea trials and warranty.

Without safety aspects 98% of the automation is already there. The problem comes when looking redundancy and safety aspects when you must increase number of sensors and plc's etc. with 2-3 times. This means that the small savings you make on the "pure" operation part of the watchkeeping engineer you will lose in maintenance and verifications of sensors. If you increase the current number of sensors onboard that is approximately 8.000 to 16.000 (or 24.000) and also increase the importance of the data, they are measuring it will mean that at least all sensors will need to be verified once a year. Some of them may be possible to cross reference with each other but still it means almost 8000 points per year more than today and working time during a year for one vacancy onboard is abt. 3800h which means that one electrician or electro technical officer (ETO) will have on average 28min per point to test them so basically we would be removing 0,5 vacancies (part of 2 existing watchkeeping engineer vacancies worktime that is not maintenance) and adding one electrician/eto vacancies plus the additional cost in capex and in maintenance, automation is not cheap so price of a new building ship is surely +100.

Mooring equipment are one set which will open discussions, onboard M/S YARA BIRKELAND are full manned mooring stations as there are onboard M/S MyStar. Ship-building engineers said in mid-1980's that mariners should invent unmanned mooring stations, or they will do that in five years' time. Nearly forty years later they exist.

There are some hundred piers round the world with vacuum mooring systems, latest piers in Tallin and Helsinki (Figure 4).

Figure 4 M/S MyStar arriving port of Helsinki, ready to active six mooring pads
Source: Author's photo

Ferries like M/S MyStar, delivered from Rauma Shipyard to Tallink 2022, have full mooring equipment onboard at the bow and stern. So, no savings are coming from the less equipment but from several daily moorings and saving minutes from the mooring operation giving a possibility to steam the journey from Tallin to Helsinki a bit slower and ending up to million euros fuel saving in a year time.

As there are different ships using the same pier AIS signal is used to identify the approaching vessel and mooring equipment are activated accordingly. Today actual mooring operation is controlled from the bridge but maybe it can be operated from the port and soon automatically (figure 5).

Figure 5 Mooring devices, on left iPad using 4G/Wi-Fi and on right back-up using radio link
Source: Author's photo

Cyber security plays an important role even today all shipping companies have had to ensure cyber security as part of ISM code. Sensor technologies will bring a new cost and it is obvious the number of different sensors is growing. Good engineers were harnessed to research automation related topics and finding are of course good from the technical point of view. These findings will surely assist to safer and more environmentally friendly shipping.

4. CONCLUSION

Autonomous shipping in limited sea area with all stakeholders involved is surely the future in shipping. Several tests have been made all over the world. Kongsberg will soon publish one year operation news from M/S YARA BIRKELAND. IMO agreed to the development of a non-mandatory goal-based maritime Autonomous Surface Ships (MASS) Code, which will become effective from 1st of January 2028. Next MSC has this on the agenda but there are several issues, Member States have different views on what MASS means for a start. There are also challenges in regulating this new phenomenon. MSC 105 decided that only cargo ships will be covered by the statute but that the preparatory work should also consider the possible extension of the scope to passenger ships.

The Code is intended to be target-based, based on the different activities of the ship and complementary to SOLAS and other conventions. MASS ships will therefore have to comply in principle with the requirements of the Conventions and the MASS Code will only apply to those functions of the ship which cannot be carried out within the framework of the Conventions due to the automation solutions.

Existing IMO instruments have historically been developed on the basis that the ship will have at least a minimum level of manning on board to carry out the various tasks required to ensure safe, secure, and environmentally sound ship operations. The ever-increasing use of automation in the operation of ships, along with the anticipated increase in the use of remote control and autonomous operation of key functions, will require a different approach, and therefore some adjustment of the accepted norms regarding onboard manual intervention and control as contained within SOLAS and other IMO instruments. It is recognized that some aspects associated with MASS may not be adequately or fully addressed in SOLAS or other IMO instruments and that additional guidance may be required on the design and operation of MASS to achieve a level of safety that is at least equivalent to that expected of a conventional ship. New MASS Code addresses the functions needed to obtain safe and reliable operations of MASS insofar as they are not adequately or fully addressed in other applied IMO instruments, such as SOLAS, while ensuring that required safety levels are maintained or enhanced through the implementation of remote control, or autonomous operation, of key functions. The MASS Code is intended as a supplement to other IMO instruments, such as SOLAS, and provides a regulatory framework for the performance of remote control and autonomous operation of key functions, as applicable [9].

Working as a captain onboard a ship first time in 1988, autonomous ships were not the topic number one at the lunch table but change is definitely coming. A remote captain, if he/she is located outside the ship and some crew members onboard a ship is still, five years before new MASS code to expected to enter force, is a topic which needs several lunch table discussions before it is formulated in mariner's head.

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DEVELOPMENT OF A NEURAL NETWORK BASED DECISION SUPPORT TOOL PROVIDING OPERATIONAL GUIDANCE ON SHIP STABILITY

Przemyslaw Krata
a) Waterborne Transport Innovation, Gdansk, Poland
E-mail: przemyslaw.krata@wtif.pl
b) Gdansk University of Technology, Gdansk, Poland
E-mail: przemyslaw.krata@pg.edu.pl

Tomasz Hinz
a) Waterborne Transport Innovation, Gdansk, Poland
E-mail: tomasz.hinz@wtif.pl
b) Gdansk University of Technology, Gdansk, Poland
E-mail: tomhinz@pg.edu.pl

Zbigniew Szozda
a) Gdansk University of Technology, Gdansk, Poland
b) Maritime University of Szczecin, Szczecin, Poland
E-mail: z.szozda@pm.szczecin.pl

Spencer Dugan
Norwegian University of Science and Technology, Trondheim, Norway
E-mail: spencer.a.dugan@ntnu.no

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Abstract

The e-navigation concept that is promoted by the International Maritime Organization focuses on, inter alia, the display of important and relevant operational information for the ship's crew in order to enhance safety at sea. Thus, any safety-critical issues in marine navigation may and shall be comprised by tools constituting components of the e-navigation solutions. The ship stability is no exception and providing reliable information would be beneficial. To address this, the Second Generation Intact Stability Criteria may be adopted, especially the operational guidance, which refers to the operation of a ship in actual sea conditions and sailing conditions. The operational guidance is designed to be used for the prevention of the following four stability failure modes: excessive acceleration, pure loss of stability, parametric rolling, and surf-riding/broaching. The combinations of ship speed and heading relative to mean wave direction that are not recommended and that should be avoided in each relevant sea state are identified. In this paper the simplified operational guidance approach is utilized as it does not require model tests or numerical methods of high accuracy. The stability assessment adopts here the Level 2 vulnerability criteria with relevant thresholds provided by the IMO MSC Circular 1627. The case study presenting the potentials of the decision support tool providing aid to the ship master was carried out for a training vessel carrying trainees, thus safety sensitive. The resulting wave characteristics and corresponding sailing conditions were used to train an artificial neural network capable of assessing stability for any received weather forecast. The research reveals promising potential for practical applications of the proposed technique, which may replace the straightforward on the fly calculations of the ship vulnerability to stability failures.

Keywords: ship stability in operation, decision support tool, e-navigation, second generation intact stability operational guidance, artificial neural network

1. INTRODUCTION

The development of tools supporting crucial components of work on-board ships has been widely noticed recently. The progress of autonomous ships will not only create a "radical change to maritime business and society" [1], but their development will lead to the remarkable growth of the decision support systems (DSS) for mariners. However, a large limitation is the public acceptance of solutions for the various safety issues posed [2]. DSSs are a contemporary trend promoted by the International Maritime Organization focusing on, inter alia, the display of important and relevant operational information for the ship's crew in order to enhance safety at sea [3]–[5]. Thus, any safety-critical issues in marine navigation may and shall be supported by tools constituting components of the e-navigation solutions. The ship stability is no exception and providing reliable information would be beneficial [6].

The main challenges related to operational ship stability are from previous standards failing to consider dynamic stability failures motions and the ambiguity on good practice for seafarers. At the design stage, a ship's dimensions and estimates of the loading conditions are used to provide a preliminary check of ship stability. Later, when more information becomes available and the design has proceeded, ship stability is assessed using the loading conditions estimated for the ship's operation. However, the insufficiency of the existing criteria is demonstrated in its failure to consider all operational scenarios, specifically those related to dynamic stability failures [7], [8], [9], [10].

To provide guidance and practices to avoid dynamic failure modes, the IS Code calls for "good seamanship" and "proper precautionary provisions." However, these terms are both vague and difficult to provide evidence for since they are typically gained by ship officers from years of experience at sea. Further guidance to ship masters has been published by the IMO in MSC Circular 707 [11] and 1228 [12]. However, the guidance is often subjective, and relies on the assessments of the officer of the watch (OOTW). This demonstrates a challenge for autonomous solutions since situational awareness comes from these assessments by the OOTW. The subconscious assessment process includes constant detection of hazards, evaluating environmental conditions and the vessel's response, and deciding when to act [13]. Due to the subjective nature of the process, it is difficult to standardize best practices among groups of navigators. Therefore, the development of decision support systems is not only in line with the e-Navigation concept but more importantly meets the needs of today's shipping market.

The state-of-the-art solution may utilize the Second Generation Intact Stability Criteria (SGISC), specifically the Operational Guidance part of this framework. The framework implements twenty years of research efforts for better understanding of ship seakeeping and stability behavior during operation [14]. Artificial Neural Networks (ANN) were implemented for the development of a meta-model constituting the essence of the planned DSS that is built upon the Operational Guidance available within the SGISC.

The remainder of this paper is organized as follows: Section 2 describes the purpose and overview of the SGISC and the basics of the utilized ANN as the core of the on-board DSS, Section 3 provides description of a sample vessel for which the DSS is developed, Section 4 presents the results that are discussed in Section 5, while Section 6 draws relevant conclusions.

2. METHODS USED FOR DSS DEVELOPMENT

2.1. Overview of the SGISC

The planned decision support tool focuses on preventing stability failures of considered ships, therefore the relevant set of criteria needs to be implemented. As the very straightforward solution funded on the IS Code satisfaction remains ineffective due to the significant limitation of this Code, a more advanced approach needs to be adopted.

The International Maritime Organization (IMO), being aware of the shortcomings of the IS Code (for which early efforts date back to 1939), began a large-scale effort to develop performance-oriented criteria in the twenty first century. The SGISC represents the compilation of knowledge stemming from stability theory, accident analysis, model tests, and computer code development. A more complete and thorough overview of the development and the background knowledge can be found in [15]–[20]. In December 2020, after nearly 20 years of development, the criteria were published in IMO MSC.1/Circ. 1627 [21].

The general concept of the SGISC is shown in Figure 1. The SGISC considers five stability failure modes: surf-riding and broaching-to, parametric rolling, pure loss of stability, excessive accelerations, and dead ship conditions. The three-level structure of the criteria was developed according to the degree of effort required to perform the assessment. Each level of criteria assesses the vulnerability of the ship in its condition and operation for a stability failure mode.

The criteria at Level 1 are as simple as the existing intact stability criteria. Level 2 increases in complexity due to its consideration of the failure mode's dynamics. Computer programs or numerical models are needed to analyze this Level. The approach within the third level is called Direct Stability Assessment (DSA). Guidelines exist on the use of DSA, but in general, advanced tools that can replicate or simulate the ship's operational behavior should be used. Methods include complex CFD tools or model tests of the ship's seakeeping behavior. The DSA is by far the most costly and time consuming Level to assess, but it also offers the highest level of accuracy [16], [18], [19], [22].

Although the emphasis is put on the prevention of stability failures by proper design making the ship invulnerable to the five considered stability failure modes, the most significant part of the SGSIC remains the Operational Guidance (OG) referring to the ship operation [20], [23], [24]. The OG incorporates a stability assessment of the ship sailing in specific sea conditions while keeping a given course relative to wave direction and steaming with an ordered speed. OG may be used to recommend changes in course and speed based on the encountered conditions. Therefore, this part of the SGISC may be used on-board during operation unlike the Level 1, Level 2 and DSA that represent the ship lifetime operation by averaging over the expected wave scatter table.

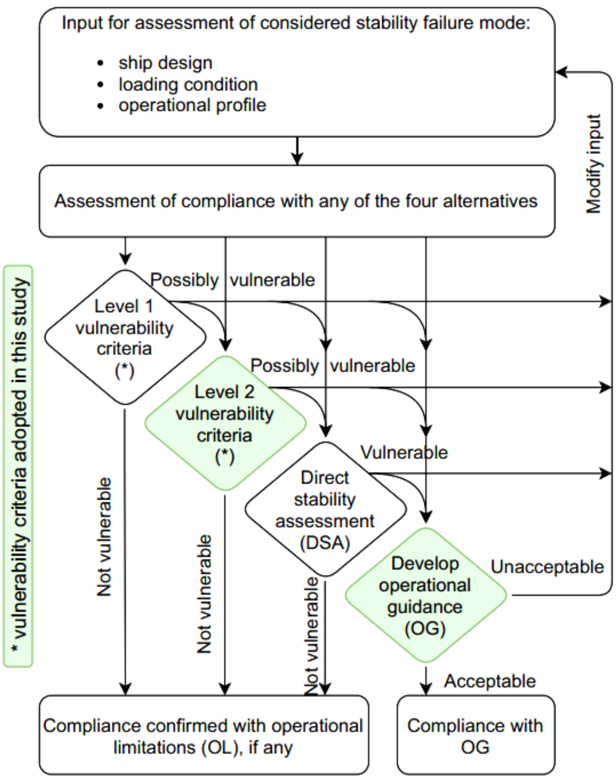

Figure 1 The general structure of the SGISC with marked parts adopted in this study

Source: Chart plotted according to [21]

In this study, the Level 2 approach was utilized to develop the OG, which is called the simplified Operational Guidance. According to the SGISC recommendations, four stability failure modes were taken into account; namely all but the dead ship condition failure mode (by its name, it considers ship behavior after a failure onboard) [21]. For each of four considered failure modes, a meta-model based on the dedicated ANN was developed, as shown in Figure 2.

The main idea is to carry out the stability assessment according to the Level 2 procedure for a wide range of loading conditions, sailing conditions and weather conditions. The combination of all parameters describing the conditions produce a large number of cases for which the vulnerability criterion is determined and compared to the standard provided by the Interim Guidelines on the Second Generation Intact Stability Criteria [21]. Finally, for each considered case the ratio of the vulnerability criterion over the standard is recorded. Ratios below one \indicate that the ship is not vulnerable, while ratios above one indicate the vulnerability of the given conditions. Once the ANN is trained using the set of computations' outcomes, the DSS may ask the ANN about the criterion over standard ratio for any set of input conditions, as presented in Figure 2.

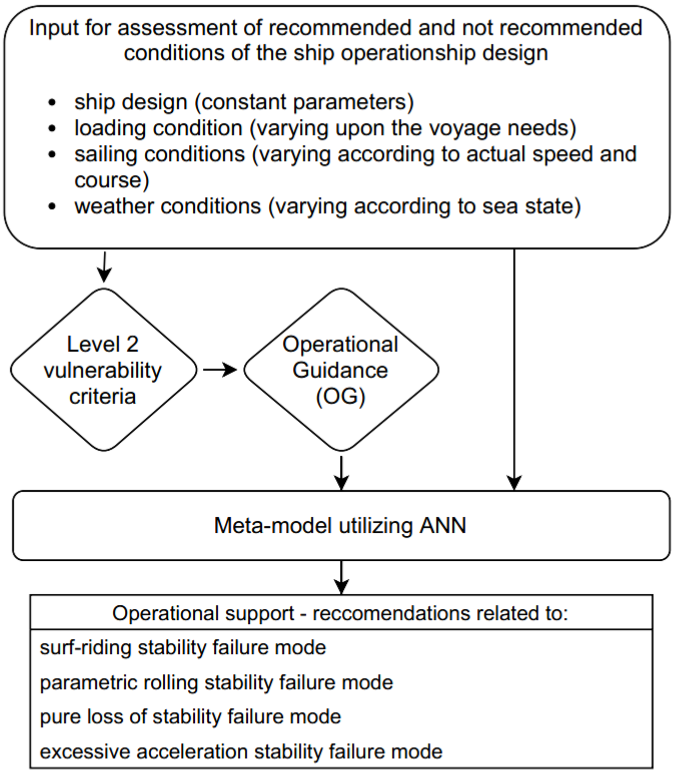

Figure 2 Development of the ANN-based meta model applicable in an on-board DSS

The main idea behind the meta-model development is to facilitate a very quick access to safety critical data during operation. The use of a properly trained ANN facilitates real-time operation of the DSS, as opposed to computing the criteria on demand.

2.2. Artificial Neural Network application to the meta-model development

ANNs are computational tools inspired by the processes of the human brain. When trained on large amounts of data, ANNs can accurately predict an output variable. The advantages of ANNs include their ability to model nonlinear or complex relationships between variables. In shipping, ANNs have been used for fuel consumption prediction or strength estimation [25], [26]. In this study, ANNs are used for quick and accurate assessments of ship stability during ship operation and based on the environmental and sailing conditions that the ship experiences. Thus, meta-models were developed by training four ANNs on preprocessed data, described in the next paragraph. The networks consist of the data input layer, several hidden layers including the first one used for the input data normalization, and the output layer, as presented in Figure 3.

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 normalization (Normalizatio  (None, 6)                13
 n)

 dense (Dense)               (None, 32)                224

 dense_1 (Dense)             (None, 64)                2112

 dense_2 (Dense)             (None, 64)                4160

 dense_3 (Dense)             (None, 1)                 65

=================================================================
Total params: 6,574
Trainable params: 6,561
Non-trainable params: 13
_________________________________________________________________
```

Figure 3 Exemplary structure of the ANNs trained as a meta-model to provide ship stability data

The training data for the ANN was obtained from computations performed by an in-house software developed for ship stability assessment according to the Level 2 procedures of SGISC. The stability-related computations that are used for the ANN development presented here, were carried out for the sample ship and ranges of input data described in Section 3. The number of computation results, i.e. the criterion obtained for each assumed operational scenario to be compared to the required standard, were not less than 70,000 for each stability failure mode.

3. SAMPLE SHIP DATA

In order to demonstrate sample calculations and methodology according to the concept presented in Section 2 we used one training vessel *Horyzont II*, which is operated by Gdynia Maritime University, Poland. The main particulars of this ship are:

- Length overall (LOA), 56.34 m;
- Length between perpendiculars (LBP), 48.37 m;
- Beam, 11.36 m;
- Design draft, 5.33 m;
- Service speed, 12 knots;
- Main engine installed power, 1280 kW.

Figure 4 displays an image of the ship in operation, the profile view of the ship, and the 3D hull model. The numerical model had to be created for the sake of computations utilizing SGISC Level 2 approach.

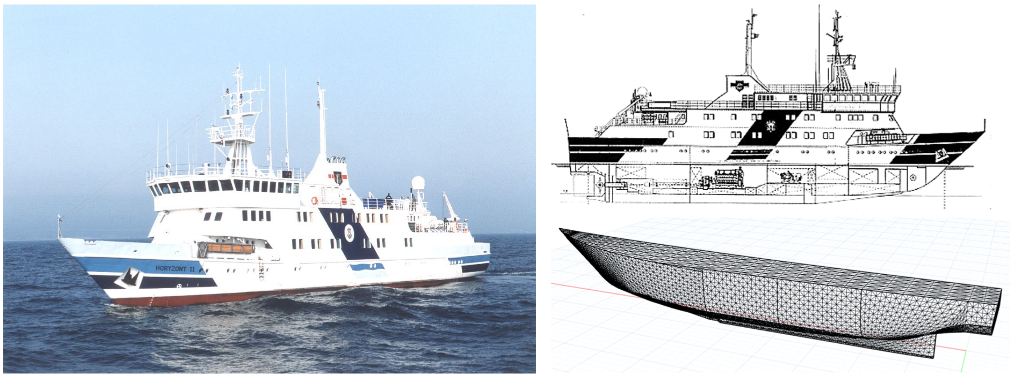

Figure 4 The research vessel *Horyzont II* used for sample computations

For the sample ship all data required by the computational procedures were determined to reflect the realistic ranges of them during the ship operation. Tables 1, 2, 3 and 4 present the relevant input data variables relevant for the computations. Four failure modes are analyzed: excessive accelerations, pure loss of stability, parametric rolling, and surf-riding stability, respectively.

Table 1 Ranges of input data relevant to the excessive accelerations failure mode computations

No	Abbreviation	Meaning	Min value	Max value
1.	Ship Mass	Actual displacement in metric tons	1100 [t]	1400 [t]
2.	LCG	Longitudinal center of gravity	21.60 [m]	22.60 [m]
3.	VCG	Vertical center of gravity	4.10 [m]	4.40 [m]
4.	X Location	Longitudinal coordinate of the most distant considered location where crew members may be present	41.50 [m]	41.50 [m]
5.	Z Location	Vertical coordinate of the most distant considered location where crew members may be present	12.50 [m]	12.50 [m]
6.	Heading	Relative angle of wave approach; 0 deg stands for following seas while 180 deg for head seas	0 [°]	±180 [°]
7.	H_Wave	Significant wave height in meters	0.5 [m]	14.5 [m]

Table 2 Ranges of input data relevant to the pure loss of stability failure mode computations

No	Abbreviation	Meaning	Min value	Max value
1.	Ship Mass	Actual displacement in metric tons	1100 [t]	1400 [t]
2.	LCG	Longitudinal center of gravity	21.60 [m]	22.60 [m]
3.	VCG	Vertical center of gravity	4.10 [m]	4.40 [m]
4.	Speed	Ship speed in meters per second	0 [m/s]	7 [m/s]
5.	Heading	Relative angle of wave approach; 0 deg stands for following seas while 180 deg for head seas	0 [°]	±180 [°]

Table 3 Ranges of input data relevant to the parametric rolling failure mode computations

No	Abbreviation	Meaning	Min value	Max value
1.	Ship Mass	Actual displacement in metric tons	1100 [t]	1400 [t]
2.	LCG	Longitudinal center of gravity	21.60 [m]	22.60 [m]
3.	VCG	Vertical center of gravity	4.10 [m]	4.40 [m]
4.	Speed	Ship speed in meters per second	0 [m/s]	7 [m/s]
5.	Heading	Relative angle of wave approach; 0 deg stands for following seas while 180 deg for head seas	0 [°]	±180 [°]
6.	H_Wave	Significant wave height in meters	0.5 [m]	14.5 [m]

Table 4 Ranges of input data relevant to the surf-riding failure mode computations

No	Abbreviation	Meaning	Min value	Max value
1.	Ship Mass	Actual displacement in metric tons	1100 [t]	1400 [t]
2.	LCG	Longitudinal center of gravity	21.60 [m]	22.60 [m]
3.	Heading	Relative angle of wave approach; 0 deg stands for following seas while 180 deg for head seas	0 [°]	±180 [°]
4.	Rps	Number of the propeller revolutions per one second	4 [1/s]	8 [1/s]
5.	Pitch	The controlled propeller pitch setting	40 [%]	100 [%]
6.	H_Wave	Significant wave height in meters	0.5 [m]	14.5 [m]

4. RESULTS

First, the results of initial computations comprise four sets of criterion over standard ratios, which were obtained for all considered cases resulting from the combination of the assumed loading conditions, sailing conditions and weather conditions. The number of intermediate stages is relatively large and different upon the stability failure mode under considerations. For instance, the set of *GZ* curves needs to be determined for the ship sailing in following seas with respect to longitudinal balance of the buoyancy and gravity forces, as presented in Figure 5.

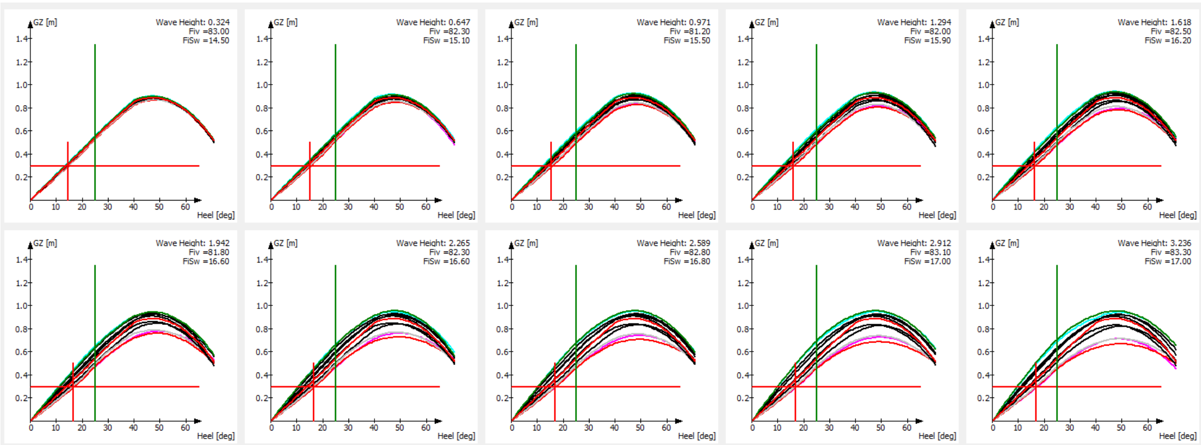

Figure 5 A sample intermediate stage of computations carried out for the research vessel *Horyzont II – GZ* curves for the ship sailing in following seas required for two failure modes: pure loss of stability and parametric rolling

Many other intermediate results had to be obtained to determine the final ratio of criterion over standard. Nevertheless, this resultant ratio is the key result of the first stage of computations since it reveals whether the ship stability satisfies the recommendations provided by the SGISC. The value of the ratio criterion over standard ranging from zero to one <0;1> confirms the sufficient stability of the ship sailing in the assumed case of loading conditions, sailing conditions and weather conditions. While the ratio larger than one (1;+∞) reveals the insufficient stability, therefore the vessel shall avoid sailing in those particular loading conditions, sailing conditions and weather conditions.

Such data sets containing the exact values of parameters describing the loading conditions, sailing conditions and weather conditions were used for training of the neural networks. The small sample of training data is shown in Figure 6.

ShipMass[t]	LCG[m]	Heading[deg]	Rps[1/s]	Pitch[%]	H_Wave[m]	Criterion
1400.0	22.6	0.0	7.0	100	10.5	0.323956
1100.0	22.1	-30.0	8.0	60	9.5	0.461404
1100.0	22.1	-30.0	8.0	60	8.5	0.374587
1400.0	22.1	30.0	8.0	90	5.5	1.325059
1100.0	22.1	30.0	6.0	90	12.5	1.038261
1100.0	21.6	30.0	6.0	100	5.5	1.122382
1400.0	21.6	0.0	7.0	100	9.5	0.396038
1100.0	22.6	30.0	6.0	90	6.5	0.412049
1100.0	22.6	30.0	6.0	90	8.5	1.017361
1100.0	22.1	30.0	6.0	98	5.5	0.894571

Figure 6 A sample of data used for training of the ANN; here the surf-riding stability failure mode

The neural networks were created in Keras software in TensorFlow environment. Once the ANNs were trained the next results were intended to assess the quality of training. The most straightforward way to achieve this was to use the build-in function providing the automatic evaluation and visualization of the prediction, as shown in Figure 7. The randomly selected share of input data was not used for training but for testing.

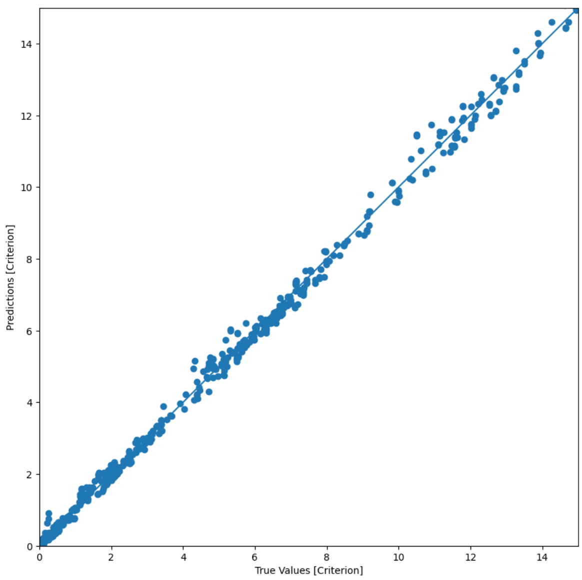

Figure 7 Visual presentation of the ANN training accuracy testing – the closer the testing points to the diagonal line, the better accuracy of training is revealed

Finally, the most important result of the ANN-based meta-model development is its capability to estimate ratio criterion over standard for the ship stability assessment in conditions other than earlier used for the networks training. The sample results are presented in Figures 8 and 9 for the surf-riding and excessive accelerations failure modes, respectively.

```
surfriding_model.predict([[1200.0,22.6,25.0,7.0,90,6],
                          [1200.0,22.6,35.0,7.0,90,6]])

1/1 [==============================] - 0s 30ms/step
array([[1.735],
       [1.563]], dtype=float32)
```

Figure 8 Sample inquiries and replies provided by the ANN-based meta-model; here for the surf-riding stability failure mode

```
#new_model.predict([[1200.0,21.6,4.5,41.5,12.5,90,6],
#                   [1200.0,21.6,4.5,7.5,45,6]])

1/1 [==============================] - 0s 102ms/step
array([[4.7875566],
       [0.       ]], dtype=float32)
```

Figure 9 Sample inquiries and replies provided by the ANN-based meta-model; here for the excessive accelerations stability failure mode

The sample results presented in Figure 8 show that for the assumed conditions the stability of the ship is insufficient, thus such conditions shall be avoided in operation because of the surf-riding hazard (the ratio criterion over standard is more than one). The sample results shown in Figure 9 describe one case to be avoided in operation – the first one with the ratio criterion over standard larger than one, and one case with sufficient stability with regards to the excessive accelerations failure mode – the ratio equal to zero.

In case of the parametric rolling and the pure loss of stability failure mode the considered ship is not vulnerable and the ratio criterion over standard is always less than one.

5. DISCUSSION

The developed meta-model was trained on data produced according to the Level 2 SGISC procedures allowing for the Operational Guidance preparation. Such OG is called the Simplified Operational Guidance, which is the limitation of this study to certain extent. The ship data are as reliable as the in-house software used for computations of all cases described by the assumed loading conditions, sailing conditions and weather conditions. However, the simplification is the intrinsic feature of the Level 2 approach since the ship vulnerability to the dangerous dynamic phenomena is assessed rather than the exact response in terms of the ship motion. Despite this, the results of this research are useful and correct, when keeping in mind the proper interpretation. The utilitarian aspect of the study is its strong point since the full set of computations was generated for about 14 hours with the use of laptop PC. Nonetheless, such computations were carried out only once for the ship and there is no need to repeat them anymore, unless the ship is rebuilt. The machine learning lasted for several hours to train the ANNs up to their high accuracy. Finally, the resultant networks are capable to provide the ship stability assessment in milliseconds. Therefore, with no doubt the developed meta-model meets the expectations.

6. CONCLUSION

The research presented here focuses on the development of the meta-model utilizing an ANN. The feasibility and efficiency of such an approach is demonstrated. The achieved results comprise, first, the meta-model development, second, the sample calculations performed with the use of the model. As the computations carried out according to the Level 2 Second Generation Intact Stability Criteria, required for the Operational Guidance preparation, are time consuming, the straightforward approach consisting of real time calculations is hardly feasible. Therefore, there is a need for a meta-model utilization. The developed meta-model based on ANN trained on the extensive data set is the main achievement of the study. The time needed to get the ship stability assessment typically ranges from 30 milliseconds up to a bit more than 100 milliseconds, which is more than enough from the Decision Support System point of view. Such a DSS may be built with the developed meta-model solely, which makes the proposed approach practical. Thus, the results are important and useful in the context of the e-Navigation concept implementation.

The further research goals will be directed towards similar machine learning techniques, though applied to the results of the Direct Stability Assessment procedure, which is significantly more demanding.

7. ACKNOWLEGMENT

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DESIGN AND DEVELOPMENT OF A NEW WEB PLATFORM FOR THE MANAGEMENT OF PHYSICAL FLOWS AND CUSTOMS DOCUMENTS AT PORT TERMINALS

Marino Lupi
University of Pisa
Department of Civil and Industrial Engineering and University Centre of Logistic Systems
Pisa, Italy
E-mail: marino.lupi@unipi.it

Daniele Conte
University of Pisa
Department of Civil and Industrial Engineering and University Centre of Logistic Systems
Pisa, Italy
E-mail: dc1996@hotmail.it

Alessandro Farina
University of Pisa
Department of Civil and Industrial Engineering and University Centre of Logistic Systems
Pisa, Italy
E-mail: alessandro.farina@unipi.it

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Abstract

This paper presents the functions a web platform with the purpose of managing documental and physical flows at port terminals. The platform was designed, for the Ligurian French and Italian coastal area, as part of the European project CIRCUMVECTIO and is currently under development in the CIRCUMVECTIO Plus European project, but it has a general applicability. As regards physical flows, the platform provides information on all possible intermodal alternative paths, from the shipment origin to the destination. In addition, the platform helps with the booking of rail and maritime services and trucking firms. Moreover, it allows to store the data of a shipment and share them among the actors involved. Finally, in the event of a disruption, such as an accident or a deletion of a maritime or a rail service, the platform allows to quickly send a notice to the stakeholders involved in the shipment, and provides the necessary information to change or delete the bookings of maritime and rail services. However, the most important feature of the platform is the documental flows management. The platform grants to upload, share and send the more relevant customs documents: not only cargo manifests and customs declarations, but also the rest of the important documents which follow the goods: bill of lading, certificates of origin, transport document, delivery order and the packing list. The platform manages not only the main European customs documents, but also those of some representative countries of the world commerce, for example: United States, China and Egypt. Customs declarations and cargo manifests could be generated and exchanged either in paper or "electronic" (that is xml) format, while other customs documents are generated and exchanged in paper format only. As a result, it is possible to upload and download on the platform the documents both as xml files and as scanned pdf or image files.

Keywords: Web platform; customs documents; physical flows; Ligurian Italian and French ports; physical flows management; customs documents management

1. INTRODUCTION

This document describes the main features of a Cross-Border Area Management (CAMP) web platform, which will manage physical and documental flows, particularly customs documents, at port terminals. This platform has been designed for the major French and Italian ports of the Ligurian Sea, in particular: Toulon, Bastia, Genoa, Savona, Livorno and Olbia. This study is part of the European CIRCUMVECTIO project [1], financed within the 'Italy – France Maritime' programme. Although it has been designed for these ports, it can have a general application. Currently, the CIRCUMVECTIO Plus [2] European project, also financed by the Italy – France Maritime programme, is physically developing the platform. The choice of ports of Ligurian Sea has been 'imposed' because of the project funding programme.

Regarding physical flows, the platform will grant the integration among the different freight transport modes in the program area (road, sea, rail) in order to develop intermodality. According to the feedback of operators in the sector, the core issues regarding physical flows concern the scarcity of information about the remaining slots on ships and the trouble of modifying the reservation in case of severe disruptions.

As regards documental flows, the platform will be able to grant the exchange of information and documents relating to the shipments, particularly those related to customs activities, which are vast and generally lead to high dwell times at ports.

Before the digitalization dwell times at Italian ports ranged from 5 to 12 days in import and from 4 to 5 days in export [3], while after the digitalization they range from 3 to 6 days in import and are equal to about 2-3 days in export [4]. In northern European ports, before the digitalization, dwell times ranged from 3 to 7 days in import and from 2 to 4 days in export [3], while after the digitalization they range from 1 to 3 days in import and are equal to about 1 day in export.

In Rodrigue and Notteboom [5] it is described that the largest part of dwell times is related to the customs documents. Documental flows are particularly massive in import. The transmission of xml (electronic) documents as a substitute of paper-only customs documents and the pre-clearance are solutions to reduce this problem.

This document presents the layout of the online platform designed in the European project CIRCUMECTIO and under development in the European project CIRCUMVECTIO Plus which integrates and manages physical flows and customs documents. In section 2, the platform main functionalities as to the management of physical flows are described. In section 3, an overview of the main customs documents is presented. In section 4, it is explained how the platform will manage the documental flows. Conclusions follow.

2. THE MAIN FEATURES OF THE CIRCUMVECTIO PLUS PLATFORM AS TO THE PHYSICAL FLOWS MANAGEMENT

The CIRCUMVECTIO Plus platform is formed by a GUI (Graphical User Interface) and by modules and databases. The databases embedded in the platform are: maritime transport operators, maritime routes, Multimodal Transport Operators (MTOs), rail freight connections, terminal operators, freight forwarders, trucking firms. The CIRCUMVECTIO Plus platform will be connected to other ones, for example: Port Community Systems (PCS); Infoblu that will give road traffic information in real-time; the 'Marinetraffic' website [6] and Port Management Information Systems (PMIS) [7] that provide the location of ships in real-time.

A general scheme of the principal modules of the suggested online platform is represented in Figure 1.

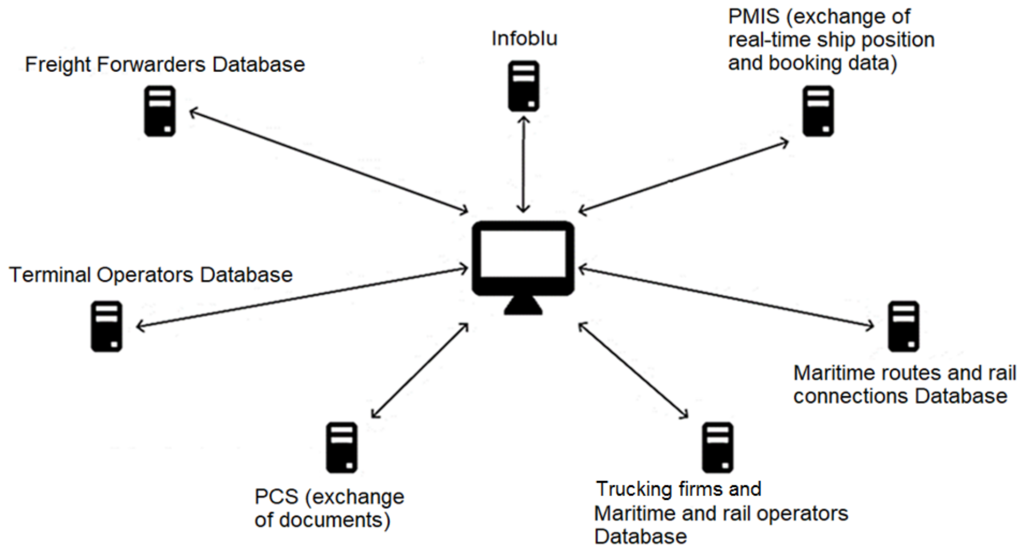

Figure 1 Interaction of the proposed platform with existing databases and websites. Source: own elaboration

The platform will be available only to registered users. The platform is intended for the following users who are also the main port stakeholders: freight forwarders; sender and receiver of a shipment; terminal operators; road, maritime and rail carriers; customs and ship agents. However, port stakeholders will not have access to the whole documentation loaded on the platform but only to the documents of their exclusive interest. The GUI of the CIRCUMVECTIO platform is composed of five menus, described below, and of an interactive map showing to the user the best path from a given origin to a destination. The menus of the platform are: Path; Shipment; Send notify; PCS - PMIS - ERIS Liner; Documents.

The menu '**Path**' opens an interactive map; the itinerary can be set by choosing: origin, destination, type of goods transported and travel preferences. In particular, the user can choose between the cheapest path and the fastest path and can also decide which transport modes to use: road + sea + rail, road + sea, road + railway, road + railway only, rail only, sea only. See Figure 2.

The main sources about the best path, which could be either intermodal or single mode, are the following:

- For road transport: the platforms 'Infoblu' for Italy and 'Autoroutes.fr' for France. Originally 'Via Michelin' was chosen, but it does not provide real-time information on traffic and road closures. Infoblu instead provides real time information on the Italian motorway network and Autoroutes.fr on the French one. The choice of Google Maps was not feasible, because its managers do not allow other apps to import quantitative data from Google Maps. It is only possible to import the entire map, for example of a city, as described in [8].
- For the maritime transport in the intermodal path:
  - from the websites of maritime operators that provide: the departure and the arrival date and time of maritime services, the name of the ships operating each service;
  - from the website www.marinetraffic.com which gives the position of each ship in real-time;
  - directly from operators, as regards the prices of ticket and the number of slots available on a certain ship. This information is private since maritime operators make preferential prices and reserve slots for the main clients. However, operators are usually reluctant to 'expose' this information on a website, therefore in the CIRCUMVECTIO Plus platform it will be shown only in demo mode.

- For the rail transport in the intermodal path:
  - from MTO (Multimodal Transport Operator) websites which provide: time of cargo closure, time of cargo availability upon arrival, number of the train;
  - directly from MTOs, as regards prices and availability of train slots. However, also in this case, operators are usually reluctant to display this information, therefore, as in the case of the maritime part of the path, in the CIRCUMVECTIO Plus platform it will be shown only in demo mode.

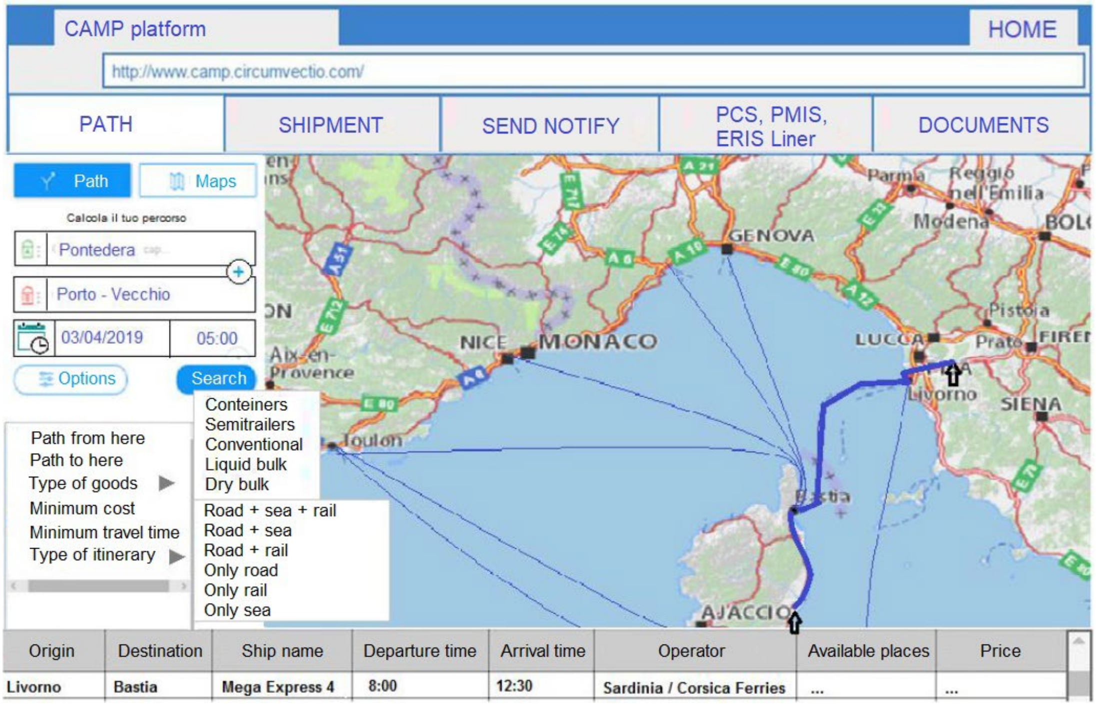

Figure 2 Example of using the 'Path' menu: determination of the intermodal route (road + sea) Pontedera - Porto-Vecchio.

Source: own elaboration

The '**Shipment**' menu is composed of four sub-menus, which redirect to precise actions on the 'Shipment sheet', described in the following:

- Create shipment: it contains all the instructions necessary for the creation of the "Shipment sheet". It allows the insertion of travel details and the choice of the carriers (maritime, railway, and road) and the terminal operators (maritime and railway).
- Change shipment data: it allows modifying an existing 'Shipment sheet'.
- View shipment data: it allows visualizing a 'Shipment sheet', but without the possibility to modify.
- Cancel shipment data: it allows canceling a 'Shipment sheet' once the shipment is consigned to the receiver. This sub-menu is necessary as the platform does not cancel automatically the 'Shipment sheet'.

The Shipment sheet for the itinerary Pontedera (Italy, Tuscany region) to Porto-Vecchio (France, Corsica region) is shown in Fig. 3.

Some information of the 'Shipment sheet' is imported from the menu 'Path', for example: address of the origin of the shipment; address of destination; dates and times of: departure, arrival at the loading terminal, ship departure from the loading terminal, arrival at the unloading terminal, arrival at the destination.

However, this information is automatically modified after the user has booked the road, maritime and, possibly, rail carriers, and the terminal operators. In addition, all the fields of the 'Shipment sheet' can also be manually modified by the user.

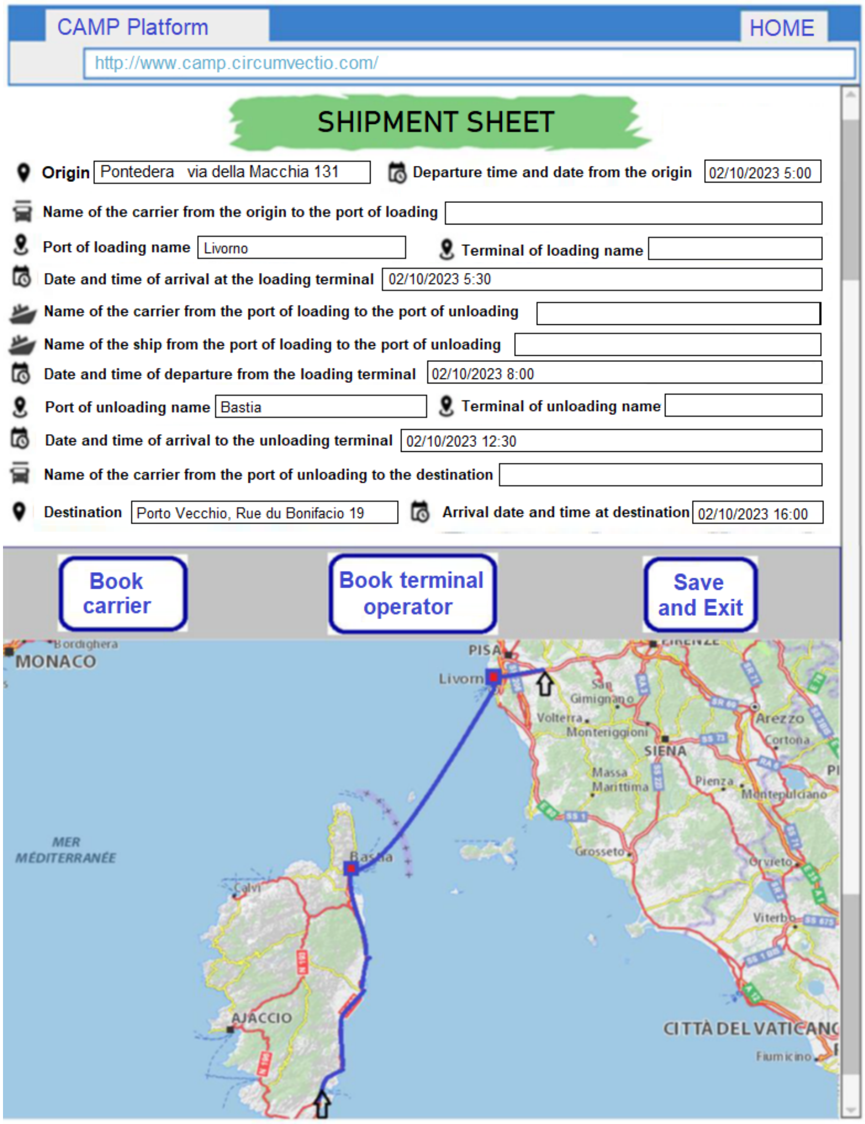

Figure 3 Example of 'Shipment sheet' for an itinerary from Pontedera to Porto-Vecchio.

Source: own elaboration

In the 'Shipment sheet' it is also shown (see figure 3):

- a map which displays the itinerary; this is gradually updated by the bookings of road, maritime and rail carriers and of terminal operators;
- the following buttons: book carrier; book terminal operator; save and exit.

After clicking on the 'book carrier' button, the user has to choose the type of carrier: rail, road, or maritime. Then the user is redirected to a page for the booking of the maritime carrier.

An example of a page for booking the maritime carrier is shown in Fig. 4, for a road carrier it is shown in Fig. 5, and for a rail carrier it is shown in Fig. 6.

If the carrier accepts reservations via the platform, the platform user can book the ship slot by clicking on the purple triangle, that is the 'Book' icon (Fig. 4,5,6).

Carriers, at present are not very inclined to share sensitive data through the platform, such as, for example, prices charged. In this case, the price field will be empty. The platform however supplies the contacts (telephone and e-mail) of vectors or terminal operators, so that the users can quickly contact them and establish a private negotiation.

After clicking on the 'book terminal operator' button, the user can choose the type of terminal operator: rail or maritime. Then, the user is redirected to the booking page of the chosen terminal operator.

An example of a booking page of a maritime terminal operator is shown in Fig. 7.

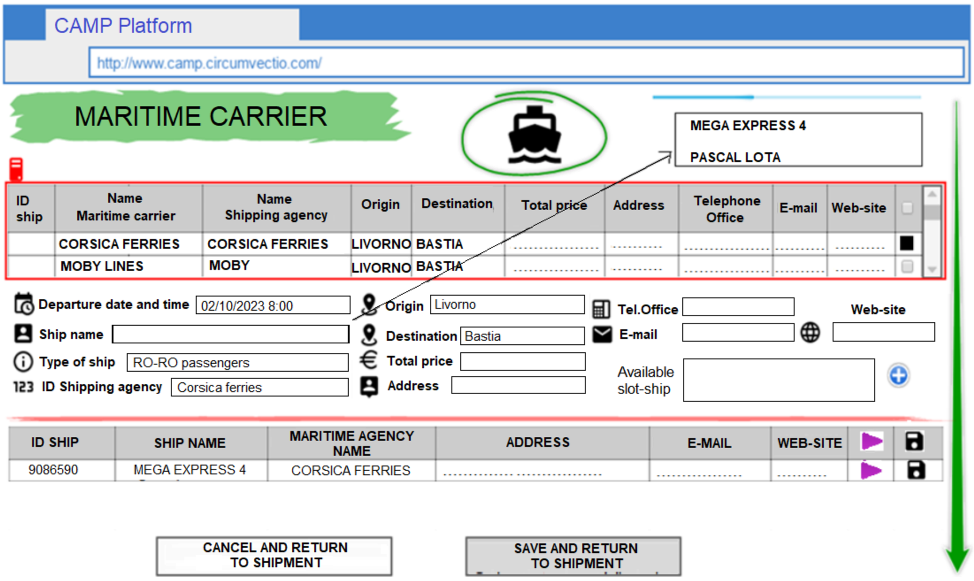

Figure 4 Booking page of a maritime carrier.

Source: own elaboration

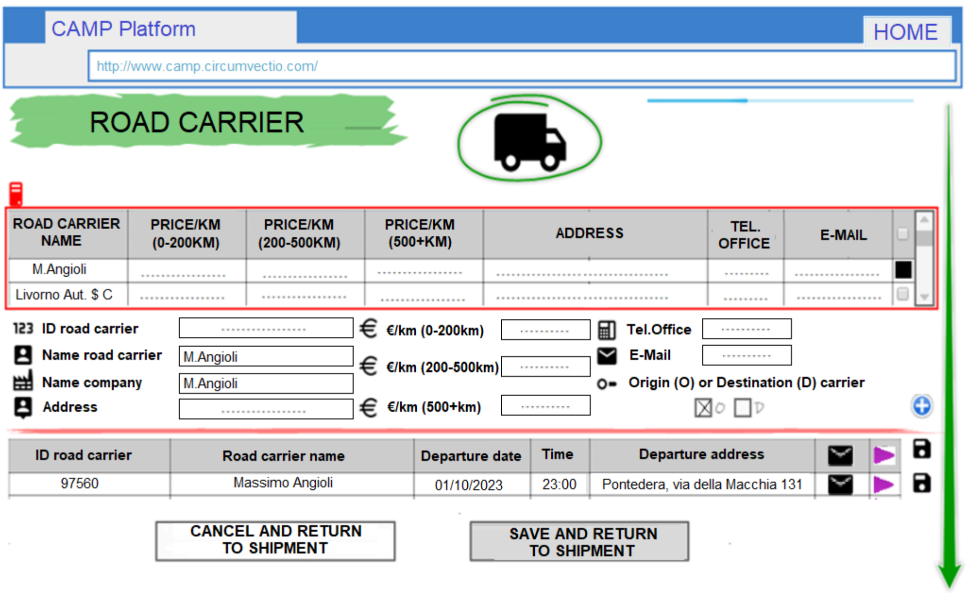

Figure 5 Booking page of a road carrier.

Source: own elaboration

The menu '**Send notify**', in a previous version of the platform was named 'Change reservation and send notify', which allowed not only to send notifications but also to change booking. However, some experts in the field stated that the change booking functionality was redundant with the previous menu 'Shipment'. It was therefore decided to limit the functionality sending notifications.

The notifications will be sent to all stakeholders involved in a given shipment, in two cases:

- In case of a serious disruption (for example engine failure or an accident) that results in such a high delay in the shipment that makes it impossible to reach the rail or the maritime terminal in time for the departure of the booked train or ship.
- In the event of a small disruption (for instance the shipment is stuck in a traffic jam), that results in a little delay of arrival at the rail or maritime terminal, however in time to board on the train or the ship booked.
- To send departure or arrival notifications.

In the case of disruptions, the notification is sent by the carrier (road, maritime or rail) that is transporting the shipment in the moment the disruption occurred. Instead, the departure or arrival notifications are sent by the sender or the receiver of the shipment, or by the freight forwarder.

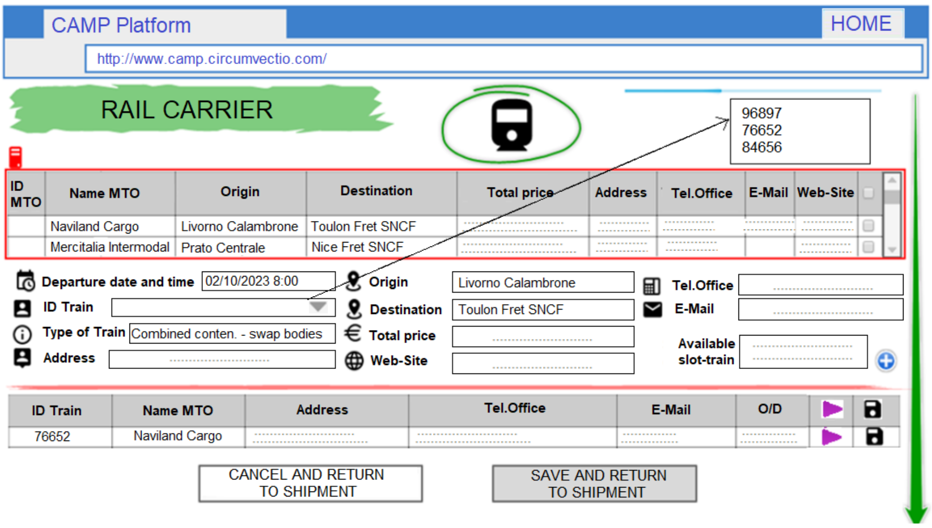

Figure 6 Booking page of rail carrier.

Source: own elaboration

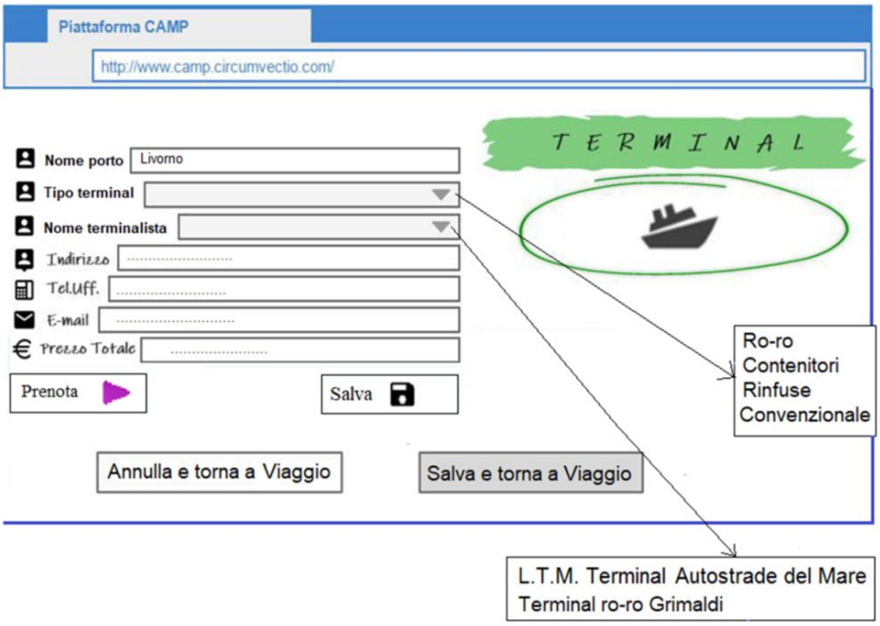

Figure 7 Booking page of a maritime terminal operator.

Source: own elaboration

The menu '**PMIS, PCS and eRIS Liner**' reports the updated links to the PCS (where it is available), PMIS and eRIS Liner web platforms of ports included in the project CIRCUMVECTIO Plus: Genova, Livorno, Olbia, Savona-Vado Ligure, Toulon, Bastia. The eRIS (electronique Réseau Informatif Service) Liner platform is the PMIS of the French ports.

At the beginning of the CIRCUMVECTIO project, interaction between the CIRCUMVECTIO Plus platform and the PMIS and eRIS Liner ones was envisaged: in particular, it was enviaged that PMIS and eRIS Liner platforms could transmit to the CIRCUMVECTIO Plus platform position of ships in real time. However, this proved to be unfeasible because the PMIS and eRIS Liner managers are reluctant to share and display this information.

Fig. 8 shows a flowchart of the use of the platform as for the management of physical flows (menu: "Path", "Shipment", "Send notify")

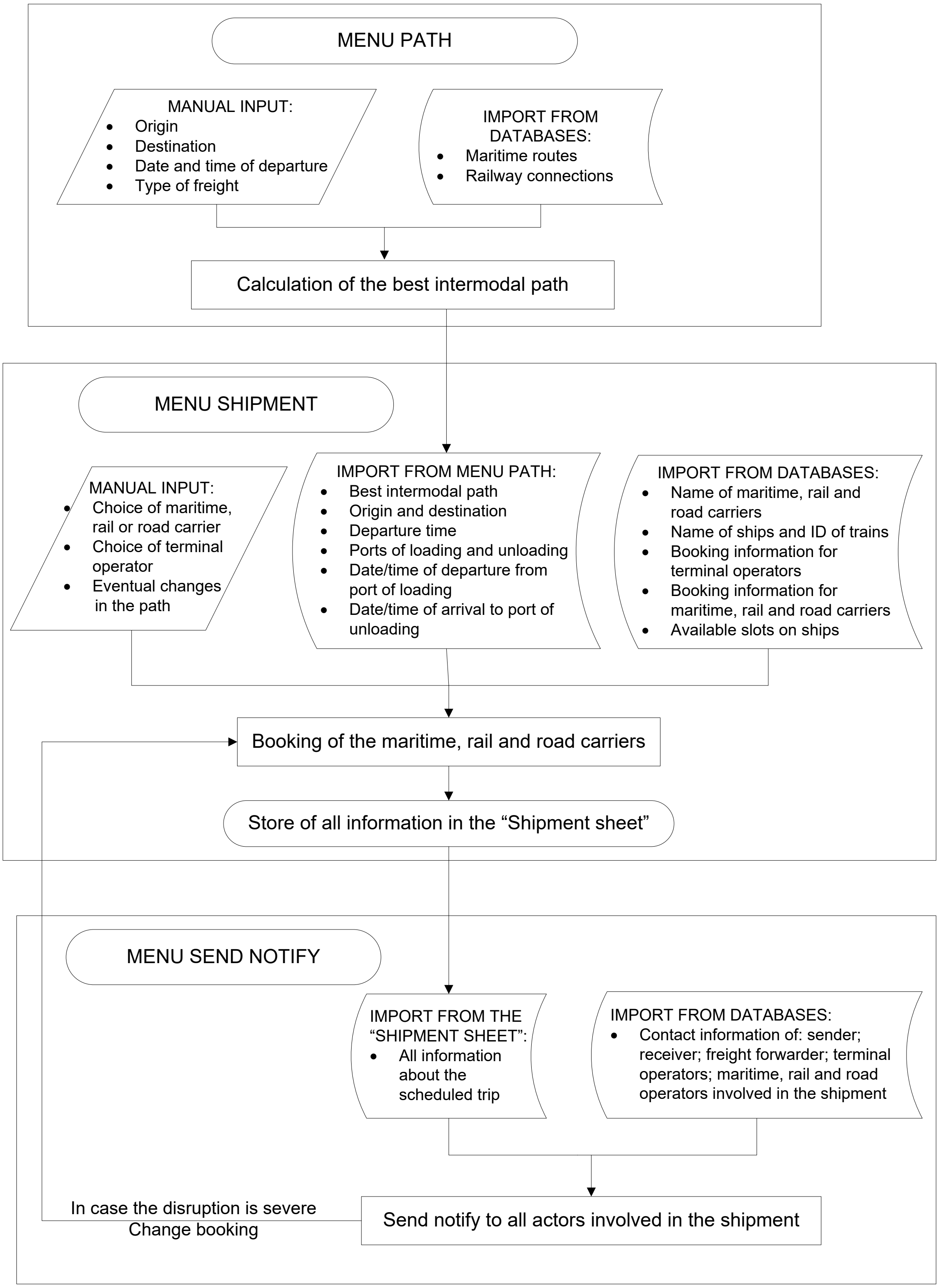

Figure 8 Flowchart of the use of the platform as for the management of physical flows: menu "Path", "Shipment", "Send notify".

Source: own elaboration

3. THE MENU 'DOCUMENTS' AND THE DOCUMENTAL FLOW MANAGEMENT BY MEANS OF THE CIRCUMVECTIO PLUS PLATFORM

The menu 'Documents' is the most important one of the CIRCUMVECTIO Plus platform, as it allows the management and integration of port documental flows.

The menu Documents is connected to a repository, where customs documents may be uploaded and downloaded.

The principal documents exchanged in export are: Outward Cargo Manifest, customs declaration, bill of lading, invoice, transport document, delivery order, packing list, and, when applicable (depending on the country with which the product exchange is carried out): EUR-1 or A.TR.

The main documents exchanged in import are: Inward Cargo Manifest, customs declaration, bill of lading, invoice, transport document, delivery order, packing list, and, when applicable (depending on the country with which the goods are exchanged): Form A or A.TR.

Outward and Inward Cargo Manifests concern an entire ship. Other documents refer to a batch of goods, except the bill of lading which refers to a whole shipment (which in general consists of several batches of goods).

An overview of the principal documents required by customs offices, and their exchange among the port actors is provided in Lupi et al. [9]. In [9], an earlier design of the platform is also presented, carried out in CIRCUMVECTIO project, which however has been refined in the project CIRCUMVECTIO Plus, after the feedback of experts in the field and studies carried out by the authors as regards Port Community Systems (PCS) and customs documents in Italy, in Europe and in the rest of the world.

The most remarkable PCS platforms are: In Italy Savona, Genoa and Livorno, see [10],[11],[12],[13],[14]; in Europe Rotterdam [15], Antwerp [16], Hamburg [17]; in the rest of the world Shanghai [18], Singapore [19], Alexandria of Egypt [20]; the U.S. ports of Los Angeles-Long Beach [21] and New York [22]. It should be noted that the PCS with the largest number of functionalities are those of Shanghai and Alexandria of Egypt, while the PCS of the U.S. ports do not manage customs documents, because the American shippers prefer not to share sensitive data through an IT platform.

The customs agencies, in Italy AIDA [23], in France Pro.douane [24] have their own specific platform.

The Italian and French cases were studied in the CIRCUMVECTIO and CIRCUMVECTIO Plus projects, as these projects were financed as part of the Italy-France Maritime Programme, but the customs platform, which is the homologous of AIDA and Pro.douane, is in operation in several other countries.

Some Italian ports are not equipped with PCS, however all main Italian ports are equipped with PMIS platforms, which grant real-time data on all the activities carried out within the port area, for example: real time information on all ships departing and arriving at the port terminals; information on the amount of freight and passengers loaded or unloaded from each ship (for example, number of TEUs, number of semitrailers, number of cars, number of passengers); availability of the parking spaces inside the port area.

The platform will dialog with the PCS of the ports of the program area. The functionalities of the menu 'Documents' of the CIRCUMVECTIO Plus platform are the following:

- Transfer documents generated in the export port, from the export port to the import port. This allows freight forwarders, customs agents and ship agents established in the port of import to produce in an easier way their own documents. At present, in fact, the PCS of the different ports do not communicate with each other.
- To allow the sharing of documents between the various subjects operating in the ports not equipped with PCS: ship agents, customs agents, freight forwarders, but also terminal operators and maritime carriers.

The possible situations considered are the following:

- Trade between Italy and another country belonging to the EU (for example France, but also Croatia): Intra-Community transfer.
- Export from Italy or France to a non-EU country.
- Import from a non-EU country to Italy or France.

In the case of intra-Community supply, the documents exchanged are only: invoice, transport document and packing list. These do not involve the use of PCS.

Documents in non-EU countries vary from country to country. In this paper, as a non-EU country, the United States was considered as an example.

3.1 Use of the platform in the case of intra-Community transfer

In the case of intra-Community transfer, there is no Customs. The freight forwarder produces the invoice, transport document and packing list in paper format. They are loaded on the platform as pdf files. These documents 'accompany' the goods in paper format and must be shown in case of eventual controls of the police and for the entrance and the exit from the port terminals.

The use of the platform in the case of intra-community transfer is shown in Fig. 9.

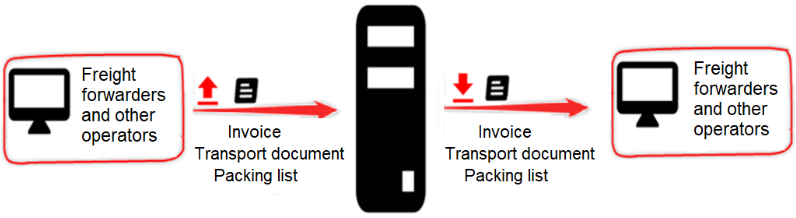

Figure 9 Exchange of documents between export port, platform and import port in the case of intra-community transfer.

Source: own elaboration

3.2 Use of the platform for exchange of customs documents outside the European Union

Initially, it was planned that documents could be directly exchanged from the CIRCUMVECTIO Plus platform to the PCS, by simply clicking on a button on the PCS or on the platform. However, this turned out to be not feasible, because:

- the collaboration of a large amount of PCS managers of several countries in the world would be necessary;
- the PCS of the U.S. do not manage customs documents, because port actors are reluctant to share the information about their freight, as shown also in [25].

As a result, it was considered only the case of uploading and downloading the customs documents on the platform, while the possibility to send the documentation between the PCS and the platform by pushing simply a button has been neglected.

The following is an example of the use of the platform for the exchange of documents between Italy/France and the United States.

3.2.1 Export from Italy or France to the United States.

Italian or French customs agents create the export customs declarations, while the ship agents produce the Outward Cargo Manifest. These documents are generated in xml format by means of the management software of ship and customs agents, and are loaded aftewards by these port actors on the CIRCUMVECTIO Plus platform.

The Italian/French Outward Cargo Manifest, available on the CIRCUMVECTIO Plus platform will allow the U.S. ship agent to produce more easily the U.S. Inward Cargo Manifest.

The export customs declaration, available on the CIRCUMVECTIO Plus platform, will allow the U.S. customs agents to draft more easily the Entry summary and the Entry / immediate delivery, which is the U.S. homologous of the Italian customs declaration of import. Bill of lading, invoice, delivery order and packing list, are generated in the port of export, and are currently shipped by the freight forwarder (Italian or French) to freight forwarders and customs agents of import (US) only in paper format. Instead when the CIRCUMVECTIO Plus platform will be operational, freight forwarders of the port of export (Italian or French) will be able to scan and load these documents on the platform in pdf format, while the freight forwarders operating in the port of import (American) will be able to download them. See Figure 10.

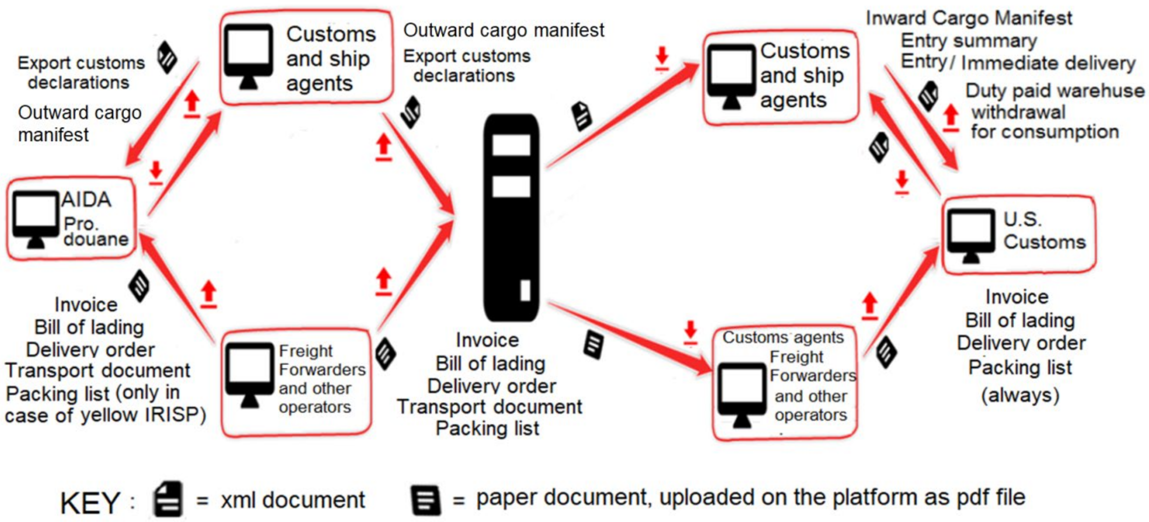

Figure 10 Transmission of export documents from an Italian or French export port to a U.S. import port, in case both ports are not furnished with PCS.

Source: own elaboration

3.2.2 Export from the United States to Italy or France.

The U.S. export declarations and the U.S. Outward Cargo Manifest are produced by means of the management software of the American customs agents and ship agents, in xml (electronic) format, and loaded on the platform. These will be unloaded by customs and ship agents of the Italian or French import port.

Starting from the American Outward Cargo Manifest, it will be much easier to draw up the Inward Cargo Manifest in the Italian or French import port.

Starting from the American export declaration, it will be much easier the Italian/French import customs declaration.

Bill of lading, invoice, delivery order and packing list are required in the ports of import, Italian and French. These are currently transferred and shared as paper documents, therefore, when the CIRCUMVECTIO

Plus platform will be operational, it will be possible to scan and load them on the platform in pdf in the American port of export and to unload them at the (Italian or French) port of import.

The invoice, however, in the United States is often exchanged also in xml format (instead of paper format): in this situation, it will be loaded on the platform as xml file (instead of pdf file). In any case, the invoice is currently produced in electronic format also in Italy or France, however, at least for now, it must also be produced in paper format: in case of police checks, in fact, it must be presented in paper format and not in electronic format. As mentioned above, the transport document is not required by US customs, and it is therefore produced exclusively in the import port (Italian/French). See fig. 11.

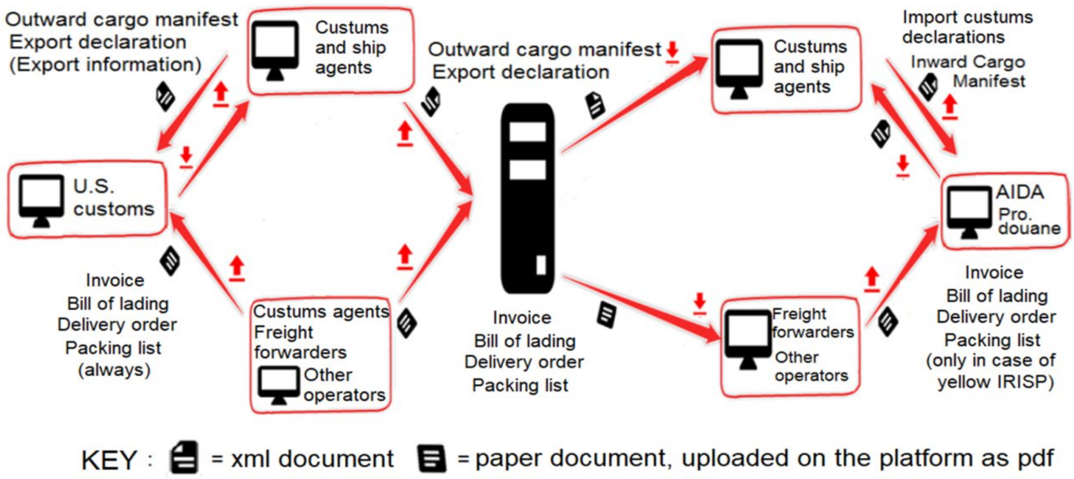

Figure 11 Transmission of export documents from a U.S. export port to an Italian or French import port, in case both ports are not furnished with PCS.

Source: own elaboration

3.3 Share of documents among the actors of export and import ports not equipped of PCS

3.3.1. Document share in the port of export (Fig.12)

At present customs agents send (by e-mail) customs declarations, in xml (electronic) format to the ship agent. The ship agent generates the Outward Cargo Manifest through its management software from the customs declaration received.

When the platform becomes operational, customs agents will load the declarations in electronic format on the CIRCUMVECTIO Plus platform. The ship agent will download them from the platform and generate the Outward Cargo Manifest through its management software without the need to collect all the customs declarations (for example by e-mail), which can be thousands even for a single Outward Cargo Manifest).

Port actors upload on the platform the documents they have produced; in addition they have access to all the documents of their own interest on the platform, including those produced by the other port actors. Each actor of the port does not have access to 'all' the documents on the platform, but only to the documents of his their own interest.

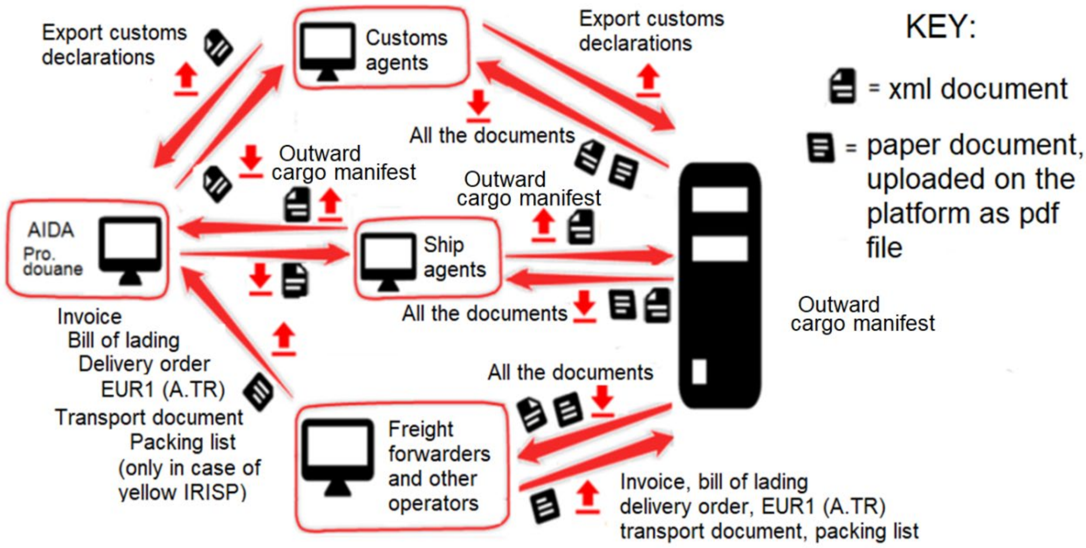

Figure 12. Sharing of documents between the actors of the export port not furnished with PCS.
Source: own elaboration

3.3.2. Share of documents in the port of import (fig.13)

Customs agents send to the ship agent 'provisional' customs declarations, i.e. without A3 codes. The 'A3'code identifies the batch of goods to which a given customs declaration is related. The customs offices assign each A3 code to each batch of goods before the customs control. The ship agent generates a 'temporary' Inward Cargo Manifest, as it lacks A3 codes, starting from the customs declarations and uploads it to AIDA. Customs offices enter the A3 codes in the Inward Cargo Manifest and send it back to the shipper.

In some ports, the ship agent must send to the customs agents the A3 codes relating to the batches of goods under their jurisdiction. In case the port is not furnished with PCS, the ship agent has to send (e.g. by email) to the different customs agents, one by one, the A3 codes. However, there can be thousands of A3 codes. This leads to a serious inefficiency, and therefore to a slowdown in the document import procedures. In other ports, Customs office either enters A3 codes, which can be in thousands, into the Inward Cargo Manifest or sends them directly to the different customs agents,. This entails a high workload for customs offices.

When the CIRCUMVECTIO Plus platform becomes operational, the ship agent will load on the CIRCUMVECTIO Plus platform the Inward Cargo Manifest, complete with the A3 codes received by customs offices. Therefore the customs agents will be capable of finding the codes A3 of their interest on the platform. This simplifies the document import procedures and therefore surely brings great benefits to the operators in terms of workload and time saved. This is already possible in ports equipped with PCS: customs agents could access and download the Inward Cargo Manifest loaded on the PCS by the ship agent.

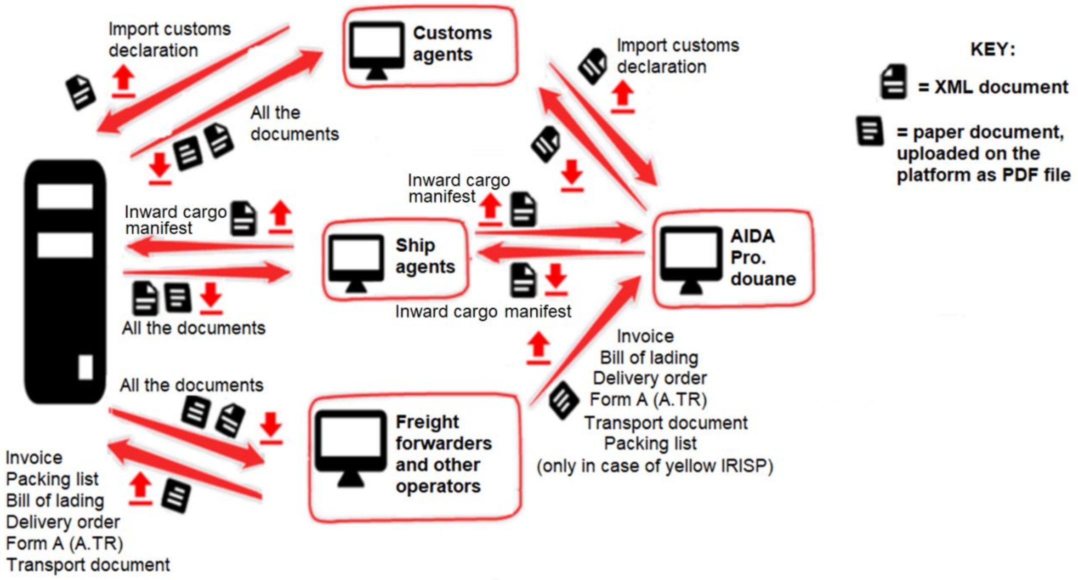

Figure 13 Sharing of documents between the actors of the import port not furnished with PCS.

Source: own elaboration

3.4 The web pages of the platform for the upload and the download of customs documents.

The CIRCUMVECTIO Plus platform will allow to upload and download the main customs documents, displayed in Fig. 10, 11, 12 and 13.

The web page of the menu 'Documentation' for the upload of a customs document is displayed in Fig. 14. The web page for the download of a customs document is shown in Fig. 15.

The authors of this paper, the author of the thesis [26] included, have carried out research on the main documents in U.S. (the most important extra European Italian partner), China (the main country of Far East) and Egypt (as representative of a Mediterranean non-European country.

This study showed that some documents are common in all countries, while several others are similar: for example, the bill of lading is recognized all over the world; while the Italian customs declaration corresponds to: the U.S. entry/export declaration, and to the Chinese and Egyptians customs declaration, which are different in some fields, but have almost the same structure as the Italian one.

In synthesis, about the customs documents, the following could be stated:

- Documents common in all the four countries (Italy, U.S., China and Egypt): Bill of lading, Delivery order, Packing list. They are all exchanged, and produced, in paper format only.
- Documents similar in the four countries:
  - Customs declaration: the Italian one corresponds to the U.S. Export declaration (in export) and to the Entry summary / Entry-Immediate delivery (in import); and to the Chinese and Egyptian customs declaration. They can be produced both in electronic (xml) and paper format
  - Inward/Outward cargo manifest: the Italian one corresponds to the U.S. Inward/Outward Cargo Manifest, to the Chinese Import / Export China Customs Advanced Manifest, and to the Egyptian Import / Export General Manifest. They can be produced both in electronic (xml) and paper format
  - Commercial invoice: the Italian one corresponds to the U.S. and Egyptian Commercial invoice and to the Chinese Fapiao. They can be produced both in electronic (xml) and paper format

- Documents of Origin: the Italian EUR1, EUR-MED and Form A correspond to the U.S., Chinese and Egyptian Documents of Origin. They are all exchanged and produced in paper format.

- Documents which are specific of a given country
  - United States: Duty Paid Warehouse Withdrawal for Consumption; Certificate of disposition of imported merchandise. They are all exchanged and produced only in paper format.
  - China: Inspection certificate of the AQSIQ (General administration for the supervision, the inspection and the quality); Insurance Police; Sales Contract; Import / Export License. They are all exchanged and produced only in paper format.
  - Egypt: Inspection report; Letter of credit. They are all exchanged and produced only in paper format.

As a result, when uploading a document on the platform, it is necessary to choose, as type of document, the corresponding Italian document, and not the document type 'Other document'. For example, in the case of the Import China Customs Advanced Manifest, the document type to choose upon the upload is 'Inward Cargo Manifest'.

The document type 'Other document' should be chosen only for the documents specific for a given country, for example the U.S. 'Duty paid warehouse withdrawal for consumption': indeed if in the group 'Other documents' a very large number of documents is stored, at the moment of download it could be difficult to find the wanted document.

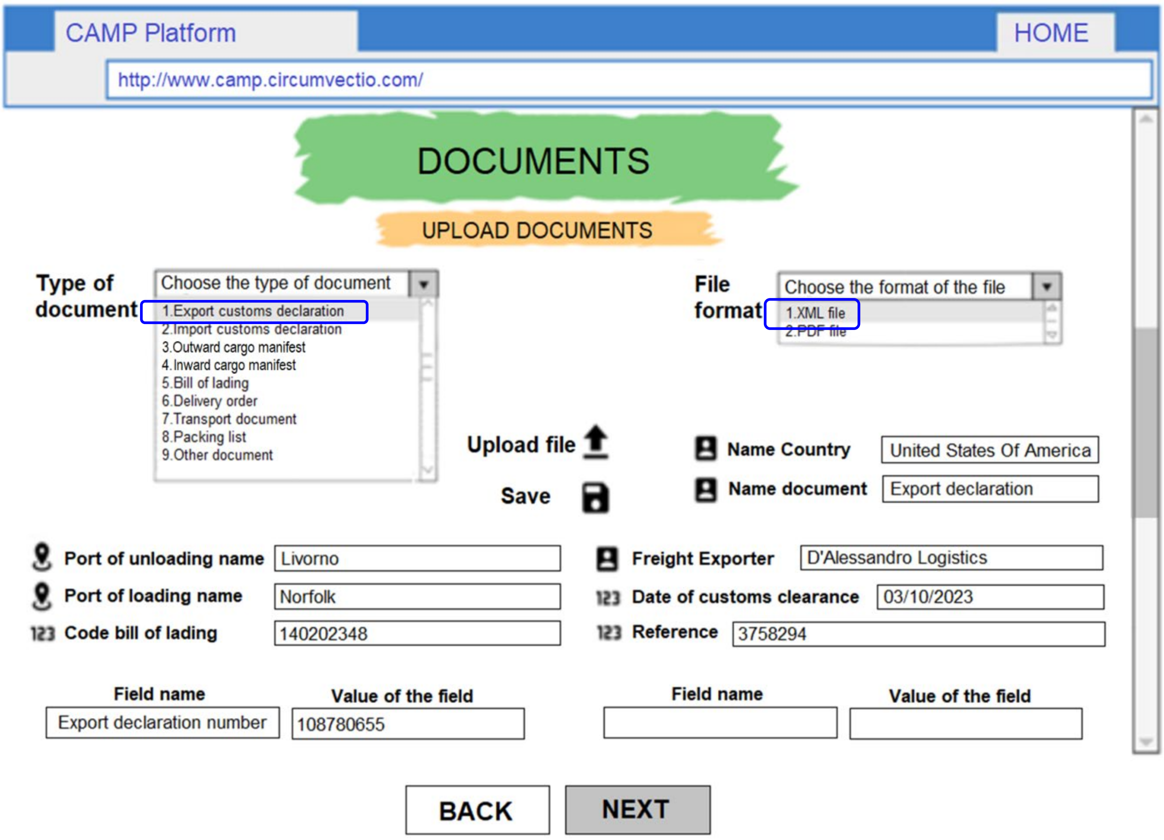

Figure 14 Menu Documents: upload.

Source: own elaboration

In fig. 14 it is reported, for example, the upload of an U.S. customs declaration of export, i.e. the 'Export declaration'. In the drop down menu 'Type of document', upper left of Fig. 14, it is necessary to choose the typology of document, in this case 'Export customs declaration'. In the drop down menu 'File format', upper right of fig. 14, the voice 'XML file' must be chosen. Then, the remaining data must be manually inserted: the most important ones are the name of the country (In this case United States of America) and the exact name of document (in this case 'Export declaration').

When downloading a document, it is necessary to choose the type of document in the drop-down menu 'Type of document' (upper left of Fig. 15): in this case, 'Export declaration'. After that, it is necessary to choose the file format in the drop down menu in the upper right of Fig. 15. It is also necessary to insert the name of the country (United States of America) and the exact name of the document ('Export declaration').

However, it is suggested to compile all possible fields of Fig. 15 in order to make it easier the search of the documents.

After, the platform shows, on the bottom of the page, a drop-down menu called 'Available Documents', where all documents fulfilling the data reported in the page fields, are displayed. The platform user chooses the correct document from the drop-down menu.

A flowchart of the use of the menu "Document" is shown in Fig. 16 as regards the document upload and in Fig. 17 as for the download of a document.

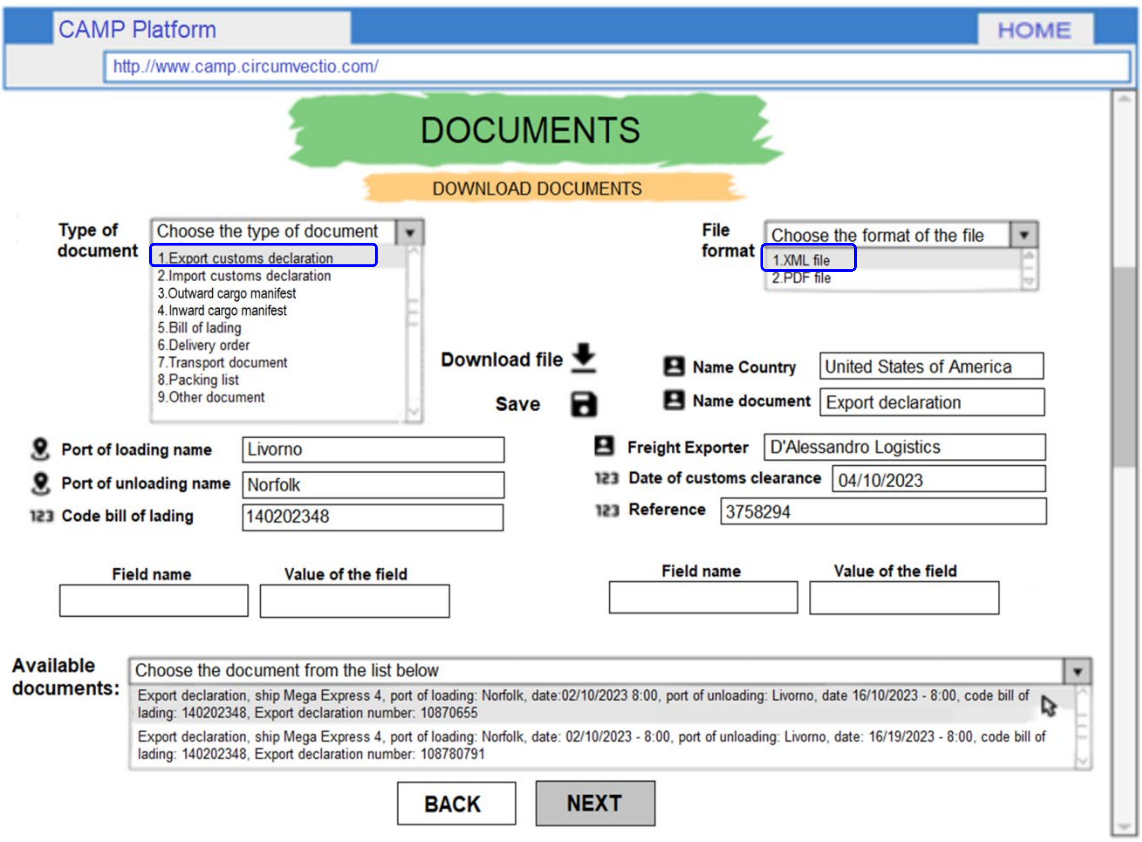

Figure 15 Menu Documents: download.

Source: own elaboration

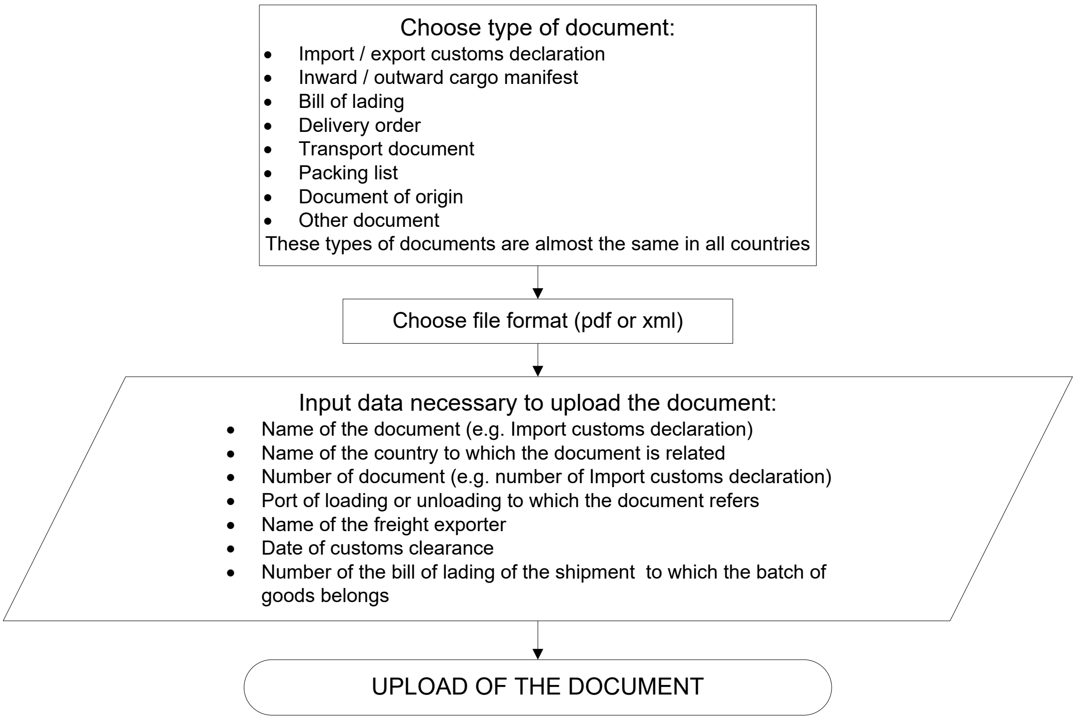

Figure 16 Flowchart of the use of menu "Documents" for the document upload.

Source: own elaboration.

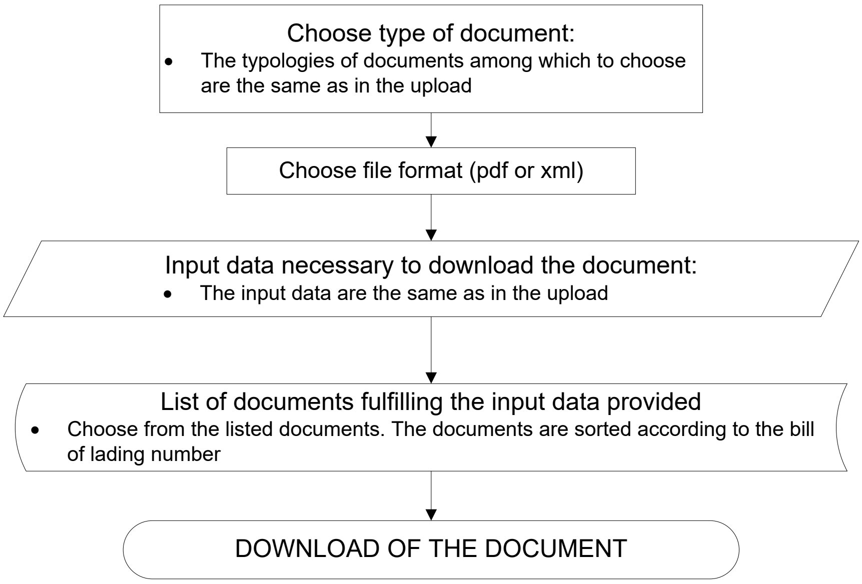

Figure 17 – Flowchart of the use of menu "Documents" for the document download.

Source: own elaboration.

4. CONCLUSIONS

This paper describes the features of a platform which will manage the documental and physical flows at ports. This platform was designed in the European project CIRCUMVECTIO and is currently under development in the CIRCUMVECTIO Plus project.

At first, the platform will allow to handle physical flows and in particular it will help the user to search for several possible travel solutions from a given origin to a given destination; it will help the user to find all the information which help in the reservation of rail and maritime operators and of trucking firms. Additionally, it will easily make the user able cancel or modify the booking and send notifications in case of interruptions.

However, the main objective of the suggested platform will be to aid in the management and integration of documental flows at ports, particularly of the customs documents.

The CIRCUMVECTIO PLUS platform will allow transfering the customs documents from the export to the import ports by uploading and downloading the documents on the platform. This will allow generating the import documents more easily and in less amount of time because all the information needed to produce the documents of import is at the disposal to port operators.

The CIRCUMVECTIO Plus platform will also grant to spread the customs documents among the port stakeholders if the port is not furnished with the PCS.

Some customs documents, such as the invoice, the customs declaration and the Outward and Inward Cargo Manifests are generated and shared generally in xml (electronic) format, but also in paper format. Instead bill of lading, documents of origin, transport document, delivery order and packing list are produced and shared still today only in paper format. Consequently, the CIRCUMVECTIO Plus platform will allow the document upload not only as xml files, but also as pdf files which are scanned paper documents.

After some interviews to operators in the sector, especially freight forwarders, it turned out that the main functionality of the CIRCUMVECTIO Plus platform is for sure the documental flows management.

However, some features of the physical flows management of key importance have emerged. While real time information on road transport is easily available from Google Maps, the same does not apply to maritime transport. In particular, especially in case of an accident or a delay in the road transport, freight forwarders have the necessity of having easily at disposal all information on ro-ro and container maritime services: scheduled departure and arrival time of maritime services, links to maritime operator websites, contacts of maritime operators to create, modify or cancel the reservation of a slot on a ship.

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DATA-DRIVEN, PROBABILISTIC MODEL FOR ATTAINABLE SPEED FOR SHIPS APPROACHING GDAŃSK HARBOUR

Jakub Montewka
Gdańsk University of Technology, Institute of Ocean Engineering and Ship Technology
Poland
E-mail: jakub.montewka@pg.edu.pl

Marcin Życzkowski
Gdańsk University of Technology, Institute of Ocean Engineering and Ship Technology
Poland
E-mail: marcin.zyczkowski@pg.edu.pl

Filip Zarzycki
E-mail: filip.zarzycki00@gmail.com
UDK 656.61.052(438Gdanjsk)

Abstract

The growing demand for maritime transportation leads to increased traffic in ports. From this arises the need to observe the consequences of the specific speed that ships reach when approaching seaports. However, usually the analyzed cases refer only to the statistical evaluation of the studied phenomenon or to the empirical modelling, ignoring the mutual influence of variables such as ship type, length or weather conditions. In this paper, a different approach to the issue is proposed, which summarizes the most important factors and leads to a probabilistic speed model for manoeuvring ships in the port of Gdańsk. For this purpose, data from the Automatic Identification System were used. This resulted in a dataset with almost 2.5k traffic scenarios. To obtain results from the dataset, three different machine learning algorithms based on Bayesian networks were then applied. The developed models can be used to predict the speed as a function of the given parameters as well as to determine the values of individual parameters for a given speed. In addition, the use of the constructed models allowed the analysis of the strength of mutual influences for two connected nodes or the sensitivity of changes for individual variables. The discussion also raised questions about the validation of the algorithms and measures to improve accuracy. The average predictive accuracy of the models of about 75% (depending on the learning algorithm used) achieved at this stage is promising, but further work is expected that can increase the predictive power of the models.

Keywords: Bayesian network, AIS data, ship speed, maritime transport, Gdańsk harbour

1. INTRODUCTION

The development of maritime transport leads to an increased handling of goods in seaports. This leads to an increase in traffic on the shipping lanes of seaports and directly in the ports. An increase in transshipment was also observed in the second largest port in the Baltic Sea basin - Gdańsk [1], where traffic intensifies accordingly. Ships are continuously monitored by port services, but the increasing shipping traffic and dynamically changing geopolitical situation make it necessary to develop new concepts and tools to improve security. Ideally, these new security concepts should be based on the existing technical infrastructure, but using new IT technologies. This could be based on archiving the Automatic Identification System (AIS) signal as a potential training database.

One of the reasons for introducing the AIS system was to ensure the safety of navigation, especially in areas of high traffic, such as access waters to ports. The introduction of the system into general use enabled automatic communication between vessels and the transmission of safety-related data. However, the general introduction of the system has applications other than navigation. Data collection allows statistical and mathematical analysis based on historical data collected by the system, followed by interpretation to improve maritime safety and reduce collision risk [2] [3] [4] [5], to develop models to characterise vessel behaviour as a function of fairway width [6], or models to characterise traffic flow and estimate correlations between vessel speeds and traffic volumes [7]. In this paper, historical AIS data from the Gdansk Bay were used.

However, there is no model that links ship speed to the parameters that affect it the most. It is a specific system based largely on randomness and many variables (hydrometeorological conditions at the time of the manoeuvre, experience of the crew, length and breadth of the ship) that have a direct influence on the speeds achieved. To account for this problem, probabilistic causal models were used in this study. The conclusions obtained can be used as an element to improve and support the work of the Vessel Traffic Service (VTS) in the Bay of Gdansk.

Maritime traffic, due to its complexity, is subject to many factors that determine the parameter under study. The use of mathematical models allows transparent analysis of the probabilities of various events depending on the given scenarios. They have also been widely used in maritime transport, for example, to develop the speed of a ship moving in ice [8], the probability of ship collisions depending on the most influential variables [9], as well as the weather route of sailing ships with monitoring and avoidance of collisions [10] or the evaluation of the risk of oil pollution by a tanker due to a collision [11]. Several attempts have also been made in the past to empirically relate the manoeuvrability in port based on observations of a ship model [12] [13], to develop an empirical ship domain model and determine the safety distance considering the acceleration and deceleration of ships based on data from AIS [14], or to make a semi-empirical assessment of the speed loss of a ship after leaving port to the open sea [15]. A normal distribution was also used to model the correlation between ship speed and traffic volume [7].

The paper is organised as follows: Section 2 presents the applied method and the selected models, describes the numerical properties, the data tools and their processing; Section 3 presents the developed probabilistic models; Section 4 consists of the analysis of the models with discussion and validation of them. Section 5 concludes the paper.

2. METHODS AND DATA

2.1. Modelling framework

The aim of this work is to develop a probabilistic model of ship speed in a confined water body based on machine learning algorithms, taking into account factors such as ship type, length, course, position and hydrometeorological conditions based on real data for the Bay of Gdańsk. For this reason, a graphical analysis of ship movements was first performed using data visualisation. Then, the modelling of speed as a function of variables was performed based on a dataset from the AIS system. The developed model allows to answer the questions about the influence of the analysed variables on the ship speeds in Gdańsk, what are the individual conditional probabilities affecting predefined speed intervals, how much the individual variables influence the speed value, which of the analysed variables has the greatest influence on the speed and to predict which algorithm is the most effective.

2.2. Modelling approach

Machine learning algorithms based on Bayesian networks were used to develop the models. Bayesian networks belong to the group of probabilistic causal models, in which both the variables and the relationships between them are described by probabilities and probability distributions, preserving the causality of the analysed phenomenon.

There are two approaches to mathematical modelling by learning Bayesian networks. The first is based on unsupervised determination of the joint probability distribution of attributes in the network and then selecting the one that best fits the implemented data.

A second approach to network learning is to ignore (in the initial phase) the dependencies between nodes. Using statistical analysis (e.g. chi-square test, mutual information test), mutual independence between selected nodes can be assumed. This type of assumption is made a priori, and it is then possible, but not necessary, to estimate a parameter for the models that determines the consistency of the assumption *a posteriori* using the maximum likelihood method [16].

In this paper we used three algorithms - two belonging to the first group (Bayesian Search and PC algorithm) and one belonging to the second group (Naive Bayes). All models allow forward reasoning and backward reasoning. Forward reasoning provides information about the probability that a key variable, i.e. ship speed (the explained variable), depends on the selected parameters of the other explanatory variables. In a model that uses backward reasoning, selecting a desired interval for the explanatory variable gives the probabilities of each value for the other nodes in the graph.

2.3. Conditional Probability Tables

The graphs tell us a lot about the structure of the probabilistic domain. To get a better insight into the numerical properties, the Conditional Probability Tables (CPT) can be helpful. They show all conditional probabilities for all possible combinations of states of the "parent" node variables. For the Naive Bayes classifier (variable has no parents, Figure 3), CPT reduces to an unconditional probability, also known as the *a priori* probability of this variable, derived only from the information extracted from the data.

For the other two algorithms analyzed in this paper, the resulting tables are more complicated. This is because the node of ship speed consists of six variables. Each variable has multiple intervals of discretized data. The larger the number of intervals of a given variable, the more conditional probabilities there are and the more extensive the matrix is. In the case under study, there are only two intervals for the "course in/out". This results in 4 (2^2) conditional probabilities. In contrast, there are already 25 (5^2) for the "ship type". Based on the relationships between each variable observed through learning, the probability for each scenario is determined. From Table 1, exemplary individual probabilities for the occurrence of a certain scenario can be derived, which the algorithm has calculated on the basis of the training data. The total size of CPT depends on the number of "parents", the number of their states, and the number of states of the variables to be analysed. Therefore, the number of cells of the CPT matrix containing information about the probability of a certain ship speed in the port of Gdańsk corresponds to 2430 scenarios.

Table 1 Part of the CPT table determined by the Bayesian Search algorithm.

Length	More than 150 m					
Ship type	General Cargo Ship					
Wind speed	4-6 Beaufort scale					
Sector	B					
Course in/out	Inbound			Outbound		
Wind side	Bow wind	Side wind	Stern wind	Bow wind	Side wind	Stern wind
Speed below 7 kn	0.0444	0.6430	0.0145	0.3333	0.1524	0.4477
Speed between 7 and 11 kn	0.9444	0.3553	0.6232	0.3333	0.4857	0.5087
Speed above 11 kn	0.0111	0.0016	0.3623	0.3333	0.3619	0.0436

2.4. Input data processing

2.4.1 Data acquisition

The models presented in this paper were developed based on a data set from the AIS receiver in the port of Gdańsk for a period of 35 days. The hydrometeorological data, on the other hand, were obtained from stations of the Ship Safety Information Exchange System, entered by the officials of the ports of Gdynia and Gdańsk.

The first step was to decode the messages recorded by the AIS receiver (consisting of a series of "sentences" written in the code ASCII) from the NMEA 0183 communication protocol between electronic ship devices into comma-separated values (CSV) format. The collected data contained over 12.5 million unique records related to received messages.

The next step was to develop a method for graphical visualization of the recorded results to analyze the trajectory of vessel traffic. Due to the large amount of expected data, the source code was written in the "Python" programming language. The visualization was created using the modules "Datashader" and "Holoviews" based on the open source maps "http://openseamap.org" (Figure 1).

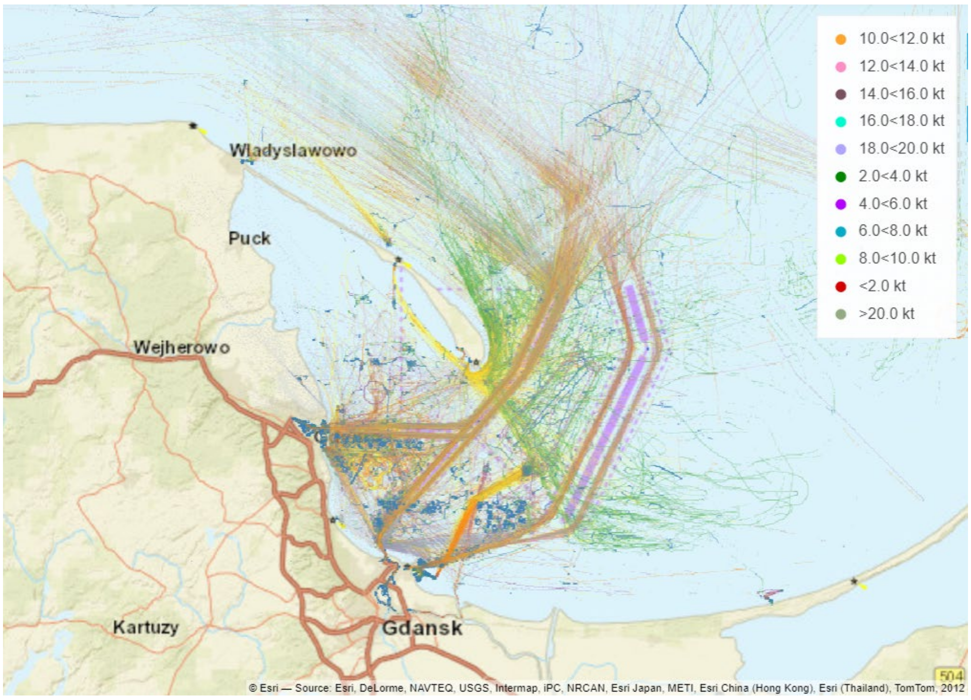


Figure 1 Visualization of data collected from the area of the Gulf of Gdańsk

2.4.2 Data filtration and selection

At this stage of the study, data were properly filtered:

- coordinates were changed from values measured in degrees, minutes, and seconds to decimal degrees;
- records containing test data with a Maritime Mobile Service Identity Number (MMSI) equal to 111111 were deleted;
- records containing no information about the vessel (no name, flag, type, etc.) were deleted;
- lines that contained speeds greater than 23 knots and less than 1 knot were deleted;
- the study area was limited to ships entering and leaving the "Nowy Port" through the Traffic Separation Scheme (TSS).

The speed selection was made because the AIS signal may also be transmitted by some aircraft, particularly those flying low over the ground and Maritime Search and Rescue (SAR) helicopters. The 23-knot limit was established based on typical speeds of ocean-going vessels entering port. On the other hand, speeds of less than 1 knot are typically sent by vessels at anchor, vessels moored in port, and fishing vessels.

Moreover, the analysis of the speed of ships approaching and leaving the "Port Północny" in Gdańsk (Deepwater Container Terminal, DCT) via the eastern TSS was also abandoned, as a considerable number of them are waiting at the anchorage to enter the port and the traffic in the above-mentioned port area is not as intense as in the case of the "Nowy Port". In the last stage, the data of ships that do not enter and do not leave the "Nowy Port" in Gdańsk via TSS were removed (Figure 2).

The analyzed area was divided into three sectors - A, B and C (Figure 2). The subdivision was introduced due to the variety of geographical positions from which the messages were received. Their number is so large that it is impossible to include each of them in the model. Therefore, in order to use the data, it was necessary to discretize them, i.e. to assign the ship coordinates to predefined sectors. The division into sectors was based on ship speed charts and port approach characteristics. Sector A covers an area from the beginning of TSS to the pilot station. Sector B includes a part of the route from the moment of pilot embarkation, through the turn of ships, to the level of the port heads of the port. At the level of the heads, the ships significantly reduce their speed. Therefore, sector C was defined for the last phase of the approach to the port. This sector also includes port manoeuvres performed by ships moored in the port.

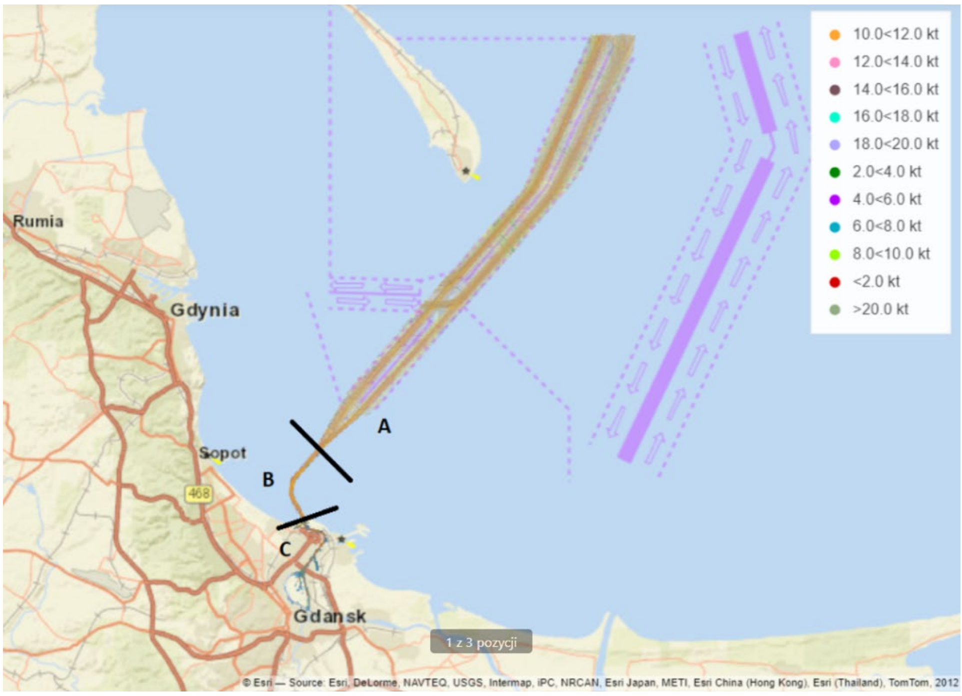


Figure 2 Visualization of data used for the study with the division of the basin into sectors

The final data set contains 834 851 unique messages received from 529 vessels (Table 2). They were classified into 5 groups according to their AIS signal identification.

Table 2 Division into types of ships and their number

Type of ship	Number of ships
General cargo	198
Other type	151
Bulk carrier	96
Container ship	54
Passenger/Ro-Ro Cargo ship	30
Total number	**529**

Other vessel types include bunker vessels, floating cranes, dredging vessels, inspection vessels, military vessels, pilot boats, pipe-laying vessels, research vessels, SAR vessels, tugboats, fishing vessels, sailing vessels, etc.

Tankers, on the other hand, are categorized as bulk carriers, as both carry types of bulk cargo, with the difference that tankers carry cargo in liquefied form. The shape and construction of their hulls, as well as the maneuvering characteristics and the speeds reached on each section, are similar, so they could be grouped in one category.

2.4.3. Input data discretization

In order to use the collected data for models, they also had to be discretized, i.e. continuous values converted into values within certain ranges. Currently, three methods of discretization are used. Uniform widths, in which the data are divided uniformly depending on the number of intervals chosen; uniform counts, in which the number of values in each of the discretization intervals is determined; and hierarchical, an unsupervised discretization method associated with clustering. However, there is also a manual discretization method that has been used in this work, since only this method meets the requirements and operational aspects of the analysed data.

The number of intervals for each of the values was determined based on the characteristics of a given variable and the importance of the defined ranges. The number of intervals is a compromise between the size of CPT, which increases significantly with increasing intervals, and the accuracy of the predictions of the developed models, as mentioned in Section 2.3. The tradeoff was achieved here through an iterative process. The intervals of the variables used in this work are listed in Table 3.

Table 3 Variable's intervals used in the model

Variable	Intervals		
Ship speed	From 1 to 7 knots	From 7 to 11 knots	From 11 to 23 knots
Ship length	From 0 to 50 m	From 50 m to 150 m	More than 150 m
Wind speed	From 0 to 4 Beaufort scale (light and moderate wind 0,0 m/s – 7,9 m/s)	From 4 to 6 Beaufort scale (strong wind 8,0 m/s – 13,8 m/s)	More than 6 in Beaufort scale (high wind/gale/storm; 13,9 m/s and more)
Wind direction	Side wind	Bow wind	Stern wind
Geographical coordinates	Sector A from north entrance to "TSS Zatoka Gdańska" to „NP" buoy (Figure 2)	Sector B from „NP" buoy to "Nowy Port" heads (Figure 2)	Sector C area of "Nowy Port" in Gdańsk (Figure 2)
Ship course	Inbound vessels – courses from 60° to 270°	Outbound vessels – courses from 270° to 000° and from 000° to 60°	

2.5. Models validation

To analyze the predictive power of the developed models, cross-validation was used. This is a statistical method used to estimate the probability of correct classification of the developed model. It consists in dividing the data set into subsets. One of them is a test set, which is used to check the learning results. The second set (called the training set) is verified. Trial uses a known test set against which the model is tested. The selected node against which the test is performed is not subject to changes resulting from the learning phases.

In this work, the "k-fold cross-validation" method was used. It is based on the assumption that the parameter "k" refers to the number of groups into which the data sample is to be divided. The scheme of the method is as follows:

1. division of the data set into k groups,
2. for each separate subset k:
   a) choosing k=1 group to be used as the test set,
   b) teaching the remaining k-1 groups,
3. evaluation of the model based on the average error in the subsets.

The number of iterations is usually 5 or 10, but there is no formal rule. It all depends on the size of the study set [17]. For the data set analyzed in this paper, the parameter k = 5 was assumed.

3. MODELS

Three different machine learning algorithms were used to develop the models. Two of them (Bayesian search and the PC algorithm) find connections between nodes based on the relationships found in the dataset during training. In the case of the third algorithm (Naive Bayes), the learning scheme does not search for mutual dependencies, but assumes that there are no mutual correlations between nodes.

The "GeNIe" software was used to develop the models and their subsequent evaluation. It has been field-tested since 1998, is widely used in both academia and industry, and has thousands of users worldwide.

3.1. Naive Bayes algorithm model

In a Naive Bayesian classifier, the dependencies between nodes are ignored. The structure of the model obtained in this way is shown in Figure 3. The model uses forward predictions. The information flow is in both directions. By specifying the intervals of interest for the variables (a bulk carrier between 50 and 150 meters long, in sector B, with a headwind between 4 and 6 knots), the user obtains the probability for the explained variable (speed). From the graph below it can be deduced that for the sample values set, the highest probability for the ship speed is between 7 and 11 knots (67%).

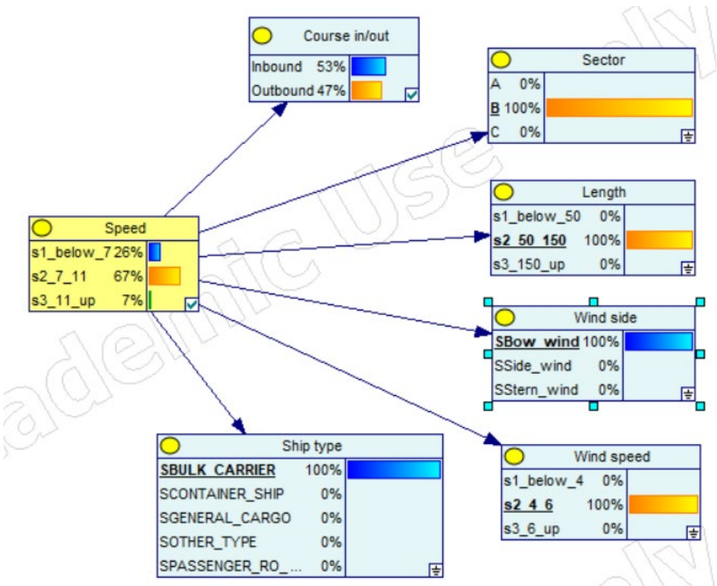


Figure 3 Forward prediction using a naive Bayesian classifier

3.2. Bayesian Search algorithm model

In the Bayesian search algorithm, the external knowledge was defined at the time when the user created the graph. Therefore, it can be seen from Figure 4 that the edges of each variable are connected to the "speed" node. This means that each of these variables affects the speed value to a greater or lesser extent. Figure 4 shows a forward prediction using the same sample values as the previous model. In this case, we get a 72% probability that the speed will be between 7 and 11 knots, 27% below 7 knots, and 1% above 11 knots.

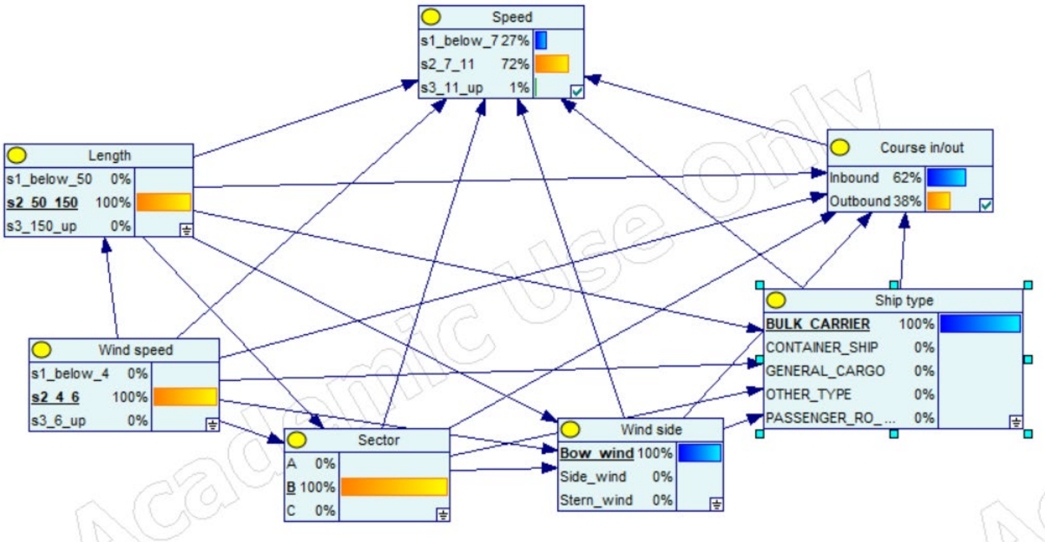


Figure 4 Forward prediction using the Bayesian Search algorithm

3.3. PC algorithm model

In this case, the algorithm finds relationships between variables but cannot determine the direction of their mutual correlation. As in the case of the Bayesian search algorithm, external knowledge was introduced, forcing connections between all variables and the "speed" node. The final diagram is shown in Figure 5. Connections that obviously had no correlations, e.g. wind speed-vessel length or wind direction-vessel type, were manually removed by the user. The parameters of the variables were adjusted in the same way as in the case of the previous two structures.

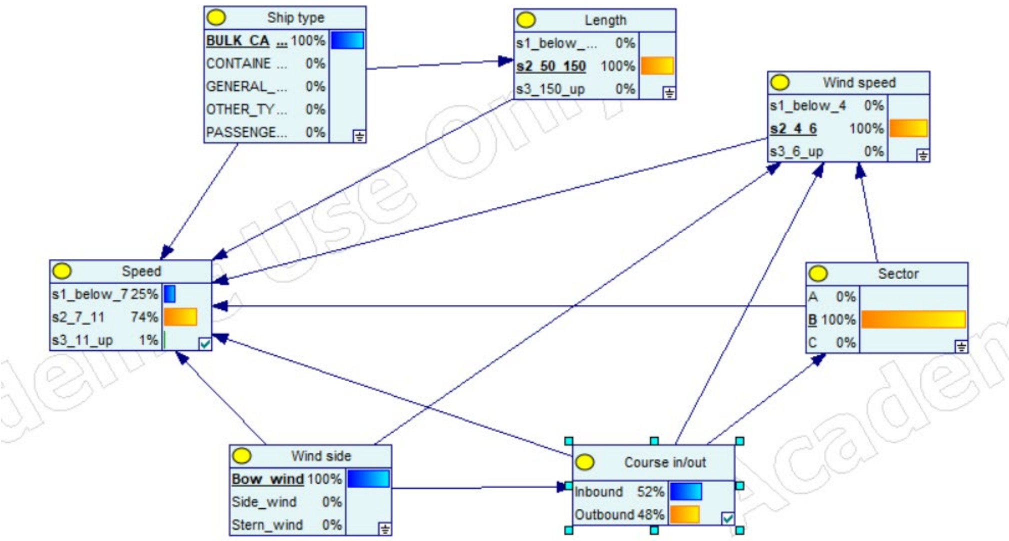


Figure 5 Forward prediction using the PC algorithm

Table 4 contains information on the probability of speed for the same parameters obtained by the three algorithms described above. The largest differences are observed in the speed group of 7-11 knots and above 11 knots. Therefore, the algorithm characterized by the highest prediction efficiency should be determined by validation.

Table 4 Comparison of speed probabilities under fixed conditions determined by algorithms

Speed interval	Ship's speed probability		
	Naive Bayes	Bayesian Search	PC
Belowe 7 knots	26%	27%	25%
7-11 knots	67%	72%	74%
Above 11,0 knots	7%	1%	1%

3.4. Speed probabilities for models under different conditions

The models described above can be used to analyze each possible scenario in such a way that they determine the probability of a given ship speed based on the given parameters. The following scenarios, which are completely different from those described in Table 4, are presented along with their corresponding probabilities in Table 5.

Table 5 Speed probabilities under different conditions determined by algorithms

Speed interval	Ship's speed probability		
	Naive Bayes	Bayesian Search	PC
Belowe 7 knots	92%	73%	39%
7-11 knots	6%	27%	58%
Above 11,0 knots	2%	0%	3%

1. For the Naive Bayes algorithm: passenger ship with a length of more than 150 m, crosswind below 4 Beaufort, in sector C;
2. For the Bayesian search algorithm: container ship with a length between 50 and 150 m, wind above 6 Beaufort, in sector B;
3. For the algorithm PC: other ship types with a length of less than 50 m, bow wind between 4 and 6 Beaufort, outbounding in sector A.

Many conclusions can be drawn from this type of analysis, such as the decrease of speed when approaching the port or the influence of wind direction and strength on the speed reached.

4. DISCUSSION AND VALIDATION

In the previous section, the construction and learning procedures of selected models were presented. In this section, the evaluation of each algorithm is presented considering the strength of influence of each variable and sensitivity analysis. A validation of the algorithms is also performed, which provides information about the accuracy of the prediction of each of them.

4.1. Analysis of the strength of influence of variables

The edges in Bayesian networks need not only represent the relationships between variables, as described in Section 3. They can also be used to represent the strength of influence between two connected nodes. It is a measure calculated from CPT that indicates how strong the influence of one variable is on another. In such an analysis, two connected discrete probability distributions are considered. The value tested can be expressed as an arithmetic mean, a weighted average, and a maximum value. The correlation measure ranges from 0 to 1, where 0 means the least influence (thinnest edge) and 1 means the greatest (thickest edge).

The strength of the influence of each variable is measured by the Euclidean distance, which is a symmetric measure and contains values from 0 to 1 [18].

4.1.1. Analysis of the strength of influence for Naive Bayes algorithm

Figure 6 shows a graphical interpretation of the relationships between the variables used in the analysis using the naive Bayesian classification algorithm. It shows that the pair "speed - sector" is the most important. To a lesser extent also "speed - length" and "speed - ship type". Other variables play only a minor role. The exact relationships between the variables are highlighted in Table 6.

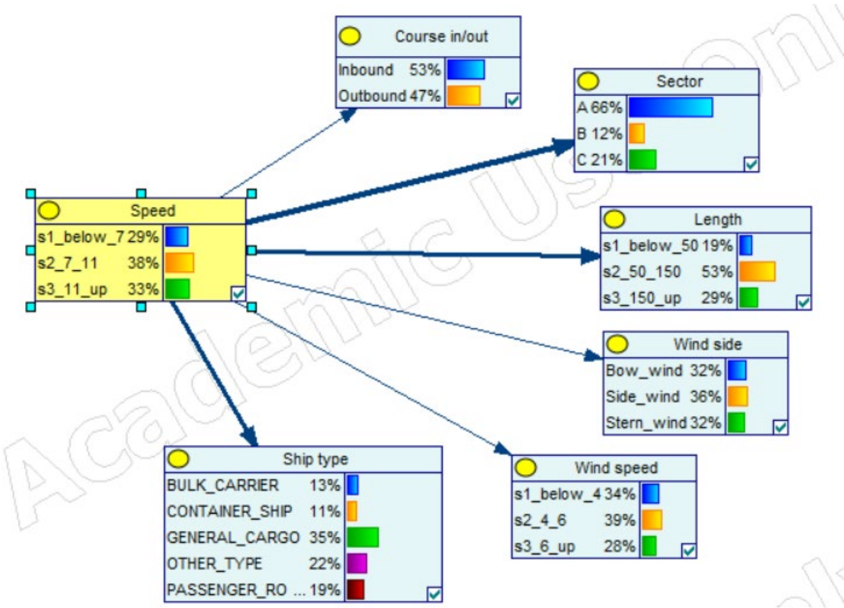


Figure 6 Graphical interpretation of the interrelationships among the variables – naive Bayesian classifier

Table 6 The strength of the influence of individual variables determined using the Euclidean distance based on the Naive Bayes algorithm

Parent node	Child node	Arithmetic average	Weighted average	Maximum value
Speed	Sector	0,46	0,46	0,67
Speed	Length	0,37	0,37	0,43
Speed	Ship type	0,34	0,34	0,45
Speed	Course in/out	0,05	0,05	0,08
Speed	Wind speed	0,02	0,02	0,04
Speed	Wind side	0,01	0,01	0,02

4.1.2. Analysis of the strength of influence for PC and Bayesian Search algorithms

The graphical analysis for the other two algorithms can be developed similarly. The differences concern the predefined connections between nodes, which are described in Section 3. In the case of the algorithm PC, where the user can assist the learning process by drawing on his own knowledge of connections, analysis of the strength of the influence between variables can help in the construction of subsequent algorithms. Identical connections have the same value. Their numerical properties with respect to the speed node are shown in Table 7.

Table 7 The strength of the influence of individual variables determined using the Euclidean distance based on the PC and Bayesian Search algorithms

Parent node	Child node	Arithmetic average	Weighted average	Maximum value
Sector	Speed	0,45	0,45	0,99
Length	Speed	0,34	0,34	0,99
Ship type	Speed	0,32	0,32	0,99
Course in/out	Speed	0,21	0,21	0,99
Wind speed	Speed	0,19	0,19	0,98
Wind side	Speed	0,09	0,09	0,24

From Table 6 and Table 7, it is also possible to draw conclusions about the strength of mutual influences between the speed variable and the other variables in two cases - when it is the parent node and the child node. The observations show that it has a much larger influence between the variables when it is a subordinate node (PC and Bayesian search algorithm). Only the direction of the wind is of negligible importance in this case.

4.2. Sensitivity analysis of variables

Sensitivity analysis evaluates the impact of variation in model parameters (usually expressed as percentage changes) on output parameters. Highly sensitive parameters have a greater impact on the modelling output. In other words, they determine the extent to which a change in one of the variables (given and conditional probability) affects the target parameter. Sensitivity measures the change in *a posteriori* probability when the value of one of the CPT columns changes.

4.2.1. Graphical interpretation of sensitive analysis

Example dependencies are shown graphically in Figure 7. It shows that the most sensitive parameter (intense red colour of the node), where even a small change has a significant impact on the velocity node, is the length and the sector. Similarly, a significant change in the heading in/out parameter (faded red - bright pink) does not noticeably affect the speed.

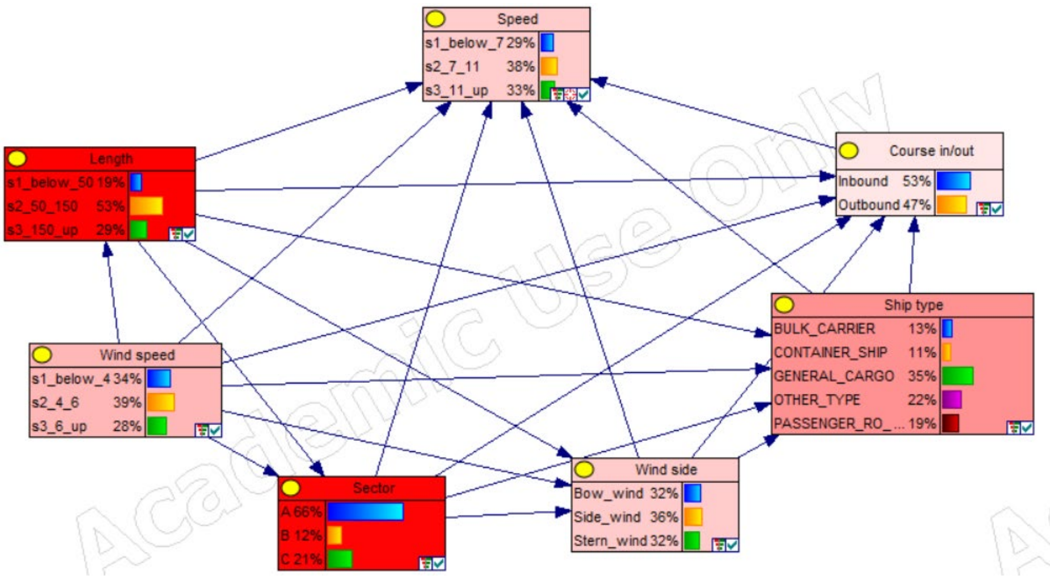


Figure 7 Graphical interpretation of sensitivity analysis – Bayesian Search algorithm

In the case of the PC algorithm analysis, the pictorial interpretation is different. This is due to the structure of the network connection. It can be observed that the change of ship type and sector parameters has the biggest impact on the speed node. However, similar to the example above, the change in heading parameters is the least important (Figure 8).

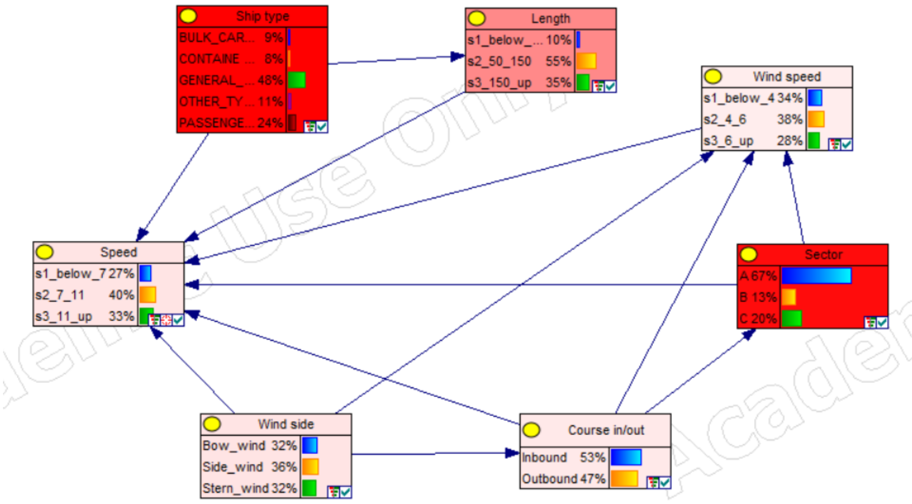


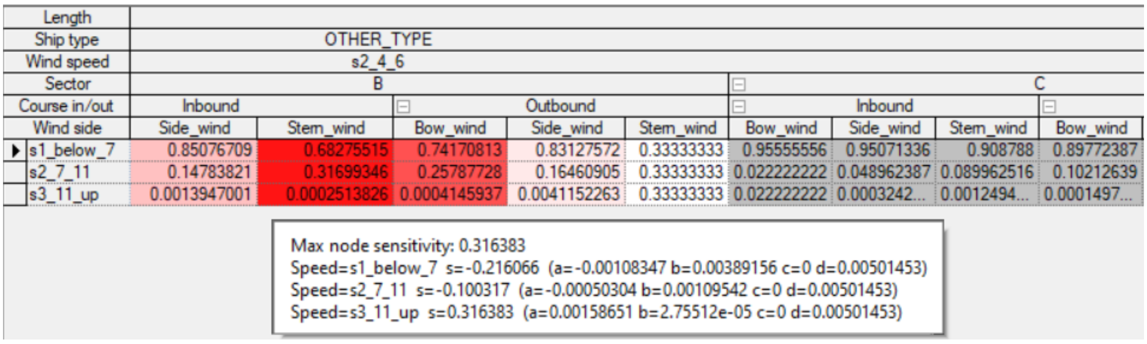
Figure 8 Graphical interpretation of sensitivity analysis – PC algorithm

For a Naive Bayesian classification model, sensitivity analysis of variables is impractical because all attributes are independent. The Speed node is the source node (Figure 3), which means that the other variables do not contain parameters that are used to compute the posterior probability distributions with respect to that variable. Therefore, the sensitivity of each of these parameters is zero.

4.2.2. Sensitive analysis figures

In addition to graphical interpretation, numerical data on compounds are also analyzed. Sensitivity details are presented in the form of a CPT based dialog box. Since there are many variables associated with the velocity node and the total number of possible scenarios is 2430, individual parameter changes are of little importance and therefore of low sensitivity. The largest sensitivity of s = 0.02 for all possible cases related to the speed node is characterized by a change for a general cargo vessel between 50 and 150 m in length entering the port in sector A, with an aft wind below 4 on the Beaufort scale.

When narrowing down the analyzed case to, for example, a ship of a different type in sector B with a length greater than 150 m, the following results were obtained. They show that for the parameters shown in Figure 9, the greatest sensitivity will be characterized by a change in wind between 4 and 6 on the Beaufort scale, incoming course, wind from astern for the speed interval above 11 knots (s = 0, 32). For ship speed between 7 and 11 knots, the sensitivity is s = 0.10, while for speeds below 7 knots it is s = 0.22. The other indices a, b, c, and d are the coefficients of the derivative. A similar analysis can be performed for each scenario and also for the general form of the algorithm (without specific assumptions).



Length										
Ship type	OTHER_TYPE									
Wind speed	s2_4_6									
Sector	B					C				
Course in/out	Inbound		Outbound			Inbound				
Wind side	Side_wind	Stern_wind	Bow_wind	Side_wind	Stern_wind	Bow_wind	Side_wind	Stern_wind	Bow_wind
s1_below_7	0.85076709	0.68275515	0.74170813	0.83127572	0.33333333	0.95555556	0.95071336	0.908788	0.89772387
s2_7_11	0.14783821	0.31699346	0.25787728	0.16460905	0.33333333	0.022222222	0.048962387	0.089962516	0.10212639
s3_11_up	0.0013947001	0.0002513826	0.0004145937	0.0041152263	0.33333333	0.022222222	0.0003242...	0.0012494...	0.0001497...

Max node sensitivity: 0.316383
Speed=s1_below_7 s=-0.216066 (a=-0.00108347 b=0.00389156 c=0 d=0.00501453)
Speed=s2_7_11 s=-0.100317 (a=-0.00050304 b=0.00109542 c=0 d=0.00501453)
Speed=s3_11_up s=0.316383 (a=0.00158651 b=2.75512e-05 c=0 d=0.00501453)

Figure 9 Numerical sensitivity analysis of variables

4.3. Validation of algorithms

4.3.1. Validation for Naive Bayes algorithm

The results of the validation for the speed of ships manoeuvring in the port of Gdańsk using the Naive Bayes Classifier algorithm are presented in Table 8. They show that the lowest accuracy occurs for the speed interval below 7 knots, with the developed model assigning 31% of the speed to other intervals (or 26% to the interval from 7-11 kn and 5% to the interval above 11 kn).

Table 8 Validation of the "Speed" variable prediction for the Naive Bayes algorithm

		Model prediciton		
Data		Speed below 7 knots	Speed between 7 and 11 knots	Speed above 11 knots
	Speed below 7 knots	**69%**	26%	5%
	Speed between 7 and 11 knots	12%	**78%**	10%
	Speed above 11 knots	0%	25%	**75%**
Total prediction accuracy			74%	

For the other speed intervals, the probability of correct assignment of the parameter is 78% and 75% for the intervals from 7-11 knots and above 11 knots, respectively. It should be remembered that the analyzed models were developed based on data from a little more than one month of observation. A higher predictive power of the model can be expected if a data set covering a longer time horizon is used.

4.3.2. Validation for PC and Bayesian Search algorithms

Table 9 shows the validation results for algorithms that use a scoring function (i.e. PC and Bayesian Search Algorithm). For both algorithms, the values included in the validation matrix are similar, so only one table is presented. The use of this classifier in the training process results in an overall precision of 77%. For all speed intervals, the prediction accuracy of the model using the classifier is higher than Naive Bayes. The largest change is observed for the lowest speed interval (74%), where the value is 5% higher than for the NB classifier. Training the network using the scoring function gives better results in terms of speed prediction accuracy than without *a priori* independence.

Table 9 Validation of the "Speed" variable prediction for the PC and Bayesian Search algorithm

		Model prediction		
Data		Speed below 7 knots	Speed between 7 and 11 knots	Speed above 11 knots
	Speed below 7 knots	**74%**	22%	4%
	Speed between 7 and 11 knots	13%	**79%**	8%
	Speed above 11 knots	1%	23%	**76%**
Total prediction accuracy			77%	

5. CONCLUSION

In this work, probabilistic models of ship speed in a confined water area were developed, taking into account factors such as the type and length of the ship, the direction of motion of the ship, the sector of the water area, and hydrometeorological conditions such as wind direction and strength. This was done based on real data for the Bay of Gdańsk and machine learning algorithms. The paper presents three mathematical probabilistic models using Bayesian networks.

Probability distributions of ship speed while manoeuvring in the Bay of Gdansk and directly in the harbour were determined, as well as the relationship between the speed and the registered explanatory variables. In addition, the individual conditional probabilities affecting the predefined speed intervals were determined and the influence of each variable on the speed value and the sensitivity of the models were analyzed. Validation was also performed and the accuracy of the models was estimated.

The models presented in the paper allow the analysis of the speed of ships as a function of the variables based on real historical data. By using Bayesian modelling, you can answer the questions of how the ship behaves under certain conditions and what conditions cause the ship's behaviour.

Cross-validation was used to analyze the effectiveness of the algorithms. The models using the scoring function were the most effective. Therefore, they seem to be a better tool for analyzing the speed of ships.

The research conducted and its detailed analysis may be useful for decision support systems in shipping. Information on exceeding the average speed in a given geographic sector by a given type of vessel may provide some warning to VTS operators as well as to users of maritime vessels entering ports. Such information may influence the decision to change the speed of an ocean-going vessel entering the destination port. Extending the models to include additional parameters such as the relationship between the vessel's draft and water depth, the direction of the current, increasing the frequency of the implemented wind data, or discretizing the data into a larger number of intervals would allow improving the accuracy of the models' predictions.

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RISK OF FOOD POISONING ON SHIPS AND PREVENTIVE MEASURES

Rosanda Mulić
University of Split, School of Medicine
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: rosanda@pfst.hr

Pero Vidan
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: pero.vidan@pfst.hr

Stipe Pupić-Vurilj
Faculty of Maritime Studies, University of Split
Split, Croatia

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Abstract

A good and healthy life requires access to safe and quality food. Consuming unsanitary water or food can lead to food poisoning. Water is considered food in this context and should be healthy. Food poisoning can be caused by various biological or chemical agents and can be prevented by proper food production, handling, storage and preparation. Food poisoning can be caused by different types of microrganismus, especially noroviruses, which have recently become more common. The paper presents the clinical picture of food poisoning, the symptoms of illness and the procedures to be followed on board, as well as all the measures to be taken to ensure the safety of food and water on board and to eliminate or minimize the risk of illness. From an epidemiological point of view, ships are closed or semi-closed environments, depending on the type of ship, which pose a high risk for the possible outbreak of various epidemics. Although the food transportation and production chain is complex and subject to strict control, the preventive measures on board regarding food supply can be defined as follows: Procurement of safe food from reliable suppliers, transportation to the ship, loading, storage, preparation and serving. Food poisoning on cruise ships can be a major problem, which is why international recommendations have been developed and accepted for the safety and monitoring of food handling, especially on cruise ships. In compliance with all standards, regulations and guidelines, food and water should be healthy for consumption when provided both ashore and on board.

Keywords: food safety, food poisoning, ship, preventive measures

1. INTRODUCTION

Food, like any substance or product, may be processed, partially processed or unprocessed. It is intended for consumption or can reasonably be expected to be consumed by people. Access to safe and nutritious food is crucial for a quality and healthy life of an individual. According to the World Health Organization, every year 600 million people, or nearly 1 person out of 10 in the world, fall ill after consuming contaminated food, whereas the consequences are fatal for approximately 420,000 people. Food can be contaminated with various bacteria, viruses, parasites or chemical substances. The consequences can vary from mild to severe [2,7].

Given the global importance of food, the World Health Organization (WHO) seeks to respond to threats to public health caused by contaminated food by [7]:

- providing independent scientific assessments of food safety hazards;
- collaborating with different organizations in establishing international food standards, guidelines and recommendations;
- assessing the safety of new technologies in the food industry;
- assisting in the implementation of appropriate infrastructures for food safety risk management;
- advocating the integration of food safety into national policies and programs in accordance with international health regulations;
- promoting systematic disease prevention and awareness programs on the importance of foodborne disease prevention;
- monitoring the global burden of foodborne diseases at national, regional and international levels;
- updating the WHO Global Strategy for Food Safety 2022-2030.

Following numerous provisions, guidelines and recommendations, food and water safety must also be ensured on ships. Healthy food and water are important for both crew members and passengers. The goal of every traveller is a successful and pleasant trip, with as little risk as possible of contracting infectious diseases, most often gastrointestinal. Depending on "who, where, when and how they travel and how long the travel lasts", the travellers should be given complete and high-quality information and advice on the causes, symptoms and treatment options for diseases during their travel. The most important protection measures for passengers consist in the careful selection of food that must be well thermally processed, i.e. the consumption of healthy drinking water [15,18].

The aim of this study is to present the causes of food and water poisoning, the clinical picture and possible treatment on board, and the measures that should be implemented to ensure the safety of food and water on board, and to eliminate or reduce the risk of illness to a minimum.

2. CAUSES AND CLINICAL PICTURES OF FOOD POISONING

2.1. Food Poisoning Caused by Bacteria

2.1.1. Salmonellosis

Salmonella bacteria represent one of the frequent causes of epidemic diarrhoea. Their survival depends on the environment they are in, so their life span ranges from a few hours on various objects in the external environment to several months in ice and frozen ground. The main natural reservoirs of salmonella are poultry and pigs, followed by rodents, ruminants and carnivores, domestic and wild animals and humans. Accordingly, the riskiest foods are eggs and chicken meat [30].

Foodstuffs can be primarily, intravitally contaminated (animal foods) or secondarily contaminated (mice, rats, contaminated work surfaces, human germ carrier or sick person). The incubation time is 8 to 24 hours. Symptoms of the disease are acute abdominal pain, nausea, diarrhoea, vomiting, elevated body temperature and general weakness. They can last several days, sometimes longer, with the need for hospital treatment [34].

2.1.2. Campylobacter infection

Campylobacteriosis is an important cause of human disease around the world, and research into the sources of infection and risk factors revealed that insufficiently thermally processed chicken meat is the most common cause of the infection. It can also be found in sheep, cattle, pigs, reptiles, seafood, water and fresh milk [3,16, 34]. The spread of infection from person to person is not common.

Incubation usually lasts 2 to 5 days. Symptoms of the disease include elevated body temperature, abdominal pain, diarrhoea, sometimes bloody, in addition to vomiting and general weakness. Proper heat treatment of food kills any pathogens that may be present.

Rehydration is one of the fundamental principles of treatment.

2.1.3. Staphylococcal food poisoning

Staphylococcus aureus, also called *golden staph,* is a gram-positive bacterium and an important pathogen in microbiology due to its resistance. In some people, it is a normal inhabitant of the nasal mucosa, pharynx and open skin wounds. People who are germ carriers, when preparing food, can cause contamination of food and the multiplication of bacteria in food, as well as the creation of toxins resistant to heat treatment. Poisoning often occurs when eating ice cream, cream cakes and meat products [18,35,37].

Incubation is short, only 30 minutes to 6 hours. Typical symptoms of food poisoning caused by *Staphylococcus aureus* are abdominal pain and cramps, diarrhoea and vomiting, usually not lasting more than 1 day [25,37].

Rehydration is required but there is no need for antibiotic treatment.

2.1.4. Food poisoning caused by Escherichia coli

Escherichia coli is a bacterium that is a common inhabitant of the intestines of humans and animals, the environment and food. These are non-pathogenic strains. However, there are also five pathogenic groups that cause gastroenteritis [5,35]:

a) Enterotoxigenic *Escherichia coli* (ETEC)
b) Enteroaggregative *Escherichia coli* (EagEC / EAEC)
c) Enteropathogenic *Escherichia coli* (EPEC)
d) Enterohaemorrhagic *Escherichia coli* (EHEC)
e) Enteroinvasive *Escherichia coli* (EIEC)

Each of these *Escherichiae* has its own epidemiological characteristics, a relatively typical clinical picture of the disease and the age group of people who most often get sick. Diarrhoea dominates the clinical picture of patients [35].

Rehydration is preferred on board. Treatment with antibiotics is considered for severe clinical symptoms that usually develop in immunocompromised persons, but in this case, hospitalization is required.

2.1.5. Food poisoning caused by *Clostridium perfringens*

Clostridium perfringens is one of the more common causes of food poisoning. It is found in raw meat, in the intestines of animals and in the environment. The growth and reproduction of this pathogen is favoured when food is stored at inappropriate temperatures. Contaminated food typically includes meat dishes [28].

Symptoms begin 6 to 24 hours after contact, start suddenly and last less than 24 hours. Patients have diarrhoea and stomach cramps [29].

Rehydration of patients is recommended.

In addition to the above, there are other microorganisms that can cause food poisoning, such as *Bacillus cereus*, *Lysteria monocytogenes*, *Yesinia enterocolitica*, *Clostridium botulinum*, *Shigella spp*, *Vibrio spp* and others. However, for an accurate microbiological diagnosis, a microbiological examination of the stool is required [30].

2.2. Food Poisoning Caused by Viruses

2.2.1. Norovirus

The route of transmission is most often through contaminated food, from person to person, and less often through contaminated water. Risky places that can lead to an epidemic are places where ready-made food is served to a large number of people, especially when it comes to closed environments such as ships, homes, hospitals, etc. Noroviruses are relatively resistant to chlorine and heat, which makes it possible for infection to spread through contaminated water from the public water supply, depending on the concentration of chlorine in the tap water. Even thermal processing of food cannot completely eliminate the risk of infection [19, 35].

Incubation is short and lasts 1 to 2 days, and symptoms of the disease appear suddenly and include acute onset of nausea and stomach pain, vomiting (more common in children) and watery diarrhoea (more common in adults). The virus is excreted in the stool 24 to 48 hours after infection, but it can also be transmitted by aerosol from vomited mass [19].

Epidemics caused by norovirus on cruise ships are particularly dangerous due to the large agglomeration of people, short incubation period and high infectivity. After clinical recovery, asymptomatic germs may remain, which means that the person is still a source of infection.

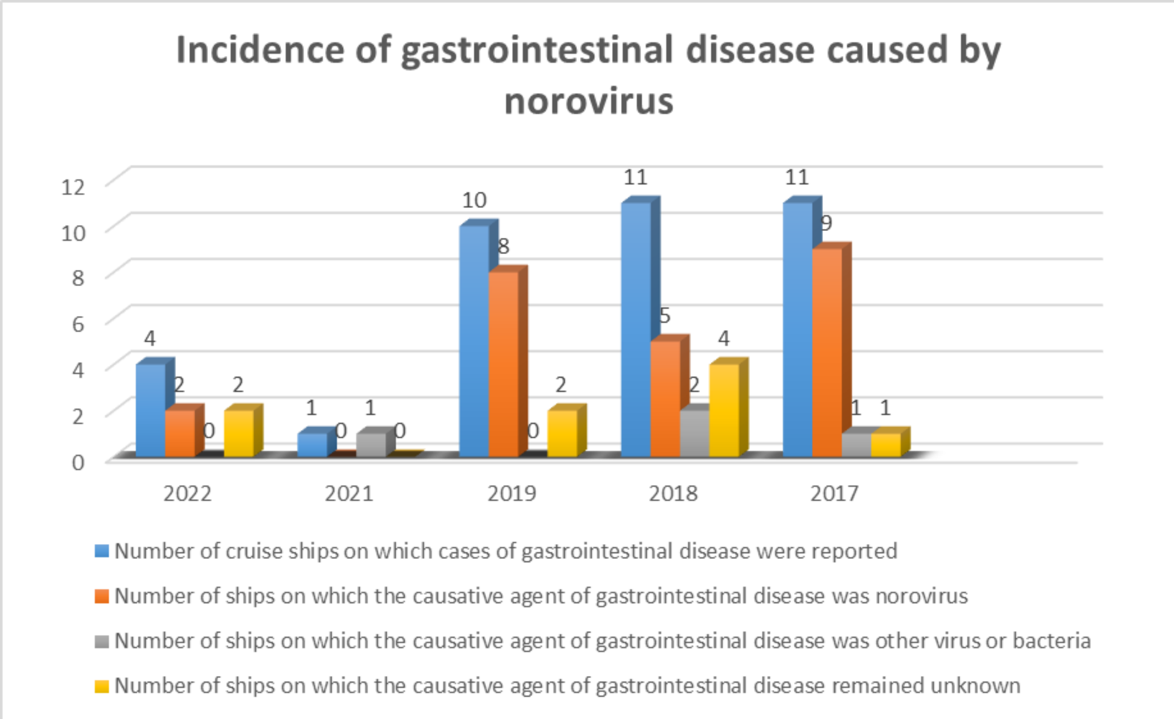
Noroviruses can be the cause of epidemic diarrhoea on cruise ships. According to publicly available data from the US Centers for Disease Control and Prevention (CDC), noroviruses were the most common and most important cause of gastrointestinal diseases on cruise ships in the period from 2017 to 2022 [23] – Table 1.

Table 1 Incidence of gastrointestinal illness caused by norovirus on cruise ships

Year	Number of cruise ships on which cases of gastrointestinal disease were reported	Number of ships on which the causative agent of gastrointestinal disease was norovirus	Number of ships on which the causative agent of gastrointestinal disease was other virus or bacteria	Number of ships on which the causative agent of gastrointestinal disease remained unknown
2022	4	2	/	2
2021	1	/	1	/
2019	10	8	/	2
2018	11	5	2	4
2017	11	9	1	1
TOTAL	37	24	4	9

Source: [23]

According to Table 1, it is obvious that the most common causes of epidemic occurrence of gastrointestinal troubles on cruise ships in the period 2017-2022 were noroviruses (24/37; 64.86%), as presented in Graph 1.



Graph 1 Comparison of the incidence of gastrointestinal diseases caused by norovirus and other pathogens, with regard to the total number of reported gastrointestinal diseases

Source: [23]

2.2.2. Rotaviruses, adenoviruses and astroviruses

These are viruses that mainly infect children, so they are not of great importance on ships. Rotavirus is resistant to washing, but chlorine inactivates it. Infections caused by rotavirus are more common in winter, while infections caused by adenoviruses are more common in summer. Symptoms range from mild watery diarrhoea to severe nausea, vomiting and fever [35].

The basic principle of therapy is rehydration.

2.3. Food Poisoning Caused by Parasites

Parasites are tiny organisms, some visible to the naked eye, which develop in several stages: egg/cyst, larva and adult form. Each of the individual development stages represents a danger [15].

Entamoeba hystolitica and *Trichinella spiralis* are relevant food-borne parasites in our geographical area.

The parasite that is systematically controlled in our food by the prescribed method is *Trichinella spp*. Trichinosis occurs when infested pork meat is insufficiently thermally processed. Most infections are mild and asymptomatic, but they can also be severe, even lethal. Symptoms include abdominal pain, diarrhoea and vomiting, and 1-2 weeks later fever, swelling of the eyelids, muscle pain and myocarditis. Cooking meat above 55°C kills encysted larvae and prevents trichinosis [36]. A developed clinical picture of the disease requires hospital treatment.

Entamoeba hystolitica is a parasite that attacks the colon. Colon infection with this parasite can result in disease of varying severity, ranging from mild, chronic diarrhoea to severe diarrhoea accompanied by the appearance of blood in the stool. The infection can also be asymptomatic. An extraintestinal infection (e.g. liver abscess) can also occur.

This infestation cannot be treated on board. Suspicion of this infestation requires an examination by a specialist doctor and possible hospital treatment.

2.4. Fish and Shellfish Poisoning

Poisonings after consumption of fish and shellfish are accompanied by gastrointestinal, neurological or histamine-induced symptoms. Poisons in shellfish meat are usually deposited by filtration, and in fish meat by consumption of poisonous dinoflagellates in the body of the smallest fish, at the beginning of the predatory chain.

Ciguatera poisoning is caused by the consumption of fish in coastal Central America, the West Indies and the Pacific, where dinoflagellates produce a toxin that accumulates in the flesh of the fish. In older and larger fish, the amount of poison is greater. Special preparation or heat treatment of fish does not reduce or eliminate the risk of poisoning, there are no external signs that could lead to suspicion that the fish is poisonous. Symptoms appear 2 to 8 hours after consumption. Abdominal cramps, nausea, vomiting and diarrhoea last 6-17 hours, followed by itching, tingling in the limbs, muscle pain, headache, feeling of alternating heat and cold. Months after poisoning, people may still feel unusual sensory phenomena and nervousness. There is no commercial test for the detection of ciguatoxin in fish [13,14,21].

Skombrotoxicism is poisoning by fish that has not been stored properly (freezing-thawing-freezing), and is caused by the breakdown of histidine in fish meat into histamine, which is the mediator of an allergic reaction.

The most common types of fish that cause poisoning are tuna, mackerel, bonito, i.e. mostly blue fish, but white fish can also be poisoning. Proper storage of fish after catching can prevent poisoning. Antihistamines and H_2 receptor blockers are used in the treatment [2,32].

Tetrodotoxin poisoning most often occurs due to the consumption of raw pufferfish (four-toothed fish), and there are more than 100 types of freshwater and marine fish that contain tetrodotoxin. The symptoms are similar to those of ciguatera fish poisoning, the outcome can be death. The poison cannot be destroyed by freezing and/or cooking [21].

Suspicion of these poisonings requires an examination by a specialist doctor and possible hospital treatment.

2.5. Metal Poisoning

Metal poisoning is a consequence of environmental pollution because heavy metals can be found everywhere. Cadmium, arsenic, mercury and lead are metals that circulate in the Earth's biosphere. To a large extent, human activities influence the concentration of metals in the atmosphere. The main sources of metals that are the biggest polluters of the environment are industrial production, metal processing, roads and vehicles, paint and battery production. When fossil fuels are burned, they pollute the atmosphere with particles of heavy metals that then settle and pollute water, soil, plants and fish. That is why they can be found in the food chain, plant and animal foods. Heavy metals have various toxic effects on all human tissues, as well as on the reproductive system [31].

These are usually chronic poisonings caused by long-term exposure to small doses of poison. Diagnostics and therapy are the responsibility of specialist doctors.

3. PREVENTION OF FOOD POISONING – PREVENTIVE MEASURES

Preventive measures are complex and differ somewhat vary according to the facilities to which they apply. Larger facilities, such as cruise ships on international voyages, require very strict and complex preventive measures [20].

All kitchen staff should be educated on the procedures for proper storage, handling and preservation of food, as well as procedures for cleaning and disinfecting kitchen utensils and dishes, and respecting the principle of "not crossing clean and unclean paths" [11,22,28]. As food poisoning is of public health importance at the global level, most countries have adopted the Hazard Analysis Critical Control Point (HACCP) management system which analyses possible critical points in detail and specifies preventive measures [6,7,8,24,26,27].

After detecting a norovirus infection, all food that could be contaminated should be thrown away, while kitchen utensils, work surfaces and all other surfaces should be thoroughly washed and disinfected, clothes and bedding that could be contaminated should be washed and personal hygiene should be maintained properly. Even 2 weeks after recovery, people who handle food should not work in a workplace that involves food preparation [16, 18]. After recovering from salmonellosis food poisoning, the so-called "healthy germs" are present up to a month after recovery, so these people should also avoid returning to work during that period, if they work as food handlers. These are just some of the facts. The food and water monitoring system both on land and at sea is very complex [6,7,17].

On merchant ships, the captain or the second deck officer is usually in charge of kitchen supervision, but the current education system does not allow them to acquire all the necessary knowledge and skills.

On cruise ships, companies are aware of the danger and possible legal proceedings. Therefore, they organise a very strict monitoring system and have specially trained and engaged personnel for these purposes [23,33].

Military ships, depending on the arrangement and size of the crew and the flag they fly, have their own, specially organized surveillance systems and procedures.

Data on contributing factors to outbreaks are critical to outbreak prevention, and environmental assessments identify contributing factors- Figure 1.

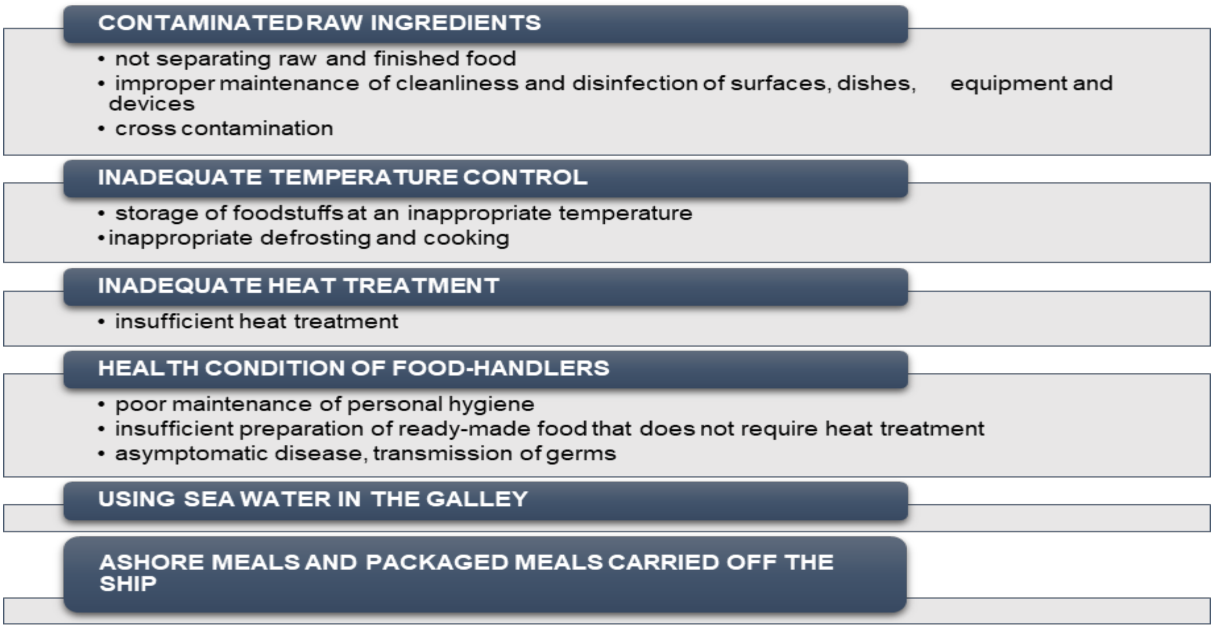


Figure 1 Factors affecting the outbreak and spread of food poisoning epidemics on board

Source: [6]

In addition to the measures that will prevent the disease itself or the spread of the disease after contracting it, it is also important to know that the outbreak of an epidemic is influenced by various factors. On ships, be they cargo or passenger ships, there are people from different parts of the world, of different age, gender and immunobiological status. These factors may affect collective immunity, and given the environment in which they are, facilitate the spread of disease from one person to another. Travelers often visit different ports, and thus expose themselves to diseases present in the countries they visit [14,33].

3.1. Legal Provisions Related to Ensuring the Safety of Food and Water on Ships

International Health Regulations (2005), lists all internationally necessary measures for preventing the occurrence and spread of infectious diseases in international traffic [20].

The Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia lays down the Rules for the statutory certification of maritime ships, occupational safety and crew accommodation. The prescribed requirements are related to the protection at work and accommodation of the crew on the ships flying Croatian ensign and contain provisions in accordance with Standard A3.1, A3.2 and A4.3 of the Maritime Labour Convention adopted by the International Labour Organization (ILO) and Rule 3-12, Chapter II-1, of the SOLAS 74 Convention and the Code on Noise Levels on Ships adopted by Resolution MSC.337.

Annex III stipulates that the galley and pantry must be equipped with all the necessary devices and equipment for storing and preparing food, cooking and serving food, and washing and storing dishes and cutlery. Technical conditions that must be met are described in detail, as well as food handling procedures in order to preserve safety [26]. Annex IV stipulates that all ships must have sufficient quantities of water for drinking, sanitary needs, food preparation and washing dishes, and the quality of the water must meet recognized sanitary standards for drinking water. Potable and fresh water systems must be separated from other systems [17].

The Ministry of Tourism of the Republic of Croatia lays down the Rulebook on the provision of catering services in mobile facilities. Articles 10, 11 and 12 describe everything that is required for catering services, in compliance with the aforementioned provisions of the Ministry of the Sea, Transport and Infrastructure, including the provision of a seat for each guest and the wearing of prescribed work clothes and footwear by staff [28].

Ministry of Labour and Social Welfare of the Republic of Croatia, based on point III of the Decisions on publication of conventions of the International Labour Organization to which the Republic of Croatia is a party based on the succession notification ("Official Gazette - International Agreements" No. 2/94), publishes the Convention on certificates of competence for onboard cooks. No one can be employed as a ship's cook if he/she does not have a certificate of competence for performing the duties of a ship's cook. Exceptions may be approved in case of an insufficient number of certified cooks, given the needs [12].

3.2. International Food Safety Organisations

The World Health Organization (WHO) aims to improve food safety at the global and national levels, i.e. to prevent, detect and promptly respond to the dangers of food and water contamination. The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations whose goal is to achieve food safety and ensure access to sufficient quantities of high-quality food for all. FAO operates in more than 130 countries around the world. The Republic of Croatia became a member in 1993 [1].

In the 1960s, FAO and WHO recognized the importance of developing international standards to protect public health and contributing to safe and quality international food trade. Codex Alimentarius is a collection of standards, guidelines and codes adopted by the Codex Alimentarius Commission (CAC). The Commission is responsible for all matters concerning the implementation of the joint FAO/WHO food standards programme. It meets once a year alternately between Geneva and Rome. The Codex Alimentarius is intended to guide and promote the development and establishment of the definitions and requirements for food, as well as their harmonisation, in order to ensure food safety, consumer health and fair international trade. The Codex includes standards for processed, semi-processed and raw food, and for distribution to the consumer. It also contains provisions related to food hygiene, food additives, residues of pesticides and veterinary drugs, contaminants, labelling and presentation of food, sampling and methods of analysis, and import-export inspection and certification [4].

In 1993, the CAC adopted the "Guidelines for the application of the Hazard Analysis Critical Control Point system" or HACCP. HACCP is a system that recognizes, evaluates and controls chemical, physical and biological hazards that are significant for food safety. It is based on principles that aim to recognize hazards that may occur at any stage of the food supply chain, i.e. during preparation, production, processing, packaging, storage, transportation and distribution. In accordance with the principles and with the aim of ensuring hazard control, a HACCP plan is designed. In the preliminary steps, it is important to create a HACCP team with the appropriate knowledge and expertise to ensure the development of the most effective HACCP plan: describe products and storage conditions, as well as their purpose; create a flowchart of the production process and have it verified by the body involved in the food business. After creation, the HACCP plan is evaluated on an annual basis or when there are any changes in the conditions of preparation, storage, distribution within the facility and/or when there are repeated consumer complaints [26].

3.3. Food Safety Measures During the Supply of Food to the Ship

3.3.1. Food safety measures during delivery

Production, processing, distribution and storage of food are subject to strict rules and controls. Vehicles and/or containers used to transport food must be clean and maintained in good condition to protect food from contamination. The construction of the vehicle must enable easy cleaning and/or disinfection. The cargo space of the vehicle and the containers used for transporting food may be used exclusively for this purpose. When at the same time one vehicle is used to transport different food, the food must be effectively separated. Food transported as bulk goods, liquid, granules or powder must be transported in boxes intended only for holding food or containers intended only for transporting food. Containers must be visibly marked, the marking must not be able to be erased or removed and it must be clear that food is being transported, e.g. with the inscription "for food products only". During transport, the risk of food contamination must be minimized. Vehicles or containers for transporting food must also be able to keep food at the appropriate temperature, with the possibility of monitoring and controlling the temperature [23].

3.3.2. Food safety measures when loading on board

When the food transport vehicle arrives at the port, the responsible person must check the quality of the food that has arrived, before loading on board the ship. All food information must be available, correct and verifiable (supplier, dates, conditions, etc.). Food should not be accepted if it is close to the expiration date, if the packaging is damaged, if it has not been transported properly, or if it has not been transported at adequate temperature. The freshness of certain food can be recognized. In fresh fish, the eyes are clear and full, the gills are moist and red, and the skin is moist, the colours are characteristic of a certain species, and the fish smells fresh. The flesh of the fish should be firm, and when you press it with your finger, the indentation on the surface of the fish should disappear. A fresh fish sinks in the water and a rotten one floats [13].

Fresh meat has a characteristic appearance and smell. Any change in colour and smell is suspicious of spoilage [12]. The freshness of eggs can be checked by placing the eggs in cold water. A fresh egg will remain at the bottom while a rotten one will float on the surface [12].

Fresh fruits and vegetables differ in weight from older fruits and vegetables, they have a solid and constant shape, and the smell characteristic of certain fruits and vegetables, while the smell of fruits and vegetables that are already in the process of aging and rotting is unusual and different. Fresh mushrooms are very different from those that are not for consumption. Mushrooms that have dark spots on the cap or stem, have dried parts, a wrinkled cap and a sour smell are spoiled [12].

When unloading food, F.I.F.O. storage principle is used (first in - first out).

Frozen and chilled products are unloaded first [8, 10]. Refrigerated food with a temperature above 7°C should be refused. Products such as eggs (4°C), minced meat (2°C) and fresh fish (0-2°C) must be delivered at a certain temperature, which needs to be checked. The temperature of frozen products should be -18°C or less. Ice crystals on frozen products indicate improper storage before delivery [8,9].

3.3.3. Food safety measures during storage on board

Ships should have adequate storage facilities, including dry food stores and refrigerated stores. Spaces for food and water storage must be of adequate capacity, and depending on this, sometimes supplies need to be reduced and taken over more often. Food is stored in quantities in which it can be consumed before the expiration date, although food that can be frozen and was frozen while it was fresh can be consumed after the expiration date marked on the product [9,15].

Food should never be stored on deck. In the freezers, the temperature should be maintained at a minimum of -18˚C and the freezers themselves should be maintained regularly (checking the correctness and insulation of the doors, checking the correct operation of the thermometer, defrosting and cleaning). When entering the freezer, staff should wear protective clothing such as gloves, as well as prescribed footwear and warm clothing. It is also recommended to reduce the number of unnecessary entries into the freezer, considering that each opening of the freezer affects its operation and the temperature inside the freezer. In the refrigerator, the temperature should be as constant as possible to avoid moisture. The recommended refrigerator temperature is 5°C, although a deviation of up to 8°C is acceptable. If possible, raw and cooked food should be in separate refrigerators, and if this possibility does not exist, then raw food should be kept at the bottom to avoid the possibility of contamination [8,9]. Proper storage of fresh foods is important, and the way some fresh foods are stored is shown in Table 2 [9].

Table 2 Storage of fresh foods of plant origin

ALWAYS IN THE REFRIGERATOR	AT ROOM TEMPERATURE UNTIL RIPENING, THEN IN THE REFRIGERATOR	AT ROOM TEMPERATURE
Apples, artichokes, asparagus, beans, beets, blueberries, broccoli, Brussels sprouts, cabbage, carrots, cauliflower, celery, cherries, sweet corn, cranberries, cucumbers, eggplant, ginger root, grapes, fresh herbs, leeks, lettuce and other greens, mushrooms, green onions, parsnips, peas, pepper, pineapple, new potatoes, radishes, raspberries, rhubarb, strawberries, pumpkins, citrus fruits, turnips.	Apricots, avocados, kiwi, mango, melon, nectarines, papaya, peaches, pears, plums, tomatoes.	Bananas, garlic, red onions, ripe potatoes, pumpkins, sweet potatoes.

Source: [9]

Dry food stores must be clean, well lit, ventilated, at a temperature of around 10°C and dry. It is necessary to inspect them regularly, to watch for the possible presence of pests or insects in the food (flour, rice) [9,15].

All food that is stored should be covered to prevent cross-contamination.

3.3.4. Water safety measures

As for ensuring the safety of water used for consumption and food preparation, for dishwashers, for laundries, toilets, etc., the regulations are determined by the Maritime Labour Convention. Regulations refer to loading, supply, storage, distribution systems and maintenance to ensure high-quality drinking water, and therefore protection against water-borne infections. The equipment used in the process of filling, distributing and storing drinking water must prevent any chemical and/or microbiological contamination [17]. With the aim of ensuring high-quality drinking water on ships, according to the guidelines of the World Health Organization and the International Water Association, water safety plans (WSP) are designed. A water safety plan has three components:

- assessment of the system (drinking water supply chain to the point of consumption),
- operational supervision (identification and monitoring of control measures applied on board)
- management and communication [38,39].

Control measures to prevent contamination of drinking water include water treatment procedures, routine monitoring and inspections, maintenance, repair or replacement of equipment, control of cross connections, marking of pipes and hoses, training of personnel, temperature control, and flushing of infrequently used equipment [17,38,39].

Regular water analysis, as one of the important WSP factors, should be highlighted as it enables quick and successful action in the event of any problems. Frequent water analysis can detect the problem in an early stage, ensure water safety and thus prevent the possibility of illness for consumers and, at the same time, the quality of business operation [17,39].

Here are some examples of water safety measures:

- water that is not used for consumption but for other purposes such as cooling, washing, steam production, etc. circulates in a system separated from drinking water,
- ice that comes into contact with food must be produced from potable water,
- steam that comes into direct contact with food must not contain any dangerous substance that will lead to food contamination, and the same applies to water used to cool hermetically sealed food containers [17,23].

3.3.5. Food safety measures during preparation and serving

The paper has already discussed the provisions on the furnishing and layout of the ship's galley and other rooms that are important in food and water storage and food preparation on board. It is also important to emphasize the hygiene measures that are implemented during the preparation and serving of food. Proper maintenance of personal hygiene is particularly important. Hands must be washed and clean:

- after using the toilet,
- after handling raw meat,
- before handling prepared food.

It is recommended to use disposable towels or electric hand dryers.

When gloves are used, they should be changed regularly. Hair should be covered and, if long, tied back, nails should be short, and work shoes and clothing should be appropriate and clean [8,9,22].

People who have developed symptoms of a foodborne infection or are suspected of being exposed to any factor that can cause illness or germs (diarrhoea, vomiting, fever, sore throat, cough, runny nose, open wounds, ulcers, etc.) must be away from the kitchen and other catering areas and are temporarily prohibited from working with food, equipment and utensils for preparation and consumption, as well as from storing food and catering textiles. For such persons, the ban on work will last up to 48 hours from the disappearance of symptoms. It is important to encourage staff to report early symptoms so that by hiding the disease, out of fear for their jobs, they do not endanger others and lead to an epidemic [8, 9, 22].

When maintaining the hygiene of surfaces and equipment used in food preparation, care should be taken to avoid the possibility of cross-contamination. The paths of raw and heat-treated ready-made food must not cross. Raw food must be kept away from cooked food and/or food that does not need to be thermally processed before consumption. Raw meat is stored in closed plastic containers at the bottom of the refrigerator. Work surfaces and cutting boards that will be used for raw food are separated from those that will be used for ready-to-eat food. Food preparation devices, dishes, knives and other accessories and work surfaces must be thoroughly cleaned and disinfected [8, 9, 22].

When the premises where food is stored and prepared are regularly maintained by cleaning and disinfection, the possibility of physical, chemical or microbiological contamination of food is reduced to a minimum. Waste containers must be in a visible place, emptied often, easy to clean and disinfect.

3.3.6. Food safety measures when handling and storing food for later consumption

Supplies and leftover food should be refrigerated as soon as possible and stored at temperatures that prevent the growth of bacterial colonies. Food served as part of the buffet is a high-risk food. Hot dishes should be kept warm, at a temperature of 63°C or higher, and cold dishes should be kept in the refrigerator until the opening of the buffet (placing the dishes and trays with food on crushed ice to maintain a low temperature). Cooked food should not be kept longer than 2 hours at a temperature between 5°C and 63°C [8, 9, 22].

Supplies and leftover food should be stored in refrigerators, that is, at those temperatures that prevent the growth of bacteria and the production of their toxins. Hot or warm cooked food should be cooled as soon as possible and then stored in the refrigerator. Leftovers are not recommended to be consumed the next day. Repeated heating and freezing of leftover food favours the development of bacteria. When reheating food, care should be taken to ensure that the heat is distributed evenly and that the temperature of the reheated food has reached at least 70°C in all parts. The best and least risky approach is to plan the exact number of meals and throw away the rest of the food [8,9, 22].

4. CONCLUSION

Food safety is important at all stages, on land and on vessels. Observing the relevant regulations during production, processing, transportation and storage of food, as well as during preparation and serving, will ensure high-quality food and water for consumption.

Outbreaks of food poisoning on ships mostly involve passenger ships and are of public health concern because of the confined spaces, the food and drinking water supply, and the potentially large number of sick passengers.

Good hygiene practices during the provision of food to the ship eliminate or minimise the risk of contamination of food and water. It is necessary to educate and train the personnel who deal with food and water on ships and other marine facilities, especially on vessels that are characteristic with regard to the ways of storing food and water, the environment, and frequent visits to different environments on land.

Both on land and at sea, it is important to respect the principles of good hygiene practice, i.e. to respect the laws and regulations that refer to the healthiness of food, reduce the risk of food poisoning and, in this way, protect the health of the crew and passengers, as well as the business reputation, especially on cruise ships.

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ESTIMATION AND FORECAST OF GREENHOUSE GAS EMISSIONS FROM SHIPS AT PORTS

Stefano Ricci
Sapienza Università – Development & Innovation in Transport Systems
Roma
E-mail: stefano.ricci@uniroma1.it

Luca Rizzetto
Sapienza Università – Development & Innovation in Transport Systems
Roma
E-mail.: luca.rizzetto@uniroma1.it

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Summary

Shipping is an environmentally friendly and energy-efficient transport mode; nevertheless, its environmental impact is not negligible: 2.5% of global Greenhouse Gas (GHG) emissions (about 940 million t/year). The turnaround time spent by ships at ports is also not negligible: 0.70-2.05 days in average (2018). Therefore, the periods spent in ports represent a good chance to minimize the GHG emissions by offering technical options for emissions limitations and less constraints and complications than during the navigation. Moreover, it brings combined positive effects on local pollutions in a typical win-win *Green Port* challenge. Actually, many ports estimate emissions because of various reasons. Structured inventories of emissions producers can help identify areas to improve energy efficiency by cost-effective strategies. The paper starts from results of inventories carried out in various ports worldwide, available in the scientific and grey literature, to depict a methodology to develop emissions inventories and forecasting. It includes: analysis of existing datasets of emissions at ports; analysis of traffic data by ship typology, handling operations at ports, turnaround times; multivariable statistical analysis for cause-effect correlations; identification of correlations, quantification of their reliability and setup of typical emission factors; setup of a generalized systematic methodology for inventory; identification of integrative local measurements and estimations. The main findings will be the design of a systematic methodology for emissions estimation from typical data related to ships operation at ports, as well as the estimation of availability and reliability of data, carefully considered in the paper.

Keywords: Ports, Environment, Emissions, GHG

1. INTRODUCTION

Maritime transport is a critical sector for the world and regional economy. According to [26], nearly 80% of the world trade volume is by sea and it will grow in the future. In 1970, the world population was 3.7 billion people, increasing steadily and will reach 8 billion in 2021 with a factor of 2.2. At the same time, global maritime trade increased from 2.6 billion tons up to 11 billion tons with a double factor of 4.2. At the beginning of 2022, the total world fleet amounted to about 103,000 vessels with about 2.2 billion GT deadweight, with a yearly increase of 2.9%. Dry bulk carriers accounted for the largest share in tons of deadweight (43%), followed by tankers carrying crude oil and its products (29%) and container ships (13%). In 2021, the largest container ship (237,200 GT) was bigger than the largest dry bulk carrier (204,014 GT) and liquid bulk carrier (170,618 GT), as well as the largest cruise ship. Experiences with other vessels and restrictions affecting access channels, port infrastructure and shipyards indicate that container ship sizes are likely to have peaked. The situation for passenger traffic looked as very similar, with a maximum growth rate of 2.2% in 2017. The following trend, affected by the 2020 crisis, generated by the sanitary mobility restrictions, has not yet recovered.

However, it also has a severe impact on the environment and climate and human health. Indeed, all transport modes have adverse impacts, such as pollution, noise, accidents, congestion, etc. and generate external costs. Decision-makers and transport providers usually only partially take these externalities into account. Meanwhile, this has adverse effects on society as a whole. Therefore, internalisation of external costs is the policy intervention to include the side effects in the decision-making process. In this context, maritime transport is an environmentally friendly and relatively energy-efficient mode of transport.

The negative impact of maritime transport on the environment is not negligible. In global terms, shipping is responsible for about 2.9% of global greenhouse gas emissions (1,076 million tons of CO_2 in 2018), about 13% of the entire transport sector. In local terms, the gaseous emissions have adverse effects, mainly near the big ports, close to the main waterways and to the approaches to channels or rivers. The correlation between the greenhouse gas emission from ships at ports and the traffic volume is evident. This research aims to find out reliable correlations between emissions and traffic, with a specific focus on emissions caused by different typologies of commercial and cruise ocean-going vessels (OGV) in ports. The goal is to set up relevant forecasting methods for the emissions of ships at ports and a qualified discussion on the reliability of the predictions themselves.

2. GREENHOUSE GAS EMISSION IN MARITIME TRANSPORT AND INCENTIVES TO REDUCE IT

Any gas in the atmosphere, which absorbs and re-emits heat, thus making the planet's atmosphere warmer than it would be is a greenhouse gas (GHG). The main GHG in the atmosphere are CO_2 (carbon dioxide), N_2O (nitrous oxide), CH_4 (methane), water vapour and ozone. GHG are naturally occurring in the atmosphere, but human activities increase their amount leading to global warming and climate change. The Global Warming Potential (GWP) of the GHG indicates the amount of warming caused over a period. Table 1 shows the GWP of different GHG [1].

Table 1. Global warming potential of various GHG

Greenhouse Gas	Global Warming Potential (GWP)
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Hydrofluorocarbons (HFCs)	124 – 14,800
Perfluorocarbons (PFCs)	7,390 - 12,200
Sulfur hexafluoride (SF_6)	22,800
Nitrogen trifluoride (NF_3)	17,200

In this context, the Paris agreement was released in 2015, aiming at limiting global warming under 2°C and achieve net-zero emissions before the end of this century. In order to fulfil these targets, the shipping sector should reduce its emission at least by 50% by 2050, according to International Maritime Organization (IMO) agreement in April 2018. Moreover, the shipping industry is required to pursue efforts to phase out the GHG emissions as soon as possible. Figure 1 illustrates the targets for the reduction of greenhouse gas emissions according to [20].

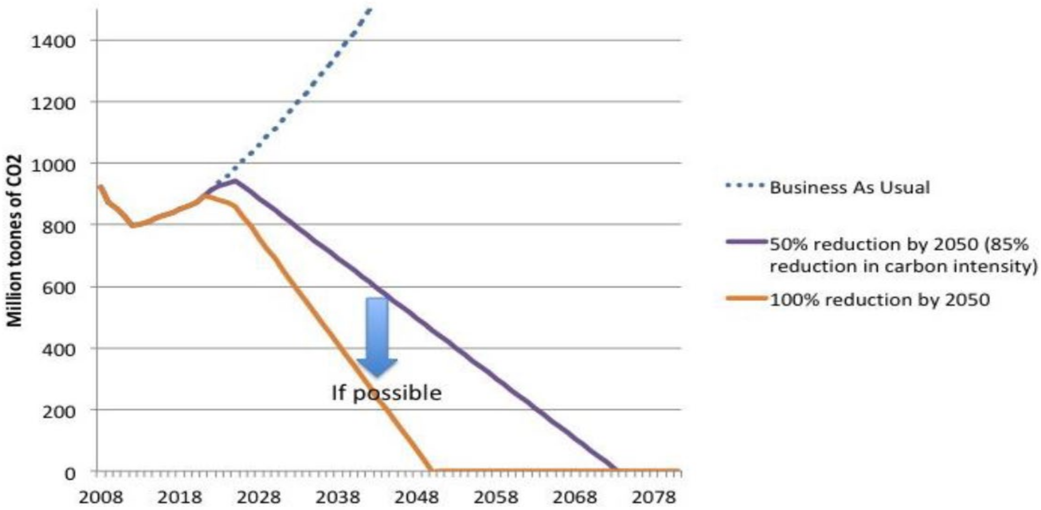

Figure 1 Carbon dioxide emissions reduction goals for international shipping

Source: [19]

The production of sustainable alternative fuels is becoming increasingly competitive because the costs of zero-carbon energy technologies are falling. Japan has proposed a short-term measure that will limit engine power, which can help meet the energy efficiency requirement for existing ships and reach the target set by IMO in 2030. Nevertheless, the limitation of engine power will change the performance of the ships minimally, thus cutting fuel use and emissions according to the cube law. However, a recent study focusing on different scenarios of engine power limits of container ships, oil tankers and bulk carriers reveals that the limitation on engine power has a negligible effect on GHG emission. Indeed, ships are normally operating far below their maximum engine power and the CO_2 reduction is not proportional to the engine power limitation.

Other technology-based measures, including cleaner fuels, engines with higher efficiency, propellers and hulls design, devices for energy recuperation and trap exhaust emissions, such as scrubbers, and various kites can contribute. In addition, operational or logistics-based measures focused on speed, fleet management, weather routing, supply chain management and other logistical operation optimisation could play an important role. Nevertheless, some of these measures could have non-trivial side effects for supply chain economics, e.g. reducing the speed and changing the number of ships in the fleet, in-transit inventory and other expenses. Moreover, measures increasing shipping costs, particularly short-sea shipping, would shift some traffic to land transport modes, largely more damaging for the environment.

In this framework, ships are spending a relevant amount of time in ports, where the most concrete and effective action could be put in place and the use of fossil fuels could be set to zero.

3. EMISSION BY VESSEL TYPOLOGIES

A wide range of parameters affects the amount of GHG emitted by ships [25]: namely ship typology, hull design, ballast water management, speed management and used fuels, combined with the technologies available onboard (Figure 2).

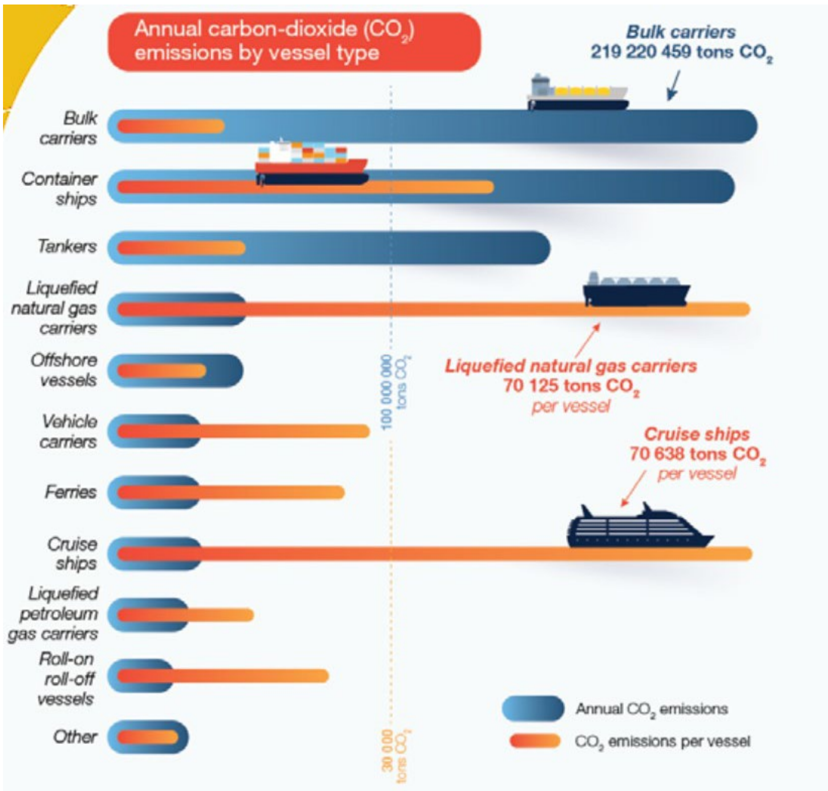

Figure 2 Annual carbon-dioxide emission per vessel-by-vessel type in 2019

Source [25]

The CO_2 emissions of large ships per ton x km are lower in comparison with smaller ships, as clearly resulting also from [8]. Container ships are emitting more GHG per ton x km than dry bulk carriers because of their higher average operational speed. Cruise and LNG ships produce the largest emission per ship. Therefore, the shift to larger tankers, bulk carriers and container ships over the past decade, in addition to the increases in efficiency and the decommissioning of less efficient vessels, caused the reduction of carbon dioxide emissions behind the increase in the fleet's deadweight.

Container ships have achieved progress also thanks to moderate commercial speed reductions, which anyway resulted in not negligible decrease of fuel consumption and associated emissions. In 2011-2019, their capacity rose by 45%, whereas the CO_2 emission increased only by 2%. Simultaneously, the emissions from tankers and bulk carriers increased by 19% and 17%, whereas the capacity of these vessels grew by 38% and 51%, respectively.

Over the next decades, the future carbon dioxide emissions reduction will be obtainable by replacing the older, less effective designed ships with new eco-designed typologies and further increasing the vessels carrying capacity and size. Nevertheless, these improvements are not enough to achieve the target imposed by IMO about halving the total greenhouse gas emissions by 2050.

In this context, the abatement measures for emissions during navigation is a recurring subject of academic research. Various works performed techno-economic analyses and comparisons of the different options and [6] provides an overview, including alternative fuels, alternative energy storage technologies and treatment of exhaust gases technologies and use of renewable energy sources.

The issue of the optimal taxation from the public bodies' viewpoint is carefully analysed in [22]. More specifically, in [4], [10] and [28] the focus is on the implementation of scrubbers and the economic affordability of investments in them for various typology of fleets and services, as well as in [2] and [11] the focus is on the optimization of liner shipping fleets management.

4. EMISSIONS AT PORTS

Ports are important nodes in shipping so that they improve continuously the way to operate. However, they bring noise, water and air pollution, including carbon emission. The common goal of the shipping industry is to provide environmentally friendly logistics services. Nevertheless, its location, energy utilisation efficiency and resource utilisation are the main reasons for their environmental problems. Emerging researches identify shipping, goods, dock and the city itself as critical emissions sources. Meanwhile, more in detail for shipping, the primary sources of emissions in ports result to be container ships, oil tankers, bulk carriers and trucks.

The GHG production is depending on the ownership and control of the sources. At ports they are:

- Direct port sources: under the direct control and operation of the port administration and include vehicles owned by port administration or leased by it, boiler and furnaces in buildings, cargo-handling equipment operated and those from other owned or operated sources;
- Indirect port sources: purchased electricity, owned buildings and operations, not including tenant power and energy purchases;
- Other indirect sources: basing on operations and including trucks, ships, cargo-handling equipment, rail locomotives, building, harbour craft, employee vehicles, and electricity purchased by tenant.

In order to respond to concerns regarding the health risks of port operations, several ports around the world have conducted port emissions assessments, although the content of the particular emissions inventory depends upon the specific set of drivers of each port.

Beyond the regulatory requirements, an emission inventory can present the port in the light of a forward-looking organisation for stakeholders and engage the stakeholders themselves in discussing how most effectively reduce the emissions from port operations. Moreover, the inventories provide solid bases for evaluating viable emissions strategy analyses and can serve as a tracking and reporting mechanism for future estimates. Moreover, a structured inventory of energy users producing emissions can help identify areas where energy efficiency and port performances can be improved by cost-effective emissions reduction strategies that can bring financial and environmental benefits.

The assessment of ship emissions includes typically two alternative approaches. In the *full top-down approach*, the total emissions are at a larger scale (e.g. regional or national) and then geographically reduced to a smaller scale. Meanwhile, in the *full bottom-up approach*, each vessel's emissions of air pollutants during its specific activity and position are under calculation and the data aggregated over time and space. Significant CO_2 emissions derive from the time the vessels stay in ports. The emissions from ships in ports are approximately 90% of global emissions from ports' operations [3]. Therefore, as anticipated, there is a better potential to reduce the GHG emission from the ship in port rather than during navigation.

Port authorities can influence the GHG emissions from ships by supporting systems and technologies and implementing incentive programs that help conserve fuel in the port area. Ports can, for instance, manage and administer the supply of alternative fuels and onshore electrical connections and apply environmentally differentiated port fees. This practice enables to power commercial ships by a link to onshore electricity network, in order to reduce pollutant emissions in the port areas caused by marine fuels in auxiliaries' engines feeding on board installations during ships stops at quays. In [7] the focus was on technical and functional features of the concerned ships power systems and technical, economic and financial feasibility of this system, in [13] the focus is on the optimization of shore power allocation and berth allocation from economic and environmental viewpoint.

In general, the variety of functional situations and typologies of ships (such as voltage, frequency, power supply and power demand on the quay) does not allow establishing general constructive solutions, since the cold-ironing system is depending on both the operational mode and the layout of each terminal.

5. METHODOLOGICAL APPROACH FOR ANALYSIS AND FORECASTING OF GHG IN PORTS

Atmospheric pollutants from ports' operations jeopardise the air quality of port cities. GHG emissions generate at ports when the ships are manoeuvring at arrival or departure and during hoteling. The proposed methodology starts from the available data concerning emissions and traffic, globally at ship typology, and looks for multivariable correlations. The consolidated and generally accepted hypothesis is that the amount of emissions generated from port activities can depend on the number of vessel calls, time spent at hoteling and manoeuvring, quantity of cargo transported, container traffic, type of engine of the calling ship's number of passengers, etc. [23]. In this context, the most appropriate and potentially robust technology bases on the analysis of the available data and the forecast of the GHG generated at ports. This analysis refers to the total number of arrivals per year for all types of ships and, selectively, per container, cruise, tankers and bulk carriers. A preliminary worldwide extended investigation on the port authorities websites and concerned publications allowed selecting the ports where the concerned data are collected and published, representing the set of case studies.

6. CASE STUDIES PORTS

The worldwide investigation provides a minimal set of ports, making public data usable for the present research. Indeed, data are normally inhomogeneous in terms of typology, units and temporal coverage. Therefore, the selection brought to the identification of eight case studies only, though distributed over four continents, as highlighted in Figure 3: Felixstowe, Gothenburg, Oslo and Valencia in Europe, Los Angeles and New York in America, Shenzhen in Asia and Sydney in Oceania. They make available data differentiated by ships' calls and transported quantity over various years, concerning GHG emissions by the corresponding typologies of ships. For some of these ports, more details and actions for the reduction of the emissions in place are below.

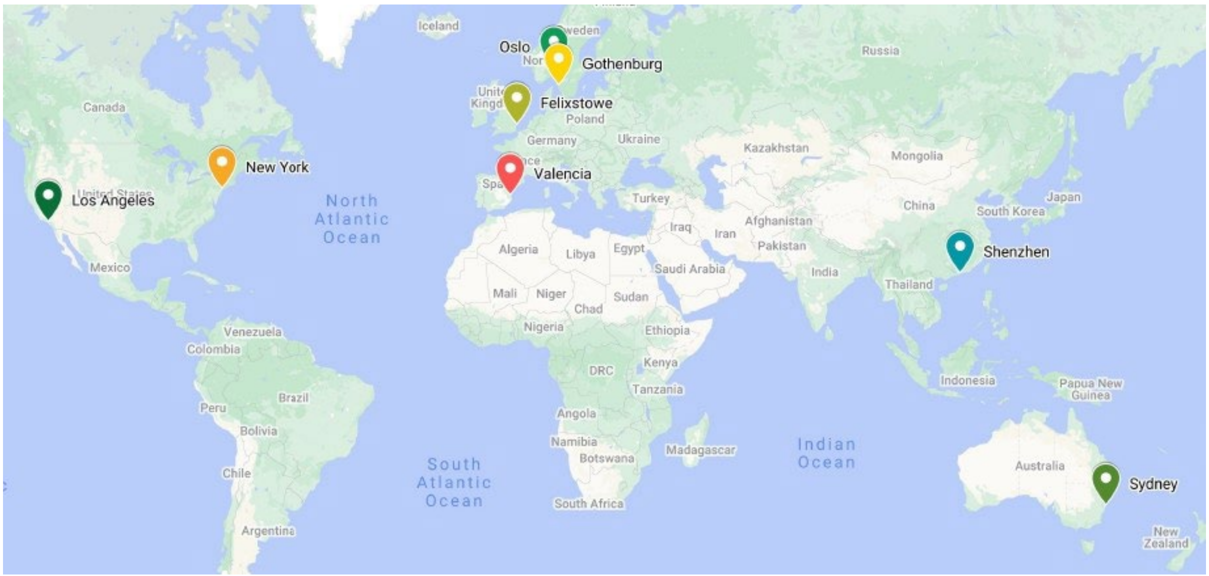

Figure 3 Selected case studies ports

Felixstowe

Felixstowe is one of the largest ports in Europe and the busiest container seaport of the United Kingdom (UK), with calls of ships coming from almost 200 countries. The port handles approximately 4 million TEU/year and 3000 ships/year, over 40% of UK container traffic. As a part of the Clean Air Strategy announced by the UK government in 2019, which aims to reduce air pollution from all sectors, the Port of Felixstowe developed a Port Air Quality Strategy (PAQS) based on baseline emissions inventory [15]. This strategy considers all relevant major emissions produced on-site: vessels at berth (63%) (Figure 4); non-road mobile machinery (NRMM), including rubber-tyred gantry (RTG) cranes, internal tractors, forklifts etc.; freight locomotives idling, entering and leaving the port; heavy road vehicles carrying goods; gas consumption for heating buildings.

Oslo

The port of Oslo is the largest in Norway, both for passengers and freight, with 50-70 ships' calls in an average week. It handles around 6 million tonnes of freight and almost 7 million passengers per year. The declared aim is the increase freight traffic by 50% and passengers traffic by 40% by 2030. Meanwhile, to comply with national and municipal targets, the emissions should be drastically lower. However, the forecasted increase in maritime traffic will reduce by itself the emissions of GHG thanks to the modal shift from road transport. The CO_2 emissions from the port operations account for approximately 4% of total emissions in Oslo city. The largest emission source is international ferries (40% of GHG), followed by onshore activities (14%) and local ferries (12%) (Figure 5) [17]. The action plan in place since 2018 estimated to reduce by 85% GHG emissions by 2030.

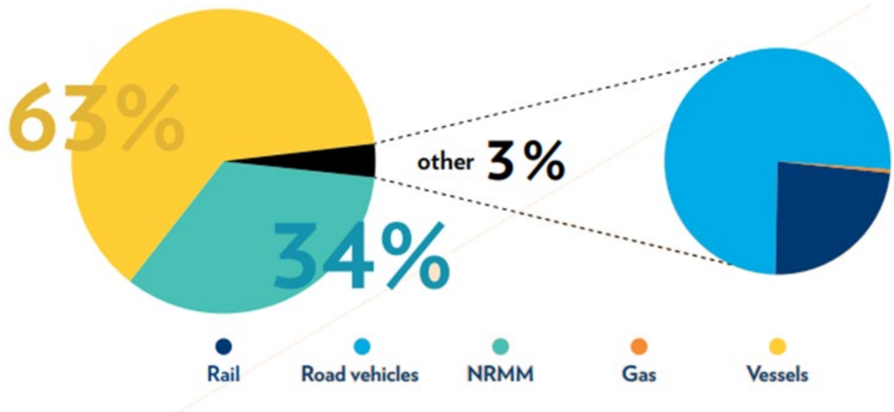

Figure 4 CO_2 emissions distribution in the port of Felixstowe in 2019

Source: [15]

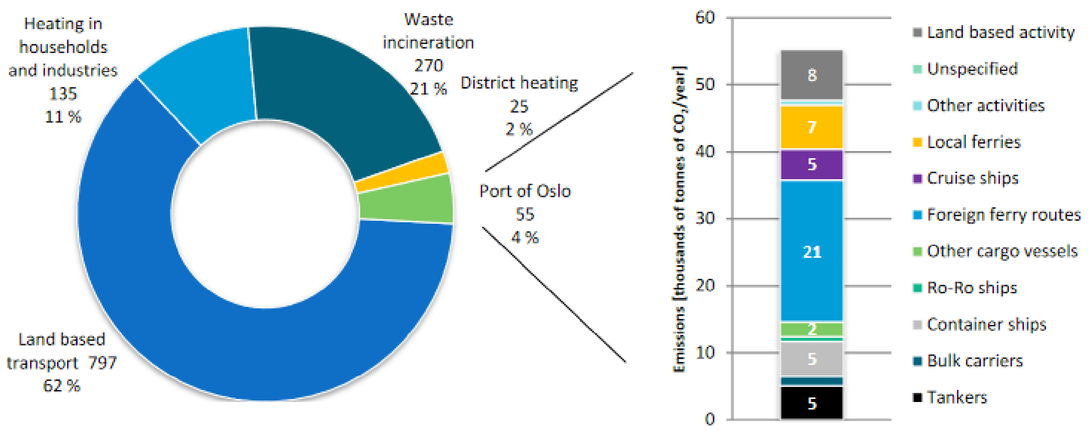

Figure 5 Distribution of GHG emissions in Oslo: total in the city, port-related and ship typology related

Source: [17]

Valencia

It is the largest port in the Mediterranean Sea and is the sixth largest port in Europe in terms of container traffic, with a yearly volume of about 5 million TEU. The terminals in the port of Valencia handles practically every type of goods and regular passenger traffic with the Balearic Islands and Italy and increasing cruise traffic. In order to improve the environmental performances, the Port Authority made significant efforts by developing relevant projects and initiatives. There is a plan to use low carbon instead of fossil fuels to motorise internal vehicles and yard machinery. As a result of efforts and measures carried out, a 17% reduction of CO_2 emissions compared to 2008 was achieved in combination with a 24% traffic increase [5] [18]. Therefore, the primary sources of the emissions are now ships. In 2021, the Port of Valencia joined the World Ports Climate Action Program (WPCAP), including 12 ports committed explicitly to decarbonisation and emission reduction jointly working on the promotion of the actions against climate changes, close collaboration with the International Association of Ports and Harbours (IAPH).

Los Angeles

It is the busiest seaport in the western hemisphere and the country's primary gateway to international trade. Located in San Pedro Bay, almost 40 km south of downtown Los Angeles, the port covers 3,500 hectares of land and water on over 60 km of shorefront. It includes cargo and passenger terminals for breakbulk, container, liquid bulk, dry bulk, automobile, warehouse, and passenger facilities. Ranked as the United States America (USA) number one container seaport, Los Angeles is the premier gateway for international commerce in North America, with 9.3 million TEU moved in 2019. The port of Los Angeles is implementing several measures to reduce the emissions from five primary sources: ocean-going vessels, harbour craft, locomotives, cargo handling equipment and heavy-duty vehicles [16]. For this purpose, in 2017, the port released the final update for the *Clean Air Action Plan*, which consists of strategies for all sources, including reducing emissions from ships. The goal is to reduce emissions and combat climate change for the next 20 years by focusing on collaborative work with regulatory agencies, industry stakeholders, environmental groups and local communities.

New York

The port, which covers New York and New Jersey, is the largest on the East Coast of the USA and the gateway to one of the most concentrated consumer markets in North America. The port has five terminals for container handling and terminals for bulk, auto, general cargo, tankers and cruise. The five main emission sources are Ocean-Going vessels (OGV), harbour craft, cargo handling equipment, locomotives and heavy-duty vehicles (HDV). OGV is responsible for 24% of the total CO_2 emissions, cargo-handling equipment for 18%, and HDV for 49%. Container ships are the largest OGV emitters, followed by cruise ships [14]. The port of New York and New Jersey is undertaking relevant measures and policies to achieve the *Paris Agreement* targets. For the OGV, New York and New Jersey developed the *Clean Vessel Incentive* (CVI) Program, which provides financial incentives in favour of using relevant fuels, engines, and technology enhancements to reduce the GHG and meet the environmental standards set by the IMO. The CVI bases on a scoring system that provides points for *Vessel Speed Reduction* (VSR) and *Environmental Ship Index* (ESI). Additional points awarded to ships with engines that meet clean standard regulations. For example, VSR requires low-steam under 10 knots from 20 nautical miles outside the territorial sea line. Moreover, incentives are for the renewal of fleet operated in terminals with Tier IV engines, hydraulic hybrids, compressed or liquefied natural gas, and ship-owners using ultra-low sulfur diesel and shore power.

Shenzhen

Shenzhen is located in the south of China and is the main terminal for shipping lines that cross the Pacific Ocean and Southeast Asia. The port industry system has become very important for the social economy of Shenzhen city by reaching 7.6 million TEU. Containers transportation is the main business in the port of Shenzhen, in addition to building materials, bulk cargo of fertiliser, food and petroleum, etc. The rapid development in recent years positioned it to 1/5 of China oceanic container throughput and 1/3 of inland coastal traffic. Over the last 30 years, the Port of Shenzhen had a major influence on transportation infrastructure, attracting foreign investments and strengthening international trade. Since 2013, Shenzhen became the third-largest container port globally due to the favourable geographical position and the bonded zone policies, hosting more than 300 supply chain companies in connection with more than 300 ports in over 100 countries. Carbon emissions of the port are from four main sources, such as heavy equipment, transportation, materials and energy consumption. To reduce the GHG emissions, the port of Shenzhen is undertaking appropriate [27] to switch to the low sulphur content oil and to use of shore power and LNG instead of oil. The most significant carbon emissions are from transportation and particularly ships at berth are the main GHG emitters. At the same time, heavy equipment for handling operations is the second biggest source of carbon emissions.

7. RESULTS OF EMISSIONS AND TRAFFIC DATA STOCHASTIC ANALYSIS

The systematic multivariable analysis of correlations, including data from all case studies, allowed for selecting the best results in a correlation between traffic and GHG emissions indicators. In particular, the correlations considered and compared in terms of stochastic fitness are linear, exponential, logarithmic, polynomial and power.

In particular, reliable correlations resulted between the amount of GHG emissions and:

1) Global ships traffic;
2) Containers ships traffic;
3) Handled containers volumes;
4) Cruise ships traffic.

Meanwhile, the correlations of GHG emissions with tanker and bulk carriers' traffic and the global amount of goods and passengers and volume of handled solid and liquid bulk resulted not reliable enough. The disparity of collected data for tankers and bulk carriers are possibly motivated by the variety of size, haulage range and power plants of these ships, which would require larger sampling datasets to achieve sufficient statistical representativeness of correlations [21] [24]. Details on the single reliable correlations, usable for forecasting purposes, follow.

GHG due to global ships traffic

For this combination, synchronous groups of data (referred to the same period) are available for the following 11 yearly sets: Felixstowe (2019), Oslo (2017), Valencia (2017 and 2018), Los Angeles (2005, 2018 and 2019), New York (2006, 2018 and 2019), Shenzhen (2014).

The most fitting correlation is a linear regression ($R^2 = 0.6552$):

$$Y = 3.7292\,X + 187902$$

Where *Y* is the yearly GHG emissions [t of equivalent CO_2] and *X* is the yearly traffic [number of ships' calls].

GHG due to container ships traffic

For this combination, synchronous groups of data (referred to the same period) are available for the following 7 yearly sets: Oslo (2017), Los Angeles (2005, 2018 and 2019), New York (2006, 2018 and 2019).

The most fitting correlation is a logarithmic regression ($R^2 = 0.7614$):

$$Y = 89323 \ln(X) - 540853$$

Where *Y* is the yearly GHG emissions [t of equivalent CO_2] and *X* is the yearly traffic [number of container ships' calls].

GHG due to handled container volumes

For this combination, also discussed in [9], synchronous groups of data (referred to the same period) are available for the following 11 yearly sets: Felixstowe (2018 and 2019), Oslo (2017), Los Angeles (2005, 208 and 2019), Valencia (2017 and 2018), New York (2006, 2018 and 2019).

The most fitting correlation is a power regression (R^2 = 0.9078):

$$Y = 16537\, X^{0.8155}$$

Where Y is the yearly GHG emissions [t of equivalent CO_2] and X is the yearly volume [millions of handled TEU].

GHG due to cruise ships traffic

For this combination, synchronous groups of data (referred to the same period) are available for the following eight yearly sets: Oslo (2017), Valencia (2017 and 2018), Los Angeles (2018 and 2019), New York (2006, 2018 and 2019).

The most fitting correlation is a linear regression (R^2 = 0.8767):

$$Y = 296.85\, X - 16918$$

Where Y is the yearly GHG emissions [t of equivalent CO2] and X is the yearly traffic [number of cruise ships' calls].

8. DISCUSSION ON RESULTS

The regression equations for the estimation of GHG emissions derived by the analysis of all datasets qualified by medium-high correlation coefficients (R^2 = 0.65-0.91), which demonstrate good reliability of the results. Nevertheless, the dimension of samplings for each combination (7-11 datasets) is relatively small because of the still not largely mature awareness of the importance of environmental monitoring of port operations.

With reference to the port's calls the largest emissions of equivalent CO_2 are from cruise ships, which account about 280 t/call, compared with the average value of about 192 t/call, taking into account all typologies of ships, meanwhile the emissions of container ships are relevantly lower, accounting to about 76 t/call (about 0.21 t/TEU). These data are strongly depending on the large energy requirements of cruise ships at ports, where the auxiliary systems for providing hoteling services for passengers remain constantly in operation.

9. CONCLUSIONS

GHG emissions is a worldwide issue and their damage to the environment is not negligible. Shipping is a relatively environmentally friendly transport mode, since it can carry the largest cargo with the least energy consumed. However, the yearly increase in the volume of transported goods causes concerns regarding air pollution. The shipping activity includes navigation at sea, manoeuvring and hoteling. The generation of emissions in ports is during the manoeuvring activity and the hoteling when moored at wharves.

In this context, the present study developed a worldwide investigation about GHG emissions data collected and published from all types of ocean going vessels (containers, cruise, bulk and tankers) and the correlations with the corresponding amount of ships and transported units' traffic. The purpose is to set up reliable mathematical relationships for emissions forecasting in ports, potentially helpful in both the design and operational phase to identify technologies and management measures to minimise air pollution in ports, e.g. those depicted in [12] and [19].

The stochastic analysis highlighted the best fitting models for various categories of vessels (cruise and container), though it was not possible to derive reliable correlation due to data scarcity and heterogeneity in some other cases (bulk and tankers). Indeed, the reliability of the regression models highly depends on the quantity and quality of the available data. Nevertheless, the estimation of GHG from global traffic of ships, cruise ships, container ships and container traffic (TEU) showed good fitness.

Therefore, the main contribution of this study, despite the limitations of available data, is the development of a set of models for the preliminary assessment of the GHG emissions from the ocean-going vessels at ports. The consolidation and the generalization of such methodologies could represent a reliable common reference to forecast the emissions at ports, with high potential for the elaboration of port emissions management plans worldwide.

Moreover, based on the achieved results, the priority further research efforts in this field should approach:

- The extension of the datasets, possibly by carrying out dedicated measurements campaigns, already planned into the environmental actions planned by various port authorities;
- The development of multiple regression models with combined sets of explanatory variables.

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SMART EQUIPMENT FOR THE PRESELECTION OF CARGO VEHICLES IN THE MARITIME PORT AREA

Florin Rusca
University Politehnica of Bucharest
Faculty of Transport
Inteligent Convergent Solutions
Bucharest, Romania
E-mail: florin.rusca@upb.ro

Aura Rusca
University Politehnica of Bucharest
Faculty of Transport
Inteligent Convergent Solutions
Bucharest, Romania
E-mail: aura_panica@yahoo.com

Eugen Rosca
University Politehnica of Bucharest
Faculty of Transport
Inteligent Convergent Solutions
Bucharest, Romania
E-mail: eugen.rosca@gmail.com

Catalin Coman
Inteligent Convergent Solutions
Bucharest, Romania

Anamaria Ilie
University Politehnica of Bucharest
Faculty of Transport
Bucharest, Romania

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Abstract

The socio-economic changes generated by the conflict in Ukraine had a strong impact on sea ports located in the eastern part of Europe on the Black Sea. Cargo flows from this country have been redirected to new, safer routes. The flow of cargo vehicles loaded with grain from Ukraine overloaded the capacity of Constanta port in Romania. The large number of vehicles present in this situation blocked the access of those scheduled for the unloading process for which the grain terminals had the maritime vessel at berth. Thus, the activity of loading the maritime vessels with grain was disrupted and some supplementary cost appeared. The paper presents smart equipment, developed by the authors, used for the pre-selection of cargo vehicles according to the access conditions in the port area. The structure of the innovative equipment, the data processing modules and the sensors used in their collection are presented in the paper. Its usefulness is tested with the help of discrete simulation model, evaluating different scenarios for the access rules and the cargo vehicles flow compositions. The obtained results will be used to promote this solution to the port authorities.

Keywords: smart equipment, maritime port access rules, discrete simulation

1. INTRODUCTION

The ongoing conflict in Ukraine has had a significant impact on the region's economy and transportation infrastructure, including its access to maritime ports. Romania has been affected by the war in Ukraine in several ways, including the disruption of trade routes and delays in shipments due to increased border controls and security measures. In the immediate aftermath of Russia's annexation of Crimea in 2014, there were concerns that Romania's maritime ports could face congestion as Ukrainian ports became inaccessible. While there have been delays in processing cargo, Romanian ports have been able to absorb the additional traffic from Ukraine [1]. However, the traffic control at the maritime port gates became a challenge. The large number of vehicles present in this situation blocked the access of those scheduled for unloading process for which the grain terminals had the maritime vessel at berth. These issues have contributed to longer waiting times for cargo ships and increased costs for shippers.

The port authorities have chosen methods to reduce this blockage by manually identifying each vehicle and directing it to a waiting area or to the terminal where it was expected. However, these methods require a large consumption of human resources and are not viable on long term. A solution is the use of smart equipment in an increasingly wide manner. Smart equipment, such as cameras, sensors, and software, can help by improving traffic control at maritime port gates in several ways [2], [3]:

- Automated processing at gate: Smart cameras and sensors can be used to automatically scan and recognize the license plates of trucks and other vehicles entering and leaving the port. This information can be used to create a digital recording of the vehicle and its cargo, which can help speeding up processing times and reducing waiting times.
- Real-time monitoring: Smart sensors and cameras can be used to monitor the flow of traffic in real-time, allowing port authorities to quickly identify bottlenecks and congestion. This information can be used to adjust gate operations, such as opening additional lanes or redirecting traffic to less congested areas.
- Predictive analytics: Smart software can analyze historical traffic patterns and use predictive analytics to forecast future traffic levels. This information can help port authorities to anticipate and prepare for peak traffic periods, such as holidays or seasonal fluctuations.
- Automated alerts: Smart sensors can be programmed to detect safety hazards, such as overloaded or oversized vehicles, and automatically alert port authorities. This information can be used to prevent accidents and improve safety in the port area.

Overall, smart equipment can help by improving the efficiency and safety of traffic control at maritime port gates, reducing waiting times for trucks and other vehicles and improving the overall flow of traffic.

To obtain quantifiable results, it is recommended that all smart equipment for traffic control and monitoring to be connected in a hub. It can help drivers and port administration in several ways:

- Centralized control: A hub can bring together data from various smart devices, such as traffic sensors, cameras, and traffic lights, into a centralized control system. This can provide to drivers and port administration a more comprehensive view of traffic conditions and allow them to make more informed decisions.
- Real-time monitoring: A hub can provide real-time monitoring of traffic conditions, allowing drivers and port administration to quickly identify congestion, accidents, or other disruptions. This information can be used to adjust traffic signals, traffic rerouting, or provide alerts.
- Predictive analytics: By analysing historical traffic patterns and using predictive analytics, a hub can help drivers and port administration to anticipate traffic conditions and plan accordingly. For example, if a hub detects heavy traffic on a particular route during rush hour, it can provide alternative route suggestions to drivers.
- Improved safety: By detecting safety hazards, such as high speed or reckless driving, a hub can provide alerts to drivers and law enforcement, improving overall safety on the roadways inside and outside of port area.

- Enhanced communication: A hub can provide to drivers and port administration real-time updates on traffic conditions, weather, and other factors that may impact their travel plans. This can help drivers to take more informed decisions and avoid delays.
- Overall, a hub for smart equipment used in traffic can help drivers and port administration by providing a centralized system for real-time monitoring, predictive analytics, and enhanced communication, leading to improved traffic flow, increased safety, and reduced waiting time at maritime port gates.

The authors are involved in development of a new Smart Hub with functions in monitoring and control of cargo flows. The first uses are found in traffic on Romanian Highway Network at border check point with Hungary. This paper presents a new application developed for the case of maritime ports.

2. LITERATURE REVIEW

The modelling of cargo vehicles flows in the area of maritime ports presents interest for the researchers and experts in the field of transport. The particularities of the maritime ports with a fixed program for arriving and departure moments of the vessels, the corelation with the traffic schedule from other land transport networks, different internal regulation for each terminal generate specific studies and research. An important part of them present activities and technologies specific to maritime ports. Thus, starting from the design to operational use of the maritime terminal in the research of Steenken et al. are presented three decision levels (terminal design, operative planning, real time control) [4]. The activity inside the terminal is studied to evaluate the capacity of terminal [5], [6], [7], the handling activity [8], [9], [10] or the impact of using dedicated algorithms for activity optimization [11], [12], [13]. The results obtained allow a better assessment of the current state of the maritime terminals, respectively the identification of measures that lead to the increase of the quality of the services offered by these ones. Also, the developed models and algorithms can also be applied to other type of terminals, which is an advantage.

Another important direction of research is developed to evaluate the connections and the correlations between maritime transport and land network (roads and railways) [14-16], [17]. The territory inside the port is limited and the land vehicles circulation schedule must be synchronized with the arrival/departure times of maritime vessels. It is important to have restricted access rules to avoid the congestion phenomenon inside the port or on access paths. The researchers understood the importance of IT systems. The rapid evolution of technology allowed the realization of another important research direction. It is focused on the use of smart equipment for monitoring and controlling the activity in seaports. These are used inside the terminal for the optimization of handling and storage activities [16], [18] and for monitoring and controlling vehicles moving to/from the port. The purpose of this equipment is to avoid blockages in port access areas with negative effects on the activity [19], [20]. Our research is based on all this knowledge and aims to develop smart equipment that allows the monitoring and control of cargo vehicles entering/leaving maritime ports. Because the development is still at the laboratory level, an impact assessment using discrete-type simulation is carried out.

3. THE SMART HUB EQUIPMENT

The smart equipment developed is identified under the name of SmartHub. This equipment is used to implement the function of monitoring and controlling traffic at maritime port gates. The structure used includes sensors, video processing, data analytics and communication components. The main parts of Smart Hub structure are:

- Sensors: The SmartHub would incorporate a variety of sensors to gather data about cargo vehicles flows incoming or outgoing from maritime port area. It might include cameras to capture images of vehicles and their license plates, RFID readers to track cargo containers and other shipments, and various other sensors to measure factors such as temperature, humidity, and air quality. The port administration and the maritime terminal owner can receive data used later in the optimization of the loading/unloading/storage activity in the maritime terminal.

- Data aggregation: The data from the various sensors would be collected and aggregated in a central database or data warehouse. This data would be analyzed in real-time to provide insights into traffic patterns and trends, as well as to detect anomalies and potential security threats. The Smart Hub allows a local data processing and their systematization.
- Analytics and decision-making: Advanced analytics and machine learning algorithms would be used to process the data and identify patterns and trends. This would enable the system to predict traffic flow, optimize resource allocation, and improve overall efficiency. The system could also be set to alert port authorities about any unusual or potentially dangerous activity, allowing them to take appropriate action.
- User interface: The Smart Hub would have a user-friendly interface that would allow to port authorities and other authorized users to monitor traffic in real-time and take decisions based on the data. The interface could include dashboards, visualizations, and other tools to help users to visualize and interpret the data.
- Integration with other systems: The SmartHub would need to be integrated with other systems used within the port area, such as: gate access control systems, security systems, and logistics management systems. This would enable a seamless flow of data and information between different systems and help insurance that the entire port operates efficiently and effectively.

The main modules of SmartHub (traffic control module, local processing module, data acquisition module, sensor control module) are connected and controlled using a IoT Hub (Figure 1).

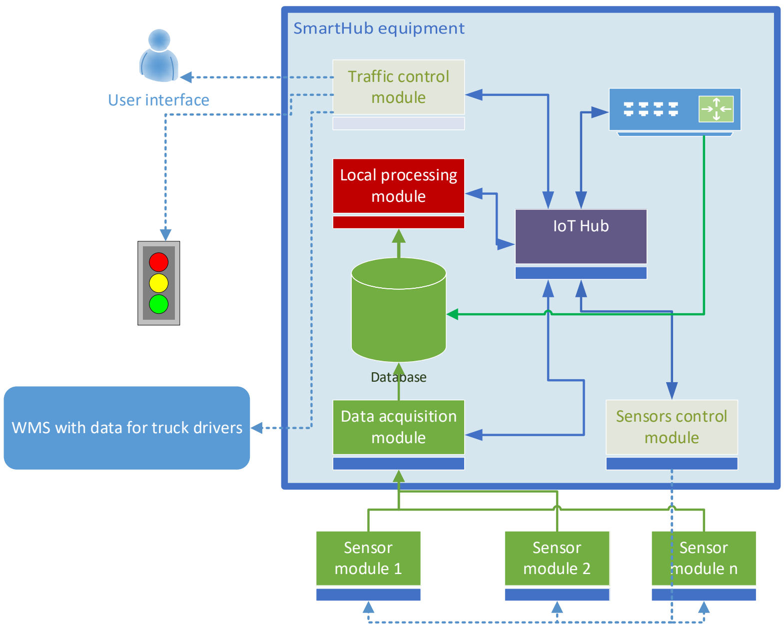

Figure 1 The SmartHub architecture

4. THE APPLICATION FOR THE CASE OF CONSTANTA MARITIME PORT

Port of Constanta is an important seaport located in Romania, and it plays a crucial role in the grain logistic chain in the region. It is the largest port on the Black Sea from European Union, which makes it a crucial gateway for the export and import of goods to and from the region. The port is strategically located, providing easy access to other ports in the Black Sea region and beyond (Figure 2). The port is equipped with modern facilities, including container terminals, grain terminals, and storage facilities, which make it an efficient hub for the transportation and storage of grain. The port's infrastructure and technology allow for quick and easy loading and unloading of ships, reducing in this manner turnaround time and costs. Cost-effective: Port of Constanta offers cost-effective services, making it an attractive destination for grain shippers. The port's location and infrastructure allow for efficient and cost-effective transportation, reducing the overall cost of transporting grain. Overall, the Port of Constanta plays a crucial role in the grain logistic chain in the region, providing an efficient, cost-effective, reliable transportation and storage hub for grain shipments.

Figure 2 The maritime ports at Black Sea

Source: https://clubferoviar.ro/portul-constanta-reconstructia-ucrainei/

The socio-economic changes generated by the conflict from Ukraine had a strong impact over maritime ports located in the Eastern part of Europe at Black Sea. The cargo flows from the ports Odesa, Berdiansk, Mariupol have been redirected to Romania. The flow of cargo vehicles loaded with grain from Ukraine overloaded the capacity of Constanta port from Romania. The large number of vehicles blocked the access of those scheduled for unloading for which the grain terminals had the maritime vessel at the berth. The waiting time increased to 48 hours or more. The activity of loading the maritime vessels with grain was disrupted and some supplementary cost appeared. A solution to reduce the negative impact is to guide the cargo vehicles to wait in some parking areas for the acceptance to be received in the port. A smart equipment can be used to identify the vehicles, to verify if they have the acceptance and to decide if they need to be guided to access gates or to a parking area.

The usage of equipment SmartHub allows the implementation of a system for the guidance of cargo vehicles in order to reduce the blockage at the entrance to the seaport. The plate number of cargo vehicle is read using a LPR camera. In parallel, a database is created with information on vehicle access to the terminal for loading/unloading processes. Using a decisional process inside the equipment the cargo vehicles with an upcoming loading/unloading deadline (under six hours) are guided to access gates of the port. Otherwise, the cargo vehicles are guided to parking places to wait until unloading/loading term is reduced under six hours. For the proposed impact assessment, we suggest a system with three parking areas. First one is dedicated for trucks accepted in the destination terminal or for which the time scheduled to be accepted (Serving Time) is between 6 and 12 hours. The second parking area is for trucks with a Serving Time between 12 and 18 hours. The last one is for trucks with a Serving Time over 18 hours.

To evaluate the impact a simulation model is developed. The simulation environment is Rockwell Arena, a dedicated software for discrete modelling. The model is used to set the required parking places in every area.

The simulation model is depicted in Figure 3. For the input flow we used exponential function according with other research made over traffic from highway [9]. The value of parameter λ was settled at 5 minutes according with our survey made of the highway. The percentage of cargo vehicles separated in four directions were (40, 30, 20,10) and were set arbitrarily without having information from the port authorities. In the case of a system implementation, these values can be easily introduced in the simulation model.

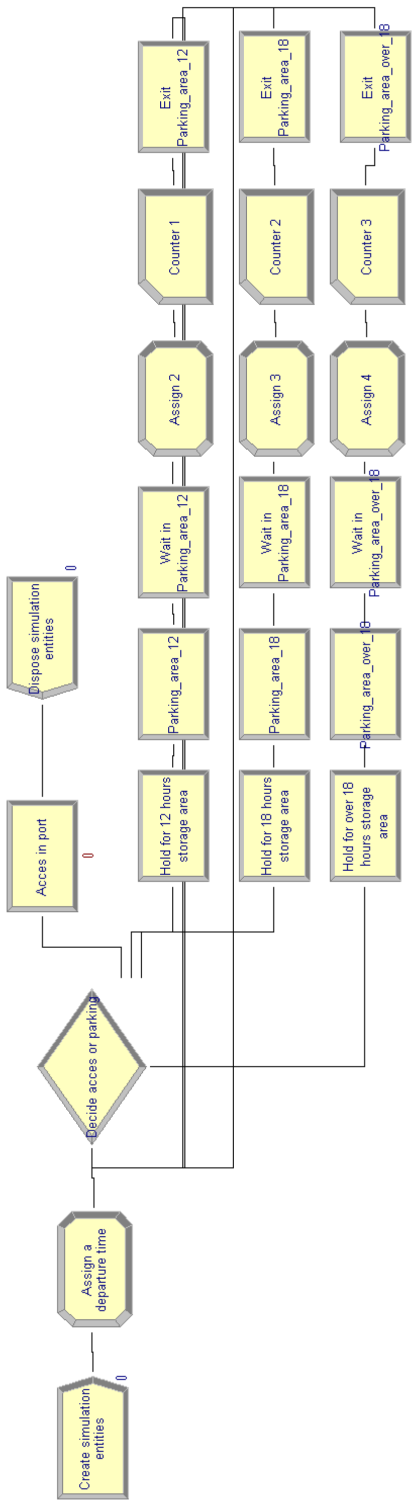

Figure 3 The simulation model

We assumed in our model the next considerations:

- every vehicle is represented in simulation by an entity,
- the entities arrival moments are in accordance with a repartition function,
- for every entity an attribute Serving Time is set with a value between 1 to 24 and represents the moment for entrance in port area,

- if Serving_Time is over 6 hours the entity is guided to an entities store. Are three stores: one for entity with Serving_Time between (6,12] hours, one for entity with Serving_Time between (12,18] hours and one for entity with Serving_Time over 18 hours
- after 6, 12 and 18 hours the Serving_Time for entities from every specific store is set to 6 hours and the entity is guided to a Process block associated with Access gate inside the port area.
- if an entity is guided to a store (with a waiting time of 6, 12 or 18 hours) and this store is full a supplementary waiting time appear until a place in the store become free.

The simulation model is used to assess the number of parking places in every area. Six sets for input data are used. The results and input data used are presented in Table 1.

Table 1 The input data and results

Scenario	Parking places in Area I	Parking places in Area II	Parking places in Area III	Waiting time for a free place in Area I [hours]	Waiting time for a free place in Area II [hours]	Waiting time for a free place in Area III [hours]	Waiting time for accessing port area [hours]	Truck waiting for a free place in Area I	Truck waiting for a free place in Area II	Truck waiting for a free place in Area III	Truck waiting for accessing port area
S1	10	10	10	3.12	7.94	9.73	0.02	10.7	19.3	11.9	0.28
S2	15	15	15	1.70	5.87	5.72	0.02	5.84	14.34	7.09	0.28
S3	20	20	20	0.59	3.85	2.42	0.02	2	9.4	3	0.28
S4	25	30	25	0.1	0.57	0.44	0.02	0.36	1.42	0.53	0.28
S5	25	35	25	0.1	0.12	0.44	0.02	0.36	0.30	0.56	0.28
S6	25	30	30	0.1	0.12	0	0.02	0.36	0.30	0	0.28

The objective of the smart equipment proposed is to reduce the queue at the access gate in the port area. It is used to read the plate number of cargo vehicles and to compare the number with the recordings from a data base. If the cargo vehicle is expected by a maritime terminal (is scheduled for loading/unloading in the next 6 hours) then is accepted inside the port area. If this condition is not accomplished the cargo vehicles are guided to a parking space. In our case study we separated this parking space in three areas: one for vehicles expected in the port area after 6 hours, another one for vehicles expected after 12 hours and finally one for vehicles expected after 18 hours. We excluded from our model the vehicles expected after 24 hours and more than that because considering these time aspects, the vehicles can use a service space located on the highway where drivers benefit from more facilities. For every simulation scenario the results show the importance of this system because the waiting time to access in the port area can have a very low value (approximately 1.2 minutes). Unfortunately, an incorrect size of the number of parking spaces leads to queues at the entrance to these dedicated areas. For example, in the S1 scenario where we have the smallest number of parking spaces, the waiting time in the queue to enter has values between 3.12 and 9.73 hours. The best and acceptable values are obtained in S6 scenario where the waiting time for every parking area is under 8 minutes.

5. CONCLUSIONS

Geographical, political and strategic changes generate extreme situations with positive and negative effects on the activity of maritime ports. From the negative category, we can mention situations of overloading the port infrastructure beyond its capacity. The effect is measured by the apparatus of an activity blocking phenomenon. In the case of the port access area for vehicles coming from the land transport networks, namely, the large number of trucks waiting for approval to enter inside the maritime terminals blocks the access of those vehicles that are scheduled for loading/unloading processes. The port authorities are forced to implement a series of rules and equipment to avoid this phenomenon.

The current research presents the structure of such an equipment made by the authors of the paper which, in combination with the development of a long-term delimited parking area near the area of the access gates in the port area, lead to the reduction of waiting queues and to a much better regulation of the access of vehicles in the port area. Using a discrete simulation model an impact assessment was developed to calculate the value of waiting time and the number of cargo vehicles waiting in queue. Also, using simulation model for different input data in six scenarios was obtained the required number of parking places in such manner to have an average value of waiting time to enter in parking areas under 8 minutes. The results obtained by simulation are influenced by the correctness of the input data. If these data present a high level of uncertainty, the results obtained may have a low level of confidence.

The current research proves its usefulness. The simulation model can be used in feasibility studies made for implementation of new smart equipment in the port gates area. In the future, the group of researchers wants to conclude an agreement with the Port of Constanta authorities for the implementation of this kind of system.

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SHIP COMPONENTS IDENTIFICATION SYSTEMS

Ladislav Stazić
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: lstazic@pfst.hr

Branko Lalić
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: blalic@pfst.hr

Danijel Bartulović
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: danijel.bartulovic@pfst.hr

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Abstract

All seafarers in the world are familiar with the problem of the wrong spare parts being delivered to the ship, either because of incorrect information in the order or because of misinterpreted information from the supplier. This problem can be easily understood by analysing the ships' Computerized Maintenance Management Systems (CMMS), where it is obvious that there is no uniform method for coding the equipment and its parts. Currently, there are a number of different coding systems for ship components and parts. The decision on which system to use rests with either the equipment manufacturer or the end user. Multiple systems are often used simultaneously on ships, leading to various problems (confusion). In addition, there are no clear standardisation rules that would solve this problem. This article serves to present the identification of the problem and the announcement of future research on this problem. In this preliminary research, three selected ship identification systems were analysed and compared, and their advantages and disadvantages were reviewed. In this way, it was determined exactly which system should be improved and modernised in future work to try to solve the problem described.

Keywords: CMMS, codification system, standardization

1. INTRODUCTION

All seafarers in the world know the problem of wrong spare parts being delivered to the ship, either because of wrong information in the requisition order or due to wrongly interpreted information by the supplier. The wrong information in the requisition order is a problem that can be attributed to several factors. One of the main factors that can be observed in the analysis of ships' computerized maintenance management systems (CMMS) is the huge amount of data that is entered into the database (hundreds of thousands of pieces of information). The error rate in data entry can vary depending on the skill level of the person and the type of text being entered. For highly skilled typists and logical texts, the error rate is as low as 0.23% [1, 2], while for more complex and incoherent texts it increases significantly and exceeds 3% [3]. According to two companies involved in the creation of CMMS databases [4, 5], this percentage is over 5% (and even up to 7%) depending on various factors. The highest percentage of errors was observed when entering various codes into the database, especially for databases created in countries with cheap (read: low-skilled) labor. The situation is slightly better when the input is done by better trained personnel (which increases the cost of building the database, and shipping companies are reluctant to opt for this solution), but the error rate is still very high. Another solution to reduce entry errors would be to facilitate the entry of a large number of codes (or to create uniform codes), both for equipment and for its spare parts. Currently, the vast majority of codes (for spare parts) are set by the manufacturers themselves, so each manufacturer designs the look of their own codes and they have no link to other manufacturers' codes. Even in the coding of equipment, which is done when CMMS databases are created, there is a large number of different systems that have no common points of contact.

To what extent a unified system for coding equipment and/or spare parts would improve this situation is a question that will remain unanswered for a long time, since there is currently no system that could be used for this purpose. No existing identification system on the market covers the coding of parts and equipment itself, certainly not when entire systems are also included. Moreover, the decision on which identification system to use in practice rests with the equipment manufacturer or the end user, i.e. the shipping company. On ships, in addition to all the other problems, several identification systems are often used at the same time (e.g. one for maintenance, another in parallel with other codes for accounting), leading to various problems (confusion). Standardization rules or laws that could solve this problem do not exist and are not under discussion.

The purpose of this paper becomes clear after all the above points have been presented. It is to highlight the above problem, identify it, and announce guidelines for future research in this area. In this preliminary research, three randomly selected systems for the identification of ship devices and equipment have been analyzed and compared, and their advantages and disadvantages have been presented.

The aim of this analysis is to preliminarily identify the best of the studied systems, which could be improved and extended in a next step (i.e. to eliminate the shortcomings of this system) in order to obtain a solution to the problem of coding of devices and equipment.

2. IDENTIFICATIONS SYSTEMS

During their professional work, the authors of the article have encountered a large number of different identification systems for marine engines and components. The three systems analyzed and described in this paper have attracted the most attention. The possibility of their expansion and/or modernization is evaluated, so that a potential new product can easily be used to uniquely code all equipment and parts on board. The names of the companies where these systems are used are not mentioned, mainly for practical reasons and to avoid publicity. Instead, these systems are referred to as Systems 1, 2, and 3. All three systems were developed in the twentieth century, and all three have proven themselves in practice. One of them has achieved considerable representativeness in practice, so it is most likely to be considered for future improvement.

2.1. Identification System 1

This identification system is constructed with numbers separated by dots. The subdivision tree has three levels, on the top level there are fifteen main groups (numbered from 0 to 14) representing the authors' view of ships and ship systems. The second level consists of subgroups that divide the main groups into smaller and more precise units; there are a total of fifty-three subgroups at this level. The subgroups are further subdivided into one hundred thirty-three second-order subgroups by adding another number separated by a period. Part of the first identification system is shown in Table 1. The table lists all the main groups and a selection of subgroups sufficient to understand the main features of this identification system.

Table 1 Excerpt of the System 1 codes [6]

Main Group		Sub-group		Second Sub-group	
0.	Containment, Protection, Accommodation				
		0.1.	Shell		
		0.2.	Decks		
		0.3.	Bulkheads		
		0.4.	Foundations		
		0.5.	Superstructure		
1.	Ship Handling – Propulsion, Positioning				
		1.1.	Engines		
				1.1.1.	Main Engines
				1.1.2.	Stern Thruster Motor
				1.1.3.	Bow Thruster Motor
		1.2.	Transmission		
				1.2.1.	Main Propulsion Shafting
				1.2.2.	Stern Thruster Shafting
				1.2.3.	Bow Thruster Shafting
		1.3.	Propulsion		
				1.3.1.	Main Propellers
				1.3.2.	Stern Thrusters
				1.3.3.	Bow Thrusters
		1.4.	Steering		
				1.4.1.	Steering Machine
				1.4.2.	Rudder, Pintle, Rudder Stock
				1.4.3.	Rudder Carrier
2.	Ship Handling – Deck Machinery				
3.	Ship Handling – Navigation, Communication, Control				
4.	Ship Handling – Bilge and Ballast				
5.	Ship Support – Electricity				
6.	Ship Support – Air				
7.	Ship Support – Water and Steam				
8.	Ship Support – Fuel Oil				
9.	Ship Support – Lubricating Oil				
10.	Ship Support – Stores				
11.	Ship Safety				
12.	Cargo Handling - care				
13.	Life Support – Sewage				
14.	Life Support – Crew care				

2.2. Identification System 2

This system is the oldest of the systems described in this paper and, moreover, the most widespread and relatively best known. It also consists of a combination of digits like System 1. The system is designed in such a way that the number of digits determines the level of subdivision. The top of the distribution tree consists of eight main groups that have only one digit, from 1 to 8. Subgroups are obtained by adding the second digit to the first, so that each main group has a large number of first-level subgroups. The tree contains a total of seventy-four first level subgroups. Adding the third digit gives the second level subgroups, of which there are a total of four hundred and twenty-six. Part of the identification System 2 is shown in Table 21. All the main groups are listed in the table, together with an overview of the subgroups, which is sufficient to understand the main characteristics of this identification system.

Table 2 Excerpt of the System 2 codes [7]

Main Group		Sub-group		Second Sub-group	
1	Ship General				
		10	Specification, Estimating, Drawing, Instruction, Courses		
				101	Contract/Specific. Work, General Design, Model Testing
				102	Drawing, Ordering etc. with Regard to Hull
				103	Drawing, Ordering etc. W.R.T. Equipment for Cargo
				104	Drawing, Ordering etc. W.R.T. Ship Equipment
				105	Drawing, Ordering W.R.T. Equipment for Crew & Passengers
				106	Drawing, Ordering W.R.T. Mach. Components, Mach/Ship Systems
				107	Estimating, Drawing & Offers W.R.T. Change Orders
				108	Purchase/Renting of Drawings, Patents, Licences & Consultati
				109	Maintenance Systems, Instruction Material
		11	Insurance, Fees, Certificates, Representation		
		12	Quality Assurance, General Work, Models		
		13	Provisional Rigging		
		14	Work on Ways, Launching, Docking		
		15	Quality Control, Measurements, Tests, Trials		
		16	Guarantee/Mending Work		
		17	Ship Repair, Special Services		
		19	Consumption Articles		
2	Hull				
3	Equipment for Cargo				
4	Ship Equipment				
5	Equipment for Crew and Passengers				
6	Machinery Main Components				
		64	Boilers, Steam & Gas Generators		
				641	Main Boilers
				644	Auxiliary Boilers
7	Systems for Machinery Main Components				
8	Ship Common Systems				

Usually, the period comes after the first three digits, although this is not a fixed rule. The second group of numbers can have two or three digits, again this is open to interpretation as can be seen in Table 3. The third group of numbers can also have two or three digits and is used to identify the equipment more precisely. Although the tree is fully described with three digits, this system has a large number of additional codes, i.e., there are more than 3500 six-digit codes that further define the subdivision. Table 3 lists all the six-digit codes of the 644 system, i.e., the exhaust gas boiler system.

This system has been renewed and modernized several times (suggestions noted when the system is used), and the number of subgroups is constantly increasing with the introduction of new devices and systems.

Table 3 Sample of six-digit codes listed under 644

646001	Exhaust gas boilers
646005	Combined boilers, complete
646007	Combined boiler casings, foundations, bolts
646009	Economizers
646011	Burners
646013	Gas air preheaters
646015	Steam air preheaters
646017	Boiler fans w/drive unit
646019	Soot blowers
646021	Photocell fans
646025	Combined boiler dosage aggregates
646027	Dosage pumps
646029	Chemical feed tanks
646031	Exhaust gas analyzers
646033	Orsat apparatus
646035	Salinometers
646037	Testwater coolers
646039	Exhaust gas coolers
646001	Exhaust gas boilers

2.3. Identification System 3

The third identification system is a distant derivative of the second system, i.e. the authors of this system partially adopted the rules and logic of system 2 and extended and modified it with new ideas to adapt its features to their needs. In this way, the system was enlarged and extended, forming its own original approach to device coding. The tree has a mixed structure (Table 4), with departments at the top of the tree that have no code designation. Each department is further subdivided into a number of smaller parts that differ in appearance and content. The coding of the maintenance department is discussed in more detail, and a brief overview is also given in the other departments section.

The maintenance department is divided into seven main groups identified by letters (A, C, E, H, M, N, O). Each main group is further divided into smaller parts within the tree by adding two digits. Each smaller part is further subdivided by adding two more digits. This subdivision of the tree goes up to the seventh level where the number has 14 digits, further subdivision is easy by adding two more digits for the next sublevel.

In this way, a very large number of codes has been created in the maintenance distribution tree, which increases with each change. The number of codes in the maintenance distribution tree is more than 20,000 at the time of this analysis.

Table 4 Excerpt of the System 3 codes

Department	Distribution tree							
MAINTENANCE								
	A	Accomodation						
	C	Communication						
	E	Electrical						
	H	Hull						
	M	Machinery						
			M01	Propulsion & Steering				
					M010101	Main Engine No1		
							M01010101	Assembly
							M01010105	Mechanical System
							M01010110	Air Starting System
							M01010115	Electrical & Control
							M01010120	Exhaust Gas System
							M01010125	Fuel Oil System
					M010105	Main Engine No2		
					M010110	Main Engine No3		
			M05	Power Generation				
			M10	HFO/MDO System				
	N	Navigation						
	O	Hull Outfitting						
ALARMS								
OPERATIONS								
DESIGN								
MEDICINES								
PROVISIONS								

The alarm department is purely numerical, so that the first level has only one digit, the second two, the third three, the fourth four, and the last six digits. The first four levels are used to organise the tree, and the fifth level uniquely determines the name of each alarm. This tree currently contains about 3700 codes.

The Operations department contains all procedures and work prescribed by various laws and company rules. It includes about 70 coded operations with more than 250 coded work procedures for these operations. All codes in this department start with P and two digits are added for each level. There are three levels in this tree.

The General design department, Medicine department and Provisions department all have the letter G as their designation. They have several hundred codes for different types of general items, mainly for different catalogues and lists.

3. COMPARISON AND DISCUSSION

As can be seen from the above, all three systems serve the same purpose, namely better and more accurate coding of ship parts or equipment. None of these systems are intended for coding of spare parts, and this part is missing in all of the systems mentioned.

The coding logic in the systems is different, each follows its own idea, its own division, and accordingly they have different number of levels and codes.

System 1 is the smallest and simplest of the presented systems, it consists of only 3 levels, with only 200 components. Such a small number of components of system 1 indicates the main problem of this system. This problem was confirmed by a detailed review of this identification system. Although the system is well designed and created, it has a major flaw. This good concept is present only at the top level, when entering the lower levels, it is obvious that the system is not complete, i.e. it does not include all components and systems that can be found on ships. Also, there is a first division in the system, but it is not defined as such. This division divides the ship into a smaller number of departments (Ship Handling, Ship Support, Life Support,...) and may be the basis for further development of this system. The significant changes that this system would require are by no means a recommendation for choosing this system as a basis for future developments.

The second system is medium sized, at the time of analysis it had 4100 components in a split tree. The concept of the tree and labeling is very good, the idea of the tree and coding is simple and high quality. The number of levels in the tree is small enough to be easily understood and large enough to allow the use of a large number of components. The system contains the vast majority of equipment found on ships and is quite up-to-date according to the latest developments in the field, which shows that the system is being modernized. At the same time, the system is partially incomplete, which leaves room for free interpretation, leading to a decrease in the uniformity of the data entered (increase in input errors). This fact was found in practice when it was discovered that different companies use different codes for the same equipment. Despite the fact that the system is simple, good and covers a large majority of systems and components, the elimination of this deficiency may be an obstacle to the future development of this system and its application as a tool for coding all devices and parts.

The third system is the most comprehensive and detailed of the three systems analyzed, with more than 20,000 components distributed across eight levels of the tree. The system defines components as completely unique; there is no problem of different coding of the same devices and components. The system has most of the devices and equipment found on ships, and it is obvious that it is frequently upgraded with new devices and technologies. Despite all the good features mentioned, this system also has some disadvantages. The large amount of data and the many levels of division have made this system confusing and often problematic in search and review. For this reason, it is questionable how the addition of another subdivision level with spare parts would affect this system, i.e. whether it would further exacerbate the observed problem. Therefore, before expanding this system with spare parts, it should be inspected in detail and simplified as much as possible.

3. CONCLUSION

A brief description of the analyzed systems showed that each of them has problems. The first system is too small and insufficiently elaborated and should be considerably expanded and enlarged, which would clear the way for the problems of System 3. The second system needs to be refined to eliminate the possibility of different interpretations of the same equipment (machine). This means adding more new components and code, which also leads to the same problems as System 3. System 3 is so bulky that the sheer size (number of system components and number of tree levels) causes problems; the codes are often too large. This system should be reorganized if it is possible to reduce the number of levels in the tree while changing the coding logic while maintaining a large number of components. One of the solutions to simplify the codes and reduce the large number series is to introduce a combination of numbers and letters in one place. Of the three systems studied, System 2 appears to be the most suitable system for modification and expansion with a spare part coding system. This system has the best coding logic, it is the most field-tested, and it generally has the fewest serious remarks. Nevertheless, it requires a significant effort to modify. The question arises whether it would not be easier to start with the creation of a new system that will contain the good features of the analyzed systems:

- As simple as the first system,
- As good or better coded than another system,
- Complete and unambiguous as the third system.

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HARMONISATION OF VTS TRAINING PROGRAMS – A CASE STUDY OF THE ADRIATIC-IONIAN REGION

Mira Šorović
Administration for Maritime Safety and Port Management, Bar, Montenegro
E-mail: mira.sorovic@pomorstvo.me

Nexhat Kapidani
Administration for Maritime Safety and Port Management, Bar, Montenegro
E-mail: nexhat.kapidani@pomorstvo.me

Žarko Lukšić
Administration for Maritime Safety and Port Management, Bar, Montenegro
E-mail: zarko.luksic@pomorstvo.me

Vlado Frančić
University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: vlado.francic@pfri.uniri.hr

Marko Strabić
University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: marko.strabic@pfri.uniri.hr

David Brčić
University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: david.brcic@pfri.uniri.hr

Ana Malovrh
University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia
E-mail: ana.malovrh@pfri.uniri.hr

Zorica Đurović
University of Montenegro, Faculty of Maritime Studies Kotor, Kotor, Montenegro
E-mail: zoricag@ucg.ac.me

Toni Maričević
Ministry of Sea, Transport and Infrastructure, Zagreb, Croatia
E-mail: toni.maricevic@pomorstvo.hr

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Abstract

This paper presents an example of harmonized training programs for Vessel Traffic Services (VTS) for a specific region controlled by more than one state. It is a result of the EU-funded Interreg EUREKA project, one of the goals of which has been to harmonise training programs for VTS operators in the Adriatic-Ionian (AI) Region. Therefore, this paper briefly describes the proposed training programs comprised of 15 modules and delivering two training levels - operational (VTS operators) and management (VTS supervisors). The modules were developed for educational content with specified training hours, based on the official and current requirements of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). In addition, the idea behind the harmonized training modules was to meet the specific requirements for VTS competencies which encompass the particularities of the Region. The Regional specifics taken into consideration included the geographical area, maritime traffic density, national legislations and requirements, and similar variables and specifics. An overall goal of the program development and harmonisation was to provide the operators with additional and tailored skills and competencies aiming to improve their overall performance and decision-making process.

Keywords: VTS training programs, VTS operator, VTS supervisor, harmonization, Adriatic-Ionian Region

1. INTRODUCTION

The need for expanding regional interconnections between maritime and land safety and security agencies has been evident in the AI Region and many (other) EU countries. This fact has been amplified by numerous challenges facing the European continent at the beginning of the XXI century. EU countries and agencies are well aware of various issues arising from the exposure of southern EU borders. Therefore, they have created many initiatives for interagency cooperation established at an institutional network level of responsible stakeholders. Criminal threats, environmental issues, massive illegal migrations, maritime risks, illegal fishing and many other problems need to be minimized in order to mitigate their negative impact on the maritime sector [1]. Also, the prevention of maritime accidents has been one of the key goals of the AI Region. Bearing this in mind, it is important to create an integrated and common platform for better responses to all activities at sea [2]. Considering the features of the Region and the specifics of maritime traffic in the area (Figure 1), a proper establishment and engagement involving all related stakeholders is essential for a sustainable protection of the AI Region. With close regional cooperation and coordination of the public administrative authorities, the aim is to raise the level of maritime safety and security in the Region. Additionally, information sharing and data transparency between the regional partners must be increased in order to ensure an overall situational awareness and provide for good cooperation and appropriate operational response between the AI national administrations [3].

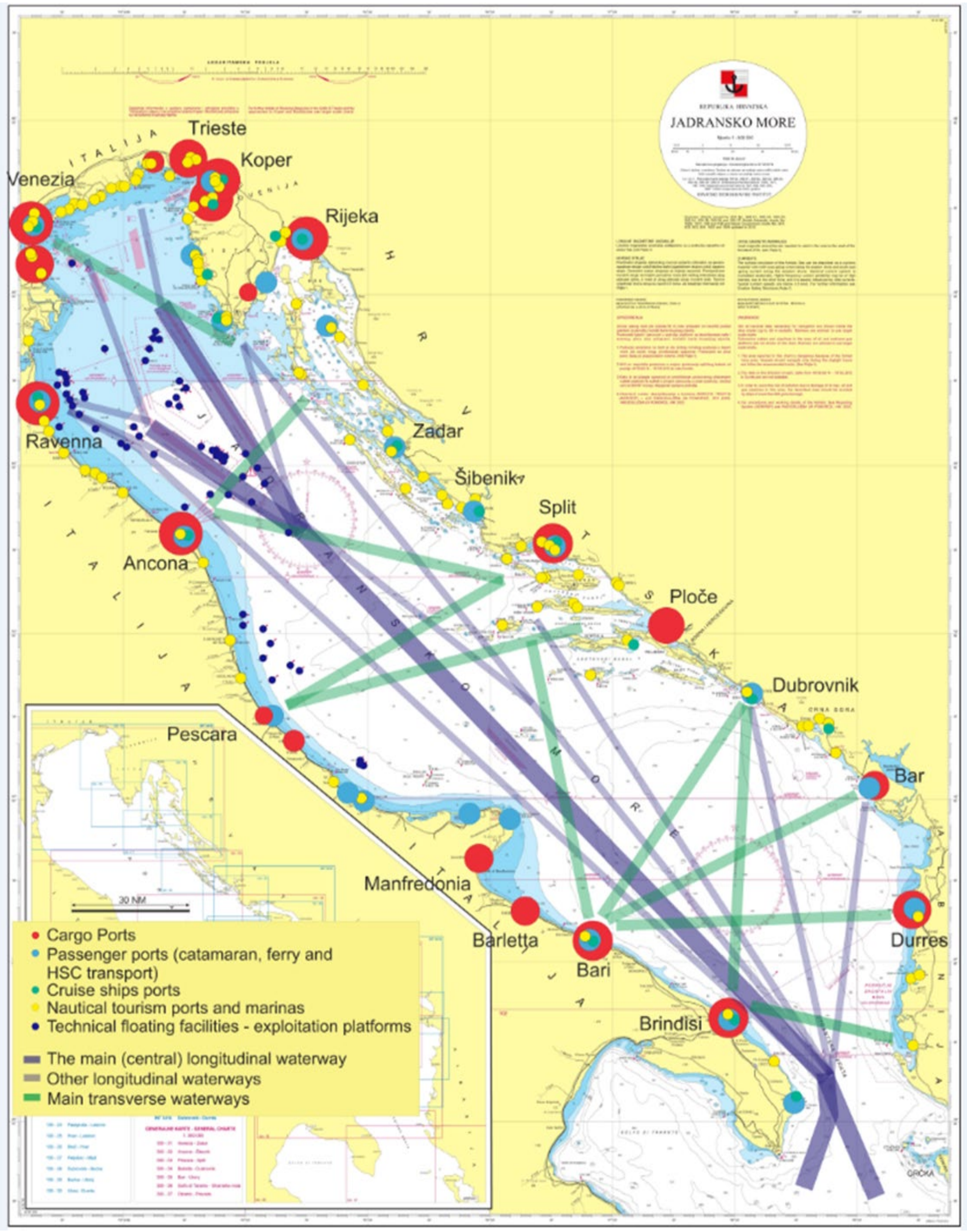

Figure 1 Significant ports and main waterways of the Adriatic Sea as a part of the AI Region

Source: Made on Nautical Chart No 101 - Adriatic Sea (courtesy ©Croatian Hydrographic Institute) and adapted based on [4]

The AI seas and countries display a strategically important part of the European maritime transport system which needs to be fully integrated into the networking initiatives of the European Union. One of the crucial initiatives for this AI Region is the EUREKA Project (INTEREG V-B Adriatic-Ionian ADRION programme 2014-2020), started on 1st December 2020, as a base for the future significant process of upgrading maritime safety [5]. It mainly refers to the implementation of the modernized ADRIREP technical solutions, the introduction of STM and the establishment of the Maritime Safety Permanent Transnational Network.

In addition to the development of systematic coordination, harmonisation of the legal basis for cooperation, enhanced data exchange level, the specific objectives of the EUREKA Project are the harmonization and standardisation of VTS services and development of the common educational framework for VTS operators. Furthermore, it is expected to reflect on the reduction of the operators' workload [6] [7]. The following chapter presents the basic features of VTS training as defined by relevant institutions. The third chapter explains the analysis of the existing VTS standards of competences, as well as VTS training elements in the referring countries. Based on the previous elaboration and having identified the missing gaps, the main section discusses a proposal for specific VTS competence standards in the AI Region and their feasibility according to current and planned resources. The paper concludes with the main findings and possible guidelines for the continuation of work both from the theoretical and practical point of view.

2. VESSEL TRAFFIC SERVICE TRAINING

Vessel Traffic Services contribute to the safety of life at sea, safety and efficiency of navigation, protection of marine environment and the adjacent shore area, worksites and offshore installations from possible adverse effects of maritime traffic [8]. The significance of the assigned roles imply that VTS personnel need to be properly trained and qualified. Furthermore, procedures and standards for VTS personnel training should be followed in accordance with the International Maritime Organization (IMO) requirements and the standards of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). Hence, the training program includes standardized training for trainees without a nautical background and for trainees with specific qualifications and certificates of competency, in accordance with the International Convention on Standards of Training, Certification and Watchkeeping of Seafarers (STCW).

The IALA Recommendations on the training and certification of VTS personnel define that competent authorities and VTS authorities establish and implement VTS training and certification in a harmonized and standardised manner, as provided by the guidelines and model courses developed by the IALA.

For specific VTS employee categories, regarding the training for VTS personnel, IALA defined a series of model courses, given and elaborated on in the continuation [9]:

- VTS Operator training (V-103/1);
- VTS Supervisor training (V-103/2);
- VTS On-the-Job training (V-103/3);
- VTS On-the-Job Instructor (V-103/4);
- Revalidation process for VTS Qualifications and Certification (V-103/5).

VTS Operator training (V-103/1) - Training of participants for becoming VTS operators should be in accordance with the IALA module course for VTS Operator Training V-103/1. The training needs to be carried out by a qualified instructor who should understand the training objectives, be academically and professionally competent, has appropriate teaching qualifications and operational experience in using a simulator [10].

Assuming that the course attendant has no previous maritime qualification, the course should provide skills through three components: Nautical knowledge, VTS theory and VTS operation. In line with the subject modules, it is recommended to perform simulation exercises such as: Basic skills, Traffic interaction and conflict resolution, and Emergencies and special situations.

VTS Supervisor training (V-103/2) - Training for a VTS Supervisor should be organized and conducted in accordance with the IALA module course for VTS Supervisor Training V-103/2. It needs to be conducted by an academically and professionally qualified instructor who has operational experience and teaching qualifications, as well as understanding of the training objectives. There is a specified VTS Operator experience needed as an entry prerequisite in order to undertake the advanced duties of a VTS Supervisor [11].

VTS On-the-Job training (V-103/3) - This model course is planned to cover the ability and functional competence required for an endorsement in a VTS Certification Log stating that the holder has completed the On-the-Job training at a VTS Centre. The training should be structured within standard operating procedures and the specific VTS centre elements, presented in realistic atmosphere, monitored and conducted according to the model. The candidates for an On-the-Job training course need to have completed VTS Operator Training model course (V-103/1) and VTS Supervisor Training model course (V-103/2) [12].

VTS On-the-job Instructor (V-103/4) - This model course is planned to provide practical guidance and training required for becoming an effective instructor of the model course V-103/3 On-the-Job Training. Each candidate for an On-the-Job Instructor is obliged to complete the model course V-103/3 On-the-Job Training before joining this model course [13].

Revalidation process for VTS Qualifications and Certification (V-103/5) - There is a realistic need for continuous professional development. The Revalidation course provides a structured means for VTS personnel to reinforce and refresh previously completed VTS training and maintain a required level of skills and performance in the areas of knowledge that have been underused and underapplied. This training should cover generic and area-specific elements of competency [9].

3. ANALYSIS OF THE EXISTING VTS STANDARD OF COMPETENCES

The IALA Recommendations on the training and certification of VTS personnel define five levels of competence used in the model courses [10].

Level 1 represents the work of a routine and predictable nature. It generally requires supervision. The instructional objective of this level is to interpret verbal/written material, understand the facts and principles, interpret charts, graphs and illustrations, estimate the future implied in data and justify methods and procedures.

Level 2 represents a more demanding range of work, involving greater individual responsibility. Those are some complex and/or non-routine activities. The instructional objective of this level is to apply regulations and theories to practical situations, apply concepts and principles to new situations and demonstrate the correct usage of methods or procedures.

Level 3 represents a skilled work that involves a broad range of work activities. Mostly, they are complex and non-routine activities. The instructional objective of this level is to recognize unstated assumptions, logical inconsistencies, distinguish between facts and inferences and analyse the organizational structure of work.

Level 4 represents work that is often technical, complex and professional with a substantial degree of personal responsibility and autonomy. The instructional objective of this level is to integrate knowledge from different areas into a problem-resolution plan. The necessary skills are well developed so that individuals can adapt rapidly to special requirements or situations.

Level 5 represents the complex techniques across a wide and often unpredicted variety of contexts. It refers to professional/senior managerial work. The instructional objective is to evaluate the adequacy with which conclusions are supported by data, evaluate the value of the work against internal criteria.

The IALA model course aims to support training organizations and teachers in creating new training programs for VTS personnel, or improving the existing training materials. It provides guidance on the necessary skills and competencies needed for VTS personnel to perform their duties safely and efficiently. The following table represents the current modules per each IALA model course. In Table 1, a summary of IALA training model courses is presented.

Table 1 Summary of IALA training model courses

	VTS Operator training (V-103/1)	VTS Supervisor training (V-103/2)	VTS On-the-Job training (V-103/3)	VTS On-the-Job Instructor (V-103/4)
MODULES	Communication Coordination and Interaction	Advanced Traffic Management	Communication Coordination and Interaction	Development of a VTS Centre-Specific Training Programme
	Legal Framework	VTS Equipment	Legal Framework	Preparation of a Trainee-Specific Programme
	Provision of VTS	Additional Personal Attributes	Provision of VTS	Delivery of On-The-Job Training
	Nautical Knowledge	Responding to Emergency Situations	Local Knowledge	Evaluation/Assessment/Examination of Trainees
	Equipment	Administrative Functions	Equipment	Completion of OJT Leading to Authorisation to Operate
	Human Factors	Legal Knowledge	Human Factors	
	Emergency Situations		Emergency Situations	

Source: IALA Model Course [10, 11, 12, 13]

When it comes to educational and training programmes in Adriatic-Ionian countries, there are certain differences. In some countries like Italy, Croatia and Greece, VTS training system is well organized with a developed regulatory framework that fully complies with international regulation, primarily with IMO requirements, and following the IALA standards. The following table represents the current state of the VTS training elements in the AI Region.

Table 2 VTS training in EUREKA partner countries

Country	VTS implemented	VTS training	VTS national program
Albania	Partially	No	No
Bosnia and Herzegovina	No	No	No
Croatia	Yes	Yes	Yes
Greece	Yes	Yes	Yes
Italy	Yes	Yes	Yes
Montenegro	Yes	No	No
Slovenia	Yes	No	No

Source: EUREKA project deliverable

Considering the role of VTS in the provision of safety of navigation, VTS personnel needs to be adequately qualified and trained. To ensure a satisfying and equal level of safety of maritime transport, the idea has been to harmonize and implement a unique training programme for VTS operators in the AI Region.

4. A PROPOSAL FOR SPECIFIC VTS STANDARD OF COMPETENCES IN THE AI REGION

In accordance with the needs and the actual situation within the Region, as well as potential room for improvements due to the new technologies and available resources, the proposed specific VTS standard of competences is presented below. This proposal refers to recognized and justified needs and tendencies towards an improved and tailored VTS education, as well as overall development of the VTS educational process. Among other advances, it provides a desirable standardization, employment and consideration of both existing and emerging technologies, as well as the review of the current curricula.

The VTS operator training course should meet the minimum entry requirements. The prerequisite standard for entry to a V-103/1 VTS operator course is the STCW II/1 OOW or equivalent qualification. If a participant does not fulfil the prerequisites, an additional training can be arranged for those who wish to start a career with VTS. For those personnel basic nautical knowledge should be introduced as a mandatory requirement. Such training should consist of lectures and practical work. It is considered an introduction to further education and attending training programs for VTS operators and it is to be conducted over 10 working days (80 hours).

The level of training in the proposed specific VTS standard of competencies was designed as a Management level for VTS supervisors and instructors and an Operational level for VTS operators. Levels of training and the proposed training modules are presented and described in the following Tables.

Table 3 Level of training with designated positions and modules

Level of training	Targeted Position	Training Module /Program (Mandatory)	Training Module (Optional)
Management	VTS Supervisors, Instructors	7, 12, 13	8, 14
Operational	VTS Operators	1, 2, 3, 4, 6, 9, 10, 11, 15	5

Source: EUREKA project deliverable

Table 4 Training Modules

Training module	Competences	Hours (Lectures and Exercises)
1 Nautical knowledge	- Use of nautical charts and publications - Complying with Collision Regulations - Proper use of Aids to navigation - Definition of port operations - Understanding of shipboard terminology	20
2 Traffic management	- Ability to clarify international and national regulations - Understanding the VTS roles and responsibilities - Determining VTS environment - Understanding of traffic management, monitoring and traffic organisation	13
3 Equipment	- Use of VHF radio system and VHF/Direction finding - Use of RADAR - Use of tracking system	10
4 Language and Communication skills	- Ability to create appropriate language and specific VTS message structures - Establishing communication in accordance with maritime rules - Establishing communication procedures (including SAR)	10
5 Personal attributes	- Ability to develop social interaction skills - Responsibility and reliability	6
6 Emergency situations	- Planning and conducting a contingency plan - Response to situations - Determining and recording activities during and after emergencies - Maintaining safe waterway	7
7 Advanced Traffic management	- Ability to perform Traffic/port management organization - Ability to react in case of pollution of dangerous cargo	4
8 VTS equipment	- Operating VTS equipment	6

9 Digital publications	- Use of digital services	6
10 Surveillance and Navigation Information Systems	- Ability to use Electronic Chart Display & Information System - Determining all features which are included in ECDIS - Ability to correct ENC charts - Understanding the roles & responsibilities of a Regional ENC Coordinating Centre (RENC) - Ability to perform System/Data update and Licencing/Maintenance - Sea Traffic Management (STM) system	20
11 VTMIS/Integrated Services	- Understanding the function of VTMIS - Determining the stakeholders of VTMIS - Use of SafeSeaNet - Use of e-Navigation - Understanding the IHO standards and products related to VTS operations	12
12 Additional personal attributes	- Developing leadership skills - Dealing with stressful situations - Human-Machine Interaction: existing technologies - Human-Machine Interaction: new/emerging technologies	8
13 Responding to emergency situations	- Planning and conducting of contingency plan	6
14 Administrative functions and legal knowledge	- Ability to plan and organize - Understanding the legislation	6
15 VTS Operator Simulator Exercises – Case Studies	- Ability to apply vessel traffic monitoring and organisation methods - Ability to deal with real life traffic management situations	8

Source: EUREKA project deliverable

The proposed specific standards refer to justified needs for improvement in VTS education and it is a step towards the harmonization of VTS training programs in the AI Region. We find this standardisation crucial for proper and reliable execution of activities and tasks related to the supervision, monitoring and surveillance of maritime traffic in the Region.

Nevertheless, due to the different approaches in the countries of the AI Region, full harmonization of training programs still fails to be achieved. The main difference is the model of staffing the VTS centres and the entry competencies of the VTS staff. This program represents solely a proposal, and does not interfere with the right of the states to regulate and conduct the manning and training of VTS personnel through their national legislation. It is also recommended that countries in the AI Region adapt and further improve the program during the implementation according to their own national regulations, practices and resources. The uniform implementation may be rendered possible and feasible with further collaboration and engagement of all related countries and respective stakeholders.

4. CONCLUSION

This paper represents a case study of the AI Region in the attempt to harmonise VTS training programs for this specific Region that is controlled by more than one coastal country. This activity is a result of the EU-funded Interreg EUREKA project, one of the main goals of which has been the harmonisation of the training programs for VTS operators in the AI Region. Therefore, this paper briefly describes the proposed training programs comprised of 15 modules and covering the delivery of two training levels - operational (VTS operators) and management (VTS supervisors). The modules were developed based on the current IALA model courses and considering specifics characteristics of Adriatic Ionian region. More precisely, the modules were developed for educational content with specified training hours and modules. In that way, the idea behind the harmonized training modules was to meet the specific requirements shaping VTS competencies which encompass the particularities of the Region. The regional specifics taken into consideration include the geographical area, maritime traffic density, national legislations and requirements, and similar variables and specifics. In accordance with all the aforementioned, the overall goal of the programs' development was to provide the operators with additional and tailored skills and competencies, with the aim to improve their overall performance and decision-making process.

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MARINE RENEWABLE ENERGY

Ljubica Vidović
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: lvidovic1@pfst.hr

Gorana Jelić Mrčelić
University of Split, Faculty of Maritime Studies
Split, Croatia
E-mail: gjelic@pfst.hr

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Abstract

The aim of this paper is to provide a brief overview of the role of marine renewable energy (MRE) in generating renewable energy to reduce global dependence on fossil fuels and mitigate the associated negative environmental impacts. The social, environmental and economic benefits, as well as the opportunities for developing and applying new MRE technologies and related innovations, particularly in European countries, are examined. Some technologies, such as offshore wind, are mature and widely recognized as proven and reliable renewable energy sources. Technologies such as wave energy, tidal energy, Ocean Thermal Energy Conversion (OTEC), or salinity gradient energy are still at an experimental stage, but could open up new opportunities in the future. Nevertheless, ocean energy has the potential to provide reliable, sustainable, and affordable renewable energy. The key to successfully harnessing ocean energy is investing in research and development, while taking into account the impact on already degraded ecosystems. Considering all these facts, MRE technologies can significantly support the sustainable development of many sectors, as they have a great potential for providing renewable, affordable and clean energy, creating well-paid jobs and reducing negative impacts on the environment. Europe strongly supports the research and innovation efforts needed to achieve climate neutrality and MRE technologies offer European countries the opportunity to become leaders in MRE production.

Keywords: marine renewable energy, innovations, sustainable development, environmental impact, EU

1. INTRODUCTION

The oceans and seas are considered a clean and renewable source of energy. Given the immense size of the oceans, MRE has great potential to solve energy problems, not only economic but also environmental, and can contribute to the achievement of all 17 Sustainable Development Goals (SDGs). Over the years, various technologies have been developed to harness the constant energy inherent to oceans in its various forms. They fall into four main groups depending on the type of energy they harness: OTEC, tidal energy, wave energy, and salinity gradient technologies.

MRE can play a major role in reducing greenhouse gasses (GHGs) emissions and decarbonizing energy systems. Since its adoption in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) has been the primary forum for cooperation among nations on climate change caused by GHGs. Its goal is "to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, within a time frame that allows ecosystems to adapt naturally and provides sustainable development" [1]. Renewable energy technology is supported in all sectors by climate protection policy [2], [3], [4]. Since the *Kyoto protoco*l [5] and the report of the *Intergovernmental Panel on Climate Change (IPCC) on CO_2 capture and storage*, there is an emerging need to reduce the emission of CO_2 to the atmosphere. "In principle, three possible routes can be envisioned focusing on:

1. the reduction of the energy consumption,
2. the efficient use of energy sources (if desired combined with capture and storage of CO_2),
3. the use of alternative energy sources with reduced or no CO_2 emission" [6].

As The Paris Agreement [7] requires technology development, as well as economic and social transformation, based on the best available science, MRE could significantly contribute to technology development and create new opportunities for future development [8].

The importance and potential of marine renewable energy (MRE) is also recognized in the European Green Deal [9]. The development of the offshore energy industry would contribute to reducing greenhouse gas emissions by at least 55% until 2030 compared to 1990 levels. The offshore wind industry would be in line with the EU Biodiversity Strategy. The offshore wind industry uses less than 3 % of European maritime space [10].

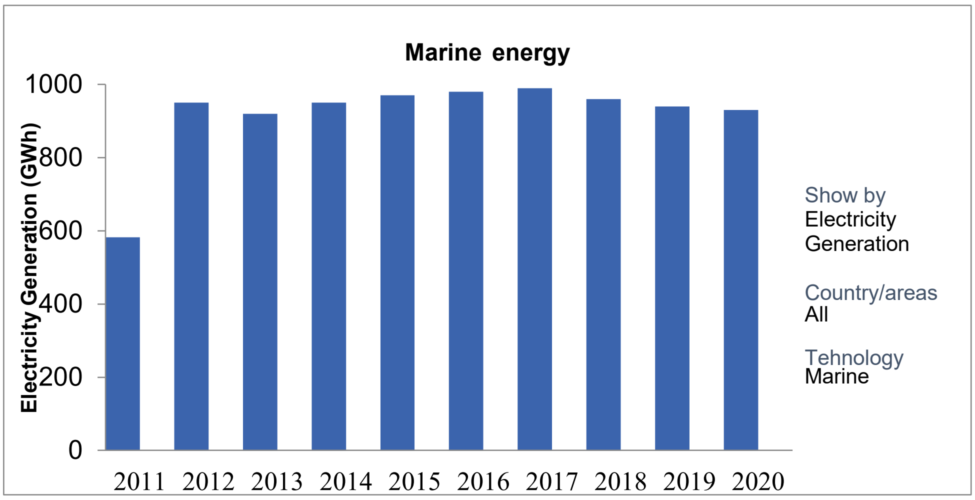
Achieving *Sustainable Development Goal (SDG) 7: Ensuring access to affordable, reliable, sustainable, and modern energy for all*, with its targets for universal access, energy efficiency and renewable energy, will open a new world of opportunity for billions of people. It will lay the foundation for poverty eradication, climate action and a sustainable world [11].

Offshore renewable energy sources can contribute to the creation of a global blue economy and energy transition, in addition to decarbonising the energy system [12]. The blue economy is defined by the World Bank as "the sustainable use of ocean resources for economic growth, improved livelihoods and jobs and ocean ecosystem health, which encompasses many activities, including renewable energy, fisheries, maritime transport, waste management, tourism and climate change" [13].

The aim of this paper is to provide a brief insight into the development of MRE, its importance in reducing global dependence on fossil fuels, and the associated long-term environmental, social and economic benefits and new opportunities, particularly in European countries.

2. MARINE RENEWABLE ENERGY

The oceans undoubtedly have potentially critical role for the development of the nature-based solutions, which should contribute to the net zero transition [14]. Graph 1 shows electricity generation (GWh) from renewable marine resources worldwide from 2011 to 2020 [4].



Graph 1 Electricity generation (GWh) from renewable marine resources worldwide from 2011 to 2020
Source: [4]

The global situation is depicted for the period 2011 to 2020. From 2011, a significant increase is seen, reaching its maximum in 2017, followed by a slight decrease in electricity generation in the following years. Apart from significant growth in 2011, there was no major boom and energy production remained constant.

In recent years, the European Union (EU) has invested an average of nearly 20 billion € a year in clean energy [10] [15], with business contributing an estimated 77%, national governments 17% and EU funds 6% [10]. By 2050, ocean energy could provide 10% of the European Union's (EU) current electricity needs, provided the legal and economic conditions are favourable. One of the biggest current problems facing the EU is the transition from a system based on imported fossil fuels to a flexible and interconnected system based on clean, renewable and unlimited indigenous resources. Europe's seas and oceans could play an important role in meeting this challenge [16].

2.1. Offshore wind energy

Offshore wind is seen as a promising investment occasion [3], [17], supported by a substantial pool of capital to fund projects, provided the right risk management framework is in place [3]. In 2021, offshore turbines accounted for more than 18% of global wind energy capacity (up from 6.5% in 2020 and the previous high of 10% in 2019) and represented nearly 6.5% of total capacity at the end of the year (4.7% in 2020) [18]. Europe dominates the market with over 70 % of the total installed offshore wind capacity, mainly concentrated in the North Sea and the Atlantic. Over the past two decades, Belgium, Denmark, China, Germany and the UK have led the expansion of offshore wind [12].

In Denmark, after the oil crisis in the 1970s, a wind energy industry emerged with its own market for products. Originally, the concept was seen primarily as a demonstration project to support the development of the wind energy industry and promote its export. Vindbey project, located on the Danish coast with a total output of 5 megawatts (MW), covered the annual consumption of 2200 Danish families [19]. The modern wind turbines on the market today have a rotor span of 164 meters and a capacity of 8 MW, and each of them can now generate almost twice as much energy as all 11 small turbines that make up the Vindeby Offshore Wind Farm [20]. The trend of increasing turbine size is inversely proportional to the installation costs and to the grid connectivity per produced energy unit [21].

Countries in Europe currently dominate and lead in both floating wind foundations and airborne wind energy demonstration projects [12]. Over the past ten years, one of the focuses of the EU's Research and Innovation (R&I) initiatives were offshore technology, floating offshore wind turbines, innovative materials and components and maintenance and monitoring which jointly were granted around €496 million [10], [22]. EU targets include "a new offshore renewable energy strategy of the European Commission as part of the EU Green Deal aiming for 60 GW of offshore wind by 2030 and 300 GW by 2050" [12].

The Commission's analysis of The International Renewable Energy Agency (IRENA) suggests that in order to achieve the Paris Agreement [7] goal of preventing the global average temperature from rising above 1.5 degrees Celsius (°C), a transition to renewable energy sources is needed. Offshore wind, in particular, should be deployed on a large scale, with a cumulative installed capacity of more than 380 GW by 2030 and over 2.000 GW by 2050 [12]. According to IRENA's statistics 2022, in 2021, the total installed capacity of offshore wind energy was 55678 megawatts (MW), and European Union 15135 MW [23].

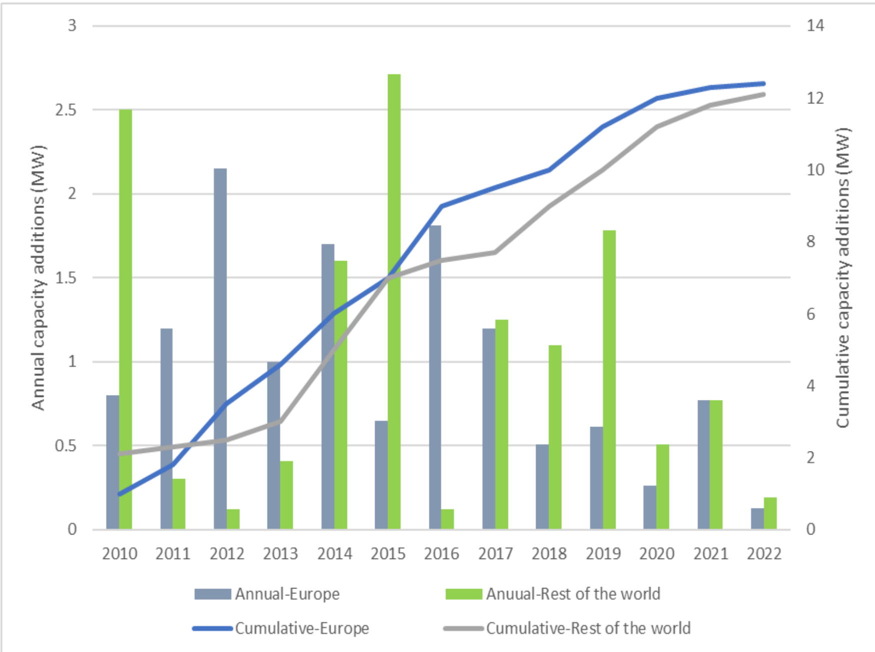
The interest in wind energy for the production of hydrogen is growing, attracting the attention of major energy consumers such as metal manufacturing and mining industries [18]. The offshore sector creates decent jobs and employment opportunities in science, technology, engineering and mathematics (STEM), as well as in other skilled occupations [3].

2.2. Wave energy

The total geophysical wave energy potential is around 32000 TWh/year [24], [25], and the global technical potential from 1750 [26] to 5550 TWh/year [27], [25]. There are currently 33 wave energy converters in operation in nine projects spread across eight countries and three continents, with a total capacity of 2.3 MW. The only project currently in operation has a capacity of more than 1 MW and was built in Hawaii in early 2020 [28].

There is a variety of design in wave energy converters, including: Point Absorbers (PA), Oscillating Wave Surge Converters (OWSC), Oscillating Water Column (OWC), Rotating Mass (RM) and other [2].

Graph 2 shows installed global wave energy capacity in Europe and the rest of the world from 2010 to 2022 [29].



Graph 2 Installed global wave energy capacity in Europe and the rest of the world from 2010 to 2022
Source: [29]

Since 2011, there has been an increase in installed wave energy capacity in Europe exceeding the value in the rest of the world. The annual cumulative values in Europe and in the rest of the world are continuously growing respectively and approximately are within close boundaries. In Europe, the maximum was installed in 2012 and in the rest of the world in 2015.

Since 2010, 12.7 MW of wave energy has been installed in Europe. With test programmes completed, 1.4 MW is currently in the water and 11.3 MW has been decommissioned [30].

2.3. Tidal energy

Tidal stream generators (TSGs) work on a similar principle to wind turbines, using the kinetic energy of moving water to drive the turbines. Some types of tidal stream generators can be installed in existing bridges without any visible aesthetic changes. In the tidal turbine, the generator is driven by spinning underwater blades. The underwater turbine uses the tides to push water onto the blades, causing them to spin. As the blades rotate, the gearbox sets the induction generator in motion, which generates an electric current [31].

Currently, tidal turbines with horizontal and vertical axes use blades that are either parallel (horizontal) or perpendicular (vertical) to the direction of water flow. The turbines are similar in design to wind turbines, but because water has a higher density than air, the blades are smaller and rotate more slowly [32].

The tides are not influenced by the weather but by cyclical constellations and can therefore be predicted in the short and long term. This is its main advantage, even if it has less potential than other renewable energy sources such as solar radiation or wind [28]. However, the conventional energy sources electricity production cost is still significantly cheaper compared to former mentioned [33], [34].

Tidal stream devices continuously raise their maturity level followed by started precommercial projects. Around 40 MW of tidal stream capacity has been deployed since 2010, with approximately 15 MW currently operational [18]. Although there has been a trend towards the use of horizontal axis turbines in recent years, new technologies to harness tidal currents continue to be explored to significantly increase resource capacity. In recent years, capacity has increased many times over, with turbines as small as 100 kilowatts (kW) growing to 1.5 MW [28].

In Europe, total research and development (R&D) spending on wave and tidal energy between 2007 and 2019 was EUR 3.84 billion, of which EUR 2.74 billion came from the private sector [10], [15]. National R&D programs provided EUR 463 million for wave and tidal energy development, while the EU provided EUR 493 million. On average, the ratio was EUR 1 billion in public funding (EU and national) to EUR 2.9 billion in private sector investment [10].

2.4. Ocean Thermal Energy Conversion (OTEC)

Georges Claude was pioneer in OTEC technology 80 years ago [35]. OTEC electricity generation is based on the principle of generating energy through the temperature difference between the warm surface and the cold layers at a depth of 800 to 1000 meters and converting this into electrical energy through a thermal circuit [28]. The disadvantage of OTEC technology is its limited geographical applicability. It can only be used in equatorial areas where the temperature difference between the warm upper and the deep cold parts of the year is at least 25°C [36].

OTEC has a special potential. Its main advantage is the ability to provide non-intermittent, continuous baseload power that is endless. OTEC can be linked to other technologies, which allows it to be used in other areas such as aquaculture, where wastewater from production can be used. There is the possibility of linking with Seawater Air Conditioning (SWAC) for cooling and Seawater Reverse Osmosis (SWRO) for freshwater production [28].

The global theoretical potential of OTEC technology is 30 TW, but the economic potential of OTEC energy is still unknown without commercial operation [37]. OTEC technology is still in the R&D phase and has not yet been commercialised [28].

2.5. Salinity gradient energy

The controlled mixing of two salt solutions with different concentrations is called salinity gradient power (SGP) or *osmotic energy*. In 1954, Pattle described the working concept of SGP for the first time [38]. In salinity gradient technology, energy is extracted from the difference in salt concentration between fluids using Pressure Retarded Osmosis (PRO) or Reverse Electrodialysis (RED). The great potential for generating this type of renewable energy lies in the riverbeds where the water flows into the ocean [12], [28]. In the future, further technological development could lead to commercial energy production [39]. The main economic drawback is the high capital cost (the cost of membranes accounts for 50-80% of the total capital cost), and in order to be competitive, the price should decrease from 10-30 EUR/m^2 to 2-5 EUR/m^2 [40].

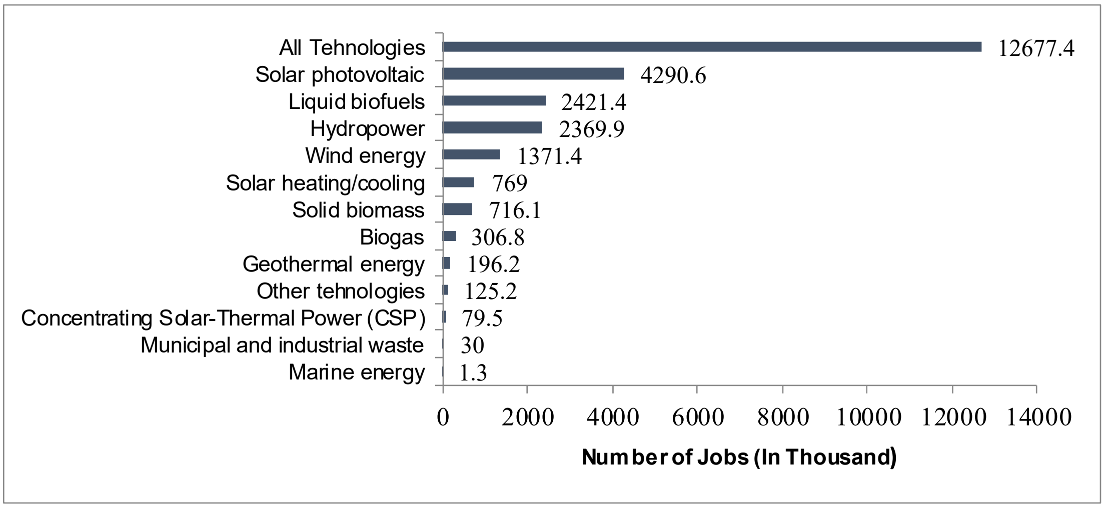
The potential for salinity gradient power is estimated at 647 GW worldwide, representing 11% of global power capacity and 23% of electricity consumption in 2011 [40]. The research related to the salinity gradient is still ongoing and the technology is still in the conceptual phase [28].

3. SOCIAL IMPACTS OF MARINE RENEWABLE ENERGY

Given the current trend in the transition to renewable energy sources, the number of people employed in this sector will reach 38.2 million by 2030 [4]. According to *EU Strategy to harness the potential of offshore renewable energy for a climate neutral future today*, 62000 people work in the offshore wind industry sector and 2500 in the ocean energy [10], [41]. In the near future, the offshore renewable energy technology sector in EU will surpass the conventional energy sector in terms of employment growth and make a greater contribution to Gross Domestic Product (GDP) growth [10].

The offshore wind energy sector will create 226000 jobs by 2030, accounting for 60% of all wind-related jobs. In the ocean renewable energy sector, it is expected 470000 new jobs by 2050, or 10 to 12 jobs (direct and indirect) per installed system MW [42].

Graph 3 shows number of jobs (in thousands) in the renewable energy sector by technology worldwide in 2021 [4]



Graph 3 Number of jobs (in thousands) in the renewable energy sector by technology worldwide in 2021
Source: [4]

As can be seen, compared to the other renewable energy sectors, marine energy has the lowest number of jobs in 2021, only 1288 jobs at the global level, or only 0.01% of all renewable technology jobs. This is still far less than the projected number of jobs in 2050.

4. ENVIROMENTAL IMPACTS OF MARINE RENEWABLE ENERGY

Offshore wind can play a major role in reducing GHG emissions and decarbonizing energy systems. The average carbon intensity of electricity generated is 475 t CO_2 per GWh [3], [43], while offshore wind farms emit between 5 and 13 t CO_2 per GWh over their lifetime [3], [44].

MRE is certainly an environmentally better option than fossil fuels, but it has drawbacks. As wind energy technology spreads geographically, the impact on wildlife will increase [45]. Some of the potential negative impacts of offshore wind farms include the risk of bird collisions with wind turbine blades or even displacement from existing habitats [46]. Collision risks, pollution, increased noise levels and changes in concrete and pelagic habitats are environmental problems associated with the development of MRE and offshore wind farms [47]. Studies of the effects of marine energy installations on animal behaviour have shown that animals are attracted to structures in the water and can sometimes have positive effects on marine life [48], [49], [50]. The creation of additional reefs in vicinity of the wind farm can lead to an increase in biological productivity [46].

The World Bank Group (WBG) framework describes "how environmental and social issues can be considered within a marine spatial plan, recommends approaches to data collection and analyses, and discusses how marine spatial planning (MSP) for offshore wind could be delivered in emerging markets" [3]. Despite numerous threats to life on the Earth, there are optimistic forecasts that the Sustainable Development Goal can be achieved [14]. The innovative technical, operational and site-specific solutions are key to combating environmental problems.

5. CONCLUSION

The oceans are considered a clean and renewable energy source. Currently, there are a significant number of innovative technologies in both offshore wind and marine energy, but aside from offshore wind, which is by far the most mature marine technology, MRE technology in general still lags far behind other energy sources. This is because most MRE technology projects are still at an early stage of development and are not yet commercialised due to their low efficiency and high cost. The high cost of the marine plant leads to high cost of the energy produced, and the underdeveloped energy storage system hinder further spread of the technology.

Although the first OTEC plant was built almost 80 years ago, no large-scale projects have yet been realized. Apart from its uniquely large potential, no commercial OTEC plant is yet in operation. The main advantage of tidal energy is its long-term predictability due to repetitive natural phenomena. However, similar to wave energy, advances in tidal energy are still in the research and development phase due to initial construction costs. Consequently, the price of electricity from wave and tidal energy is still very high. Among the other MRE technologies, salinity gradient power is the least developed and is still in the pilot phase.

Ocean energy has great potential to become a new source of reliable, sustainable, and affordable energy. In addition to the great advantages of ocean energy as a clean and renewable source of energy, as opposed to fossil fuels, it has another great advantage over fossil fuels - it is not dependent on geopolitical factors. The immensity of the ocean is another advantage of MRE, as it makes it easier to find a suitable location for the plant and minimises the possibility of spatial conflicts. Unfortunately, MREs are not quite ready for commercialization and require huge investments in research and development. It is also difficult to assess the potential environmental, and particularly marine ecosystem, impacts associated with MRE. Considering all this, MRE technologies offer a great opportunity to provide renewable, affordable and clean energy, which is crucial for the sustainable development of many sectors. It also opens up the possibility of creating well-paying jobs and reducing negative impacts on the environment. Europe is investing heavily in research and innovation to achieve climate neutrality, and the emerging sector of MRE technologies is a great opportunity for European countries to become leaders in the MRE energy sector.

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ANALYSIS OF INACCURATE DEPTH DATA ON NAUTICAL CHATS AND RECOMMENDATIONS FOR IMPROVING ACCURACY

Lea Vojković
University of Split
Faculty of Maritime Studies
Split, Croatia
E-mail: lvojkovic@pfst.hr

Srđan Vujičić
University of Dubrovnik
Maritime Department
Dubrovnik, Croatia
E-mail: srdjan.vujicic@unidu.hr

Josipa Vujević
Hydrographic surveyor/Data Processor – freelance
Split, Croatia
E-mail: skasela@gmail.com

Dejan Lovrinčević
Hydrographic Institute of the Republic of Croatia
Split, Croatia
E-mail: dejan.lovrincevic@hhi.hr

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Abstract

Much of the world's oceans, seas, and coastal waters are not surveyed as recommended by the International Hydrographic Organization (IHO). Therefore, the question arises as to how these specific areas can be accurately surveyed and nautical charts updated. Current methods of hydrographic surveying include the following: single-beam and multibeam systems, sweep systems, side-scan sonars, and more recently Light detection-and-ranging systems (LIDAR) and Laser Scanners. Aero-photogrammetry and remote sensing have always been used to collect spatial data and therefore occupy an important place in hydrography. With the development of technology, all these research and survey methods, together with satellite imagery, provide a high degree of accuracy and precision of spatial data. By means of consolidated data obtained through various survey methods and developed spatial-time databases, Geographic Information System (GIS) technology makes it possible to gain insight into the broader sea and coastal area and hence to define the risk areas for navigation and to set the priorities for more detailed hydrographic surveys. The paper analyzes the causes of inaccurate depth data on nautical charts, maritime accidents caused by incorrect depth data and provides a classification of the causes and recommendations to reduce the number of inaccurate depth data.

Keywords: nautical chart, hydrographic survey, depth

1. INTRODUCTION

Nautical charts show a specific navigation area with all the elements needed for safe passage and orientation at sea [1]. They show the depths, the relief of the sea bottom and its morphological characteristics, the configuration and characteristics of the coastline, dangerous shallows, reefs, all the navigation warnings, as well as all light and other navigation signals related data [2].

The quality of sea bottom representation is one of the most important factors contributing to the safety of navigation while using the nautical chart. One of the symbols used for that on maritime chart is the depth [3]. Depth is the vertical distance from the current sea level to the sea bottom [4]. Depths enhance navigational safety by adding a numerical value to many navigation hazards (shallows, wrecks, reefs and other obstacles) [3]. Which depths are most important and which will be included on the chart depends on the knowledge and experience of marine cartographers. According to [5] depths are divided into three types: critical, significant and typical depths. Critical depths display the shallowest values over wrecks, channels, ports entrance and the recommended waterways. Significant depths indicate unexpected changes in the sea bottom relief or the minimum/maximum depth within a closed depth contour. Typical depths show a relatively flat relief and normal sea bottom incline. Depths are entered on the map based on the hydrographic survey. During depth selection an error can occur for several reasons, also a change in the sea floor relief can happen after the correct depth entry on the chart.

According to maritime accident reports, the main cause of maritime accidents is the human factor, and modelling of maritime accidents always emphasizes the factors related to human error and organization. In this paper, an emphasis is placed on the analysis of possibility of grounding in which the main cause of accidents is not a human, organizational or technical factor, but rather the insufficiently explored navigation area or the depth information displayed on the nautical charts. It is a human factor, but in this case not always influenced by the people on the ship. The paper analysis the reasons behind potential errors on nautical charts and gives recommendations on how to reduce the number of inaccurate depth data on nautical charts using modern technologies.

2. HYDROGRAPHIC SURVEY

The International Hydrographic Organization (IHO) brings together national hydrographic offices from 98 countries. One of its tasks is the unification of national standards. For this purpose, a whole series of publications - recommendations for national offices to follow is published. Among these is the standard for hydrographic survey defined in publication S – 44 [6].

According to the Hydrographic Activity Act of the Republic of Croatia, hydrographic surveys include: sea depth survey, marine geodesy, geodetic and other coastal, sea, seabed surveys, oceanology, geology, geophysics, and marine environmental protection activities in part relevant to hydrography and hydrographic navigation safety. Furthermore, according to the Hydrographic Activity Act [7] a person or a legal representative managing the harbor, except for the military harbors, shall submit a hydrographic survey to the Hydrographic Institute of the Republic of Croatia at least once every five years for the full harbor area. It is also stated that the Harbor Master office may require the survey within a shorter period than five years if the sea floor is subject to frequent changes (sedimentation and other), and to a longer period of five years if the sea floor is less susceptible to changes but not for periods longer than ten years. According to the law, the mandatory survey applies only to harbors. Every three years, the Port Authority or the concessionaire are obliged to submit to the Harbor Master office a report on the state of depth referred to in Article 3, paragraph 1, item 3 of the Regulation on the conditions to be met by ports, certified by the Hydrographic Institute of the Republic of Croatia. The harbor captain may require a report on the state of depth more frequently if depth is subject to frequent change (falling cargo and others), it may set a longer deadline for depth reporting if depth is less susceptible to change, but not over five years. [8]. Status of Hydrographic Surveying and Charting Worldwide is shown in Publication C-55 and for Croatia presented in Figure 1.

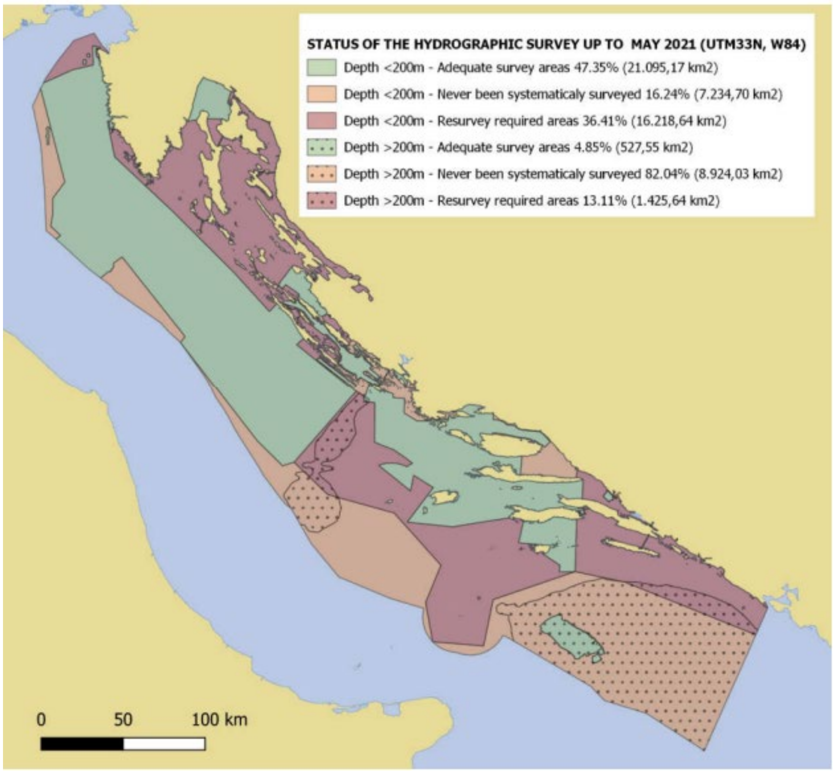

Figure 1 Status of hydrographic survey in Croatia Status of hydrographic survey in accordance with the IHO C-55 criteria [9]

An interesting question to ask about hydrographic surveys is how often they should be carried out and after how much time their quality can be considered questionable. Regarding the time intervals between the surveys, there is a section in the IHO S-44 publication [6], as one of the basic documents for the quality of hydrographic surveying:

"It should also be noted that where the sea floor is dynamic (sand, waves) surveys conducted to any of the Orders in this Standards will quickly become outdated. Such areas need to be resurveyed at regular intervals to ensure that the survey data remains valid. The intervals between these resurveys, which will depend on the local conditions, should be determined by nation authorities."

Also, in the C-13 publication, the amount of traffic in a given area is mentioned as one of the parameters for the need to conduct a new survey: "Requirements for hydrographic surveys arise as the result of policy decisions, product user reports or requests, national defense needs, and other demands. The inception of a specific hydrographic survey project follows an evaluation of all known requirements and establishment of priorities. Among the many objective and subjective factors that influence the establishment of priorities are national and agency goal, quantitative and qualitative measures of shipping and boating, the adequacy of existing surveys, and the rate of change of the submarine topography in the area."

In practice, different data are used on the official electronic navigational charts (ENC) as information on the quality of a hydrographic survey. The first objects are Survey reliability (M-SREL) and Quality of data (M-QUAL) [10], which serve to mark the area of survey with different properties. There are attributes between start and end dates of the survey. These attributes represent the only depth-related data in a chart area and are quite hidden from the mariner. Therefore, a simple categorization of hydrographic survey according to their quality has been introduced as basic information on which a mariner can quickly rely on for the quality of the survey.

This is called CATZOC, or Category Zones of Confidence. Based on the spatial properties of the hydrographic survey (horizontal and vertical accuracy, depth density, etc.), they are divided into categories of letters or stars (A1, A2, B, C, D and U). The problem is that there is no category of period after which a survey (which, when placed on a chart, is given, for example, the CATZOC category A1), loses its quality, i.e. when it could be considered less reliable. The IHO Standard S-67 [11] contains a section describing how mariners can rely on these survey categories, which is poor practice of determining these categories with the lack of survey age as a parameter.

The excerpt reads: "Impact of ZOC categories upon mariners. Put in simple terms, mariners should be able to navigate with confidence in areas with ZOC A1 and A2 classifications. It is also unlikely that uncharted dangers affecting surface navigation exists in ZOC B areas.

In ZOC C areas marines should exercise caution since hazardous uncharted features may be expected, particularly in or near reef and rocky areas. A very high degree of caution is required for areas assessed as ZOC D, as these contain either very sparse data or may not have been surveyed at all. Finally, it is good practice to treat ZOC U areas with the same degree of caution as ZOC D areas."

3. THE CAUSE OF DEPTH ERROR

Depth is one of the fundamental limiting elements of navigational safety. Hydrographic data of particular areas are made before the use of new technologies and do not have the accuracy required by the current S-44 standard [6] for hydrographic survey of the International Hydrographic Organization. Apart from the old survey, the actual depth may deviate from the measured position because of other factors. Factors that can cause inaccurate depths on the map can be divided into natural and human.

Table 1 Causes of inaccurate depths in nautical chart

Natural factors	- natural sediment accumulation - earthquake
Human factors	- error while entering depth data on new edition charts - error while determining the depth position - old hydrographic surveys - insufficiently explored area - human error during the depth selection procedure that will determine which depths from the hydrographic survey will be displayed on the chart - an error when updating maritime charts on board - accidental loss of cargo - illegal dumping of waste material

Source: Authors

The natural factors that can cause inaccurate depth data on the maritime charts are sediment accumulation and earthquake. Natural sediment accumulation and sea bottom changes can cause significant depth differences in a short period of time. Accumulation may be caused by rivers or sea waves. Although earthquakes are considered natural disasters, not every earthquake is considered catastrophic. There is a possibility of deformation on the edges of the tectonic plates when the depth of the sea floor is moving, causing changes in depth. According to IHO recommendations, each Coastal State should have a timeline of hydrographic survey of navigation areas. Seismic sensitive areas should be included in this plan, especially after active earthquakes. Therefore, it is necessary to determine the risk of changes in the depth of a given sea area relative to the density of the transport, the type of soil and the depth of the sea.

Depth changes in areas deeper than 20 meters are not considered hazardous for navigation, therefore, when developing earthquake recommendations, the shallower area should be analyzed. In the Republic of Croatia, the active earthquake area is the Dubrovnik area. The underlying cause of seismic activity on the eastern coast of the Adriatic Sea lies in the undercutting of the Adriatic micro plate under the External Dinarides. Their number and strength are growing from northwest to southeast, so the largest number of earthquakes and the strongest earthquakes occur in the area from Ston and Dubrovnik to Albania [6]. When analyzing the depths of the Dubrovnik area, it was found that the navigable area is predominantly deep and that the last hydrographic survey of the Dubrovnik area is from Gruž, part W - 2018, part E 2008-2013, part S - 1998.

Human factors that cause inaccurate data on nautical charts are:

- The entry of the wrong depth on charts can occur in hydrographic offices that make the maritime charts. The cause may be a mistake while copying the depth from an older hydrographic survey to new charts. While manually writing the data, it is possible that some depth data is not included in the new edition, and that further issues of the chart are released without the mentioned depth. Such errors caused by manually copying data from raster surveys can be reduced by regular hydrographic surveys, which are recommended in areas with critical and significant depths.
- Much of the hydrographic survey in the world and in Croatia dates from the time before the use of GPS. When determining the depth in time before the use of GPS, there was a possibility of error in determining positions by astronomical methods.
- According to [12], 50% of the coastal area in the world is either unexplored or explored with inadequate equipment in accordance with IHO S-44 standards. According to the same author, in the Republic of Croatia 45.09% of the territory with depths less than 200 meters are unexplored or not explored with proper accuracy. According to the C-55 report, status of Hydrographic Survey and nautical cartography in the world for July 2023, it is estimated that 47% of areas with depths of less than 200 meters are sufficiently hydrographically surveyed, for 36% of the area a re-survey is required and 17% of the area is never really surveyed. For areas with depths deeper than 200 meters in the Republic of Croatia, 82% of the area has never been surveyed while 13% of the area needs a re-survey. The figures for the status of hydrographic survey for July 2023 follow in Figure 1.
- Also, as one of the factors that influence the safety of using a hydrographic survey while making a navigation chart, is the potential risk of a human error during the procedure of selecting depths from the hydrographic survey that will be displayed on the chart. Namely, this procedure is done manually, which is relatively feasible in cases with small hydrographic surveys (usually about 100 000 to 400 000 depths). However, in the case of large hydrographic surveys, demanding navigational areas (such as the Šibenik harbor, Šibenik Channel and St. Ante Channel with approximately 7 000 000 depths), the manual selection method becomes practically impossible and some very dubious methods of thinning the depths used certainly diminished the quality of the selection. There is not yet a functional system for automatically selecting depths for official nautical charts.
- The SOLAS Convention specifies the nautical aids (charts and publications) that ships have to possess at any point of navigation. It is also stated that all publications and charts must be the latest official edition and must be continually updated according to the latest editions of Notice to Mariners and Radio Navigation Warnings.

Making corrections to the chart is a constant task, which must also be performed on the ship during the voyage. There are several different methods for this because of a variety of sources and types of information and these procedures are explained in detail in many mariners' manuals such as the British Hydrographic Office NP100. In the event of non-fulfillment of the above-mentioned criteria, i.e. maintenance of the chart portfolio updated at any time, the vessel is subject to financial penalties by the competent state authorities and the temporary ban of entering the port (URL 4). In the event of negligence of the navigation officer and incorrectly entered corrections (as a recorded case of accidentally deleted marking of the isolated danger), the navigation safety is seriously compromised and a disaster may occur.

4. ANALYSES OF SHIP GROUNDING CAUSED BY INACCURATE DEPTH DATA REPRESENTED ON NAUTICAL CHARTS

Ship grounding is a position of the ship at a standstill, in which the ship touches the sea floor to a degree that does not permit further navigation with its own machinery or equipment, without damaging the hull, machinery or equipment of the ship [13].

Ship grounding can be observed through two scenarios:

- grounding that occurrs while the engine is still running (the event that followed after the ship continued to navigate along an insecure route due to a human or technical error),
- grounding that occurrs while the engine is not running (the event that followed because the ship could not stay on the navigational path due to mechanical error, environmental impacts, anchor problems, or assistance error [14]).

According to maritime accident reports, the main cause of maritime accidents is the human factor and modeling of maritime accidents always emphasizes factors related to human error and organizational factors. In this paper, an emphasis is placed on the analysis of grounding in which the main cause of accidents is not a human, organizational or technical factor, but rather the insufficiently explored navigation area or the depth information displayed on the nautical charts. It is a human factor, but in this case not always influenced by the people on the ship. The reasons behind potential errors on nautical charts have been analyzed in this paper and recommendations have been made to reduce the number of inaccurate depth data on maritime charts using modern technologies.

Examples of grounding because of inaccurate information on nautical charts are presented in Table 2. The examples were taken at random from IHO Data Quality Working Group (DQWG7-5) and their full list is presented in List of hydrographic data quality related incident, public version [15]. The full list includes the non-random sub-sample examples of 18 nautical accidents from 1992 to 2013, which does not include accidents from Africa, South America and the Caribean.

An analysis of the data taken from DQWG7-5 for 18 analyzed grounding accidents caused by inaccurate information on a nautical chart from 1992 to 2013 shows that the largest number of ships involved in a maritime grounding accident were passenger ships and tankers. (Figure 2.)

Table 2 Examples of grounding caused by inaccurate depth data

NAME OF VESSEL	YEAR OF NAUTICAL ACCIDENT	NAUTICAL ACCIDENT
USS Guardian (Mine Countermeasure vessel)	2013	“Mine Countermeasure vessel grounded on reef in Philippine waters. The digital chart aboard USS Guardian, showed a position about eight nautical miles in error. At the time of the grounding the vessel was attempting passage through a channel just half that width”.
MT Challenge Prelude (tanker)	2012	“Vessel touched bottom during berthing with a pilot on board “Although the official nautical chart indicated an available depth of 11.83 m, it was discovered that the draught allowed at this berth by the port authority was restricted to 9.44 m”.
Costa Concordia (cruise ship)	2012	“Cruise ship grounded at underwater rock in Isola del Giglio. 1st error: nonfunctional change in voyage plan; 2nd error: route planning on small-scale paper charts only; 3rd error: insufficient route monitoring; 4th error: assessing distances using radar echoes instead of no-go zone on integrated navigation system; 5th error: insufficient presence of the Captain, and insufficient communication of his intentions; 6th error: ship handling errors”.

VLCC	2010	"Near Hongkong VLCC ran aground in an uncharted dumping ground, where local barges had been discharging mud, sand and/or other unknown spoil. No information relating to this activity was circulated".
Sea Diamond (cruise ship)	2007	"Grounding and sinking in Santorini Caldera, Aegean Sea, Greece because of discrepancies between the actual mapping of the sea area and the official charts used by the Sea Diamond (and all other vessels) at the time of the accident reef that gashed *Sea Diamond* was 131 metres from shore instead of the charted 57 metres, and at a depth of 3.5 metres to 5 metres instead of the charted 18 metres to 22 metres".
Octopus (jack-up barge) and Harald (tug)	2006	"Grounding caused by not systematically surveyed area and it was marked like that in nautical chart. ECDIS didn't display clear warning about possible uncharted dangerous".
Greenpeace ship Rainbow Warrior	2005	"Inaccurate nautical information on chart Tubbataha Reef which was charted 1,5 miles from position of grounding. Many Philippine charts have not been re-surveyed in some 80 years. Transferring this aged data to an electronic chart does not increase its accuracy".
British Enterprise (tanker)	2004	"Grounding in Port of Istanbul, Turkey because of uncharted shoal or obstruction. During the investigation, it was found that at least two other vessels had grounded in this anchorage in recent years. Investigations carried out after these accidents had not identified the shoal area. Research into the survey history of the area has indicated the presence of a shoal with about 10m least depth on 19th century and early 20th century charts, which is not shown on modern charts. The area lies close to a geological fault line, and it is possible that seismic activity, and the very strong currents that can be experienced in the area, have combined to make the bottom topography unstable. A 1979 survey of the area failed to find any evidence of its existence".

Source: Made by authors according to DQWG7-5 examples

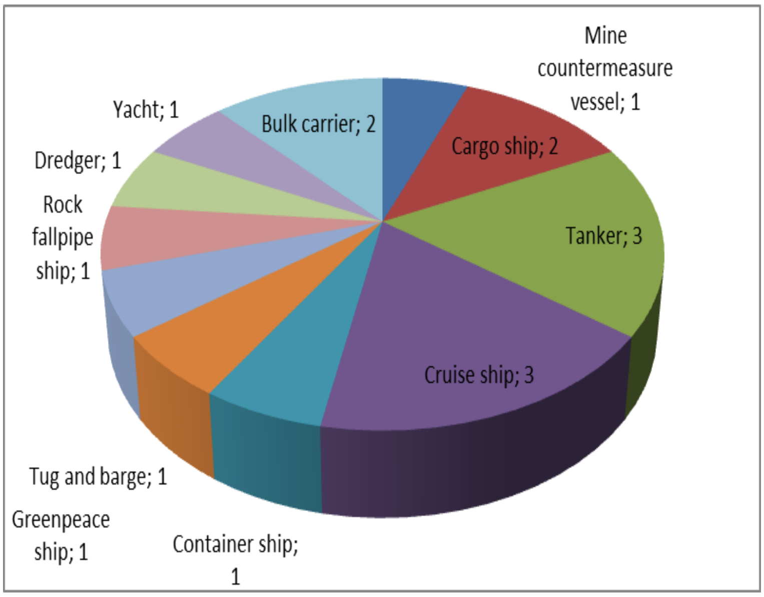

Figure 2 Percentage of Ship accidents findings caused by inadequate hydrographic data quality for 18 non-random sub-samples of nautical accidents caused by unreliable maritime chart data from 1979 to 2013 analyzed by DQWG7-5

In order to evaluate the main causes of grounding presented by (DQWG7-5), DQWG7-5 authors analyzed current data presented in the following figures. A conclusion from this list of categories should be that the causes of grounding for hydrographic data quality related incidents as per Figure 3 are presented as follows:

- improve charting procedures,
- improve the data exchange,
- teach the use of nautical chart limitations,
- incorrect assumption of chart error,
- improve the quality of description,
- improve the quality of display
- Include quality information.

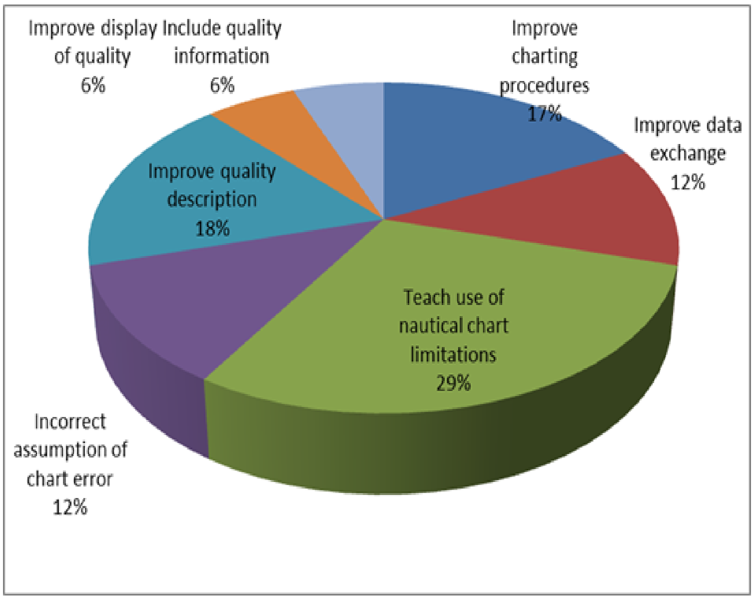

Figure 3 Ship accidents findings causes by inadequate hydrographic data quality for 18 non-random sub-samples of nautical accidents caused by unreliable maritime chart data from 1979 to 2013 analyzed by DQWG7-5

Based on the cases presented in Table 2, it is concluded that seafarers view the data on nautical charts as information with a high percentage of accuracy and that this is precisely the reason for the majority of maritime accidents shown in Table 2.

5. MODERN TECHNOLOGIES IN THE SERVICE OF PRELIMINARY HYDROGRAPHIC SURVEYING OR HYDROGRAPHIC SURVEY PLANNING

Systems for hydrographic surveying, preliminary hydrographic surveying or hydrographic survey planning can be acoustic and non-acoustic.

Acoustic systems represent a standard in hydrographic survey [6]. They are divided single beam echo sounders and multi-beam systems and interferometric sonars. Their application is very expensive because it involves the mobilization of people and platforms / ships to which these devices are installed, and self-evaluation and data processing are a lengthy process. These methods represent a standard for IHO recommendations in data collection, as they provide a high degree of accuracy and precision of data both spatially / locally and deeply / vertically. In the Republic of Croatia, the Hydrographic Institute of the Republic of Croatia HHI is responsible for the development of navigational safety service in the Adriatic Sea, in conformity with the recommendations of:

- International Hydrographic Organization (IHO),
- International Maritime Organization (IMO),
- International Association of Lighthouse Authorities (IALA).

This means that acoustic survey systems, i.e. Integrated systems of Global Navigation Satellite System (GNSS) and Inertial Reference Unit (IRU) or Motion Reference Unit (MRU) are used to achieve high precision and accuracy of survey.

Non-acoustic systems are:

- Airborne Laser Systems which present a new technology with high productivity in shallow waters. They can measure depths of up to 50 m and more. They have far the highest data collection speed and are suitable for areas near shoals and shallow waters. They are not always widely used because the mobilization costs are high. An example is the bathymetric LIDAR Sensor. Unlike Terrestrial LIDAR Systems Using Infrared Wave, Bathymetric Lidar System uses green wave and captures the coastline so it is possible to gain a 3D view of the submarine and landline in one whole [16];
- Airborne Electromagnetic System depth and mapping techniques in shallow waters. Their main feature is that the system works independently of water stagnation and is good in assessing some of the natural disasters and the extent / size of the affected area;
- Remote sensing of high-resolution satellite imagery has recently been used only to a limited extent. Today, the development of methods for a more precise reading of depth from high-resolution satellite images is resumed as complementary mapping techniques, both naval objects and depth on navigation charts. Some satellite examples and size of the grid are presented in Table 3.

Table 3 High resolution satellite results for depth readings

Data/raster from the satellite	Size of the grid/resolution
WorldView-2 and 3	2m
Sentinel-2	10m
Landsat-8	30m

Source: Authors

Non-acoustic systems have great potential applications in mapping and for charts update when a preliminary assessment of top priority areas of survey is necessary because of the limited, incomplete, inaccurate detailed information on charts or in hydrographic databases, or for any other reason for depth changes (natural disasters, erosion of the coastline, causing sediment, seismic activity or change caused by human activity).

By developing new technologies for spatial data collection and information technology for their management, processing and storage, new ideas and solutions are created for easier planning and decision making. By combining existing navigation charts and hydrographic databases with satellite imagery and laser data within a GIS platform, a precise basis for planning detailed hydrographic surveying projects is created. Within such intelligent solutions, decision-making is based on queries that have been the basis of the data previously entered in the GIS and their so-called data about data (metadata). This means that it is possible, for example, to identify the navigable routes of interest, and to explore which areas need a detailed hydrographic survey in respect of the time of the last survey (or areas that have never been thoroughly studied), from satellite images gaining insight into the critical navigation areas if the depths are less than 20 m deep and then set the priority areas of the survey. All this shortens the planning time and reduces the costs of the entire hydrographic survey project.

6. CONCLUSION

Croatia, like most other countries, has a large area of territorial waters that are not surveyed or inadequately surveyed. As tourism becomes widespread, and more and more people go out to sea, the issue of navigational safety becomes a very important factor, if not the most important. A maritime accident can be caused by inaccurate depth information on the nautical chart. The information on the navigation charts has been collected over a longer period of time using different metering methods of different accuracy and makes a unique unit or navigation chart that is currently in use. The longer time period plays an important role since they have a defined position and height dates, and the mapping of a historical cartographic presentation itself, if used as a source for cartographic data on maps currently in use, can lead to inaccurate data. In order to minimize the possibility of such a scenario, regular hydrographic surveying is required, especially in the waterway areas with depths less than 20 meters. It is important to teach mariners about the nature of information in nautical charts, especially the frequent occurrence of poor data quality to reduce the number of grounding due to unreliable depth. The question is how to quickly and efficiently address these problems and requirements, without losing quality and standard values set by international organizations.

In order to effectively check or update existing navigation charts and reduce the number of inaccurate depths, it would be ideal to make a new measurement. Since this option is long-lasting and expensive, a solution is again being imposed in the form of establishing an intelligent information technology system. This would mean in particular the use of GIS platforms that allow the simple insertion of data from different sources and their transformation within different positions as well as the elevation dates. Ultimately, spatial data consistency would be created, meaning a unique position and height datum in which all relevant data is displayed. The data is stored in layers and gives the platform itself a spatial view of problematic areas. Combining this data pool with information from new technologies, it is possible to carry out repairs or define polygons / areas that require a new hydrographic survey. The defined polygons/areas are the basis for calculating the time needed for the survey and also defining the coast of survey depends on the chosen technology.

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SCUTTLING – AN OVERVIEW OF THE IMPACT ON THE MARINE ENVIRONMENT

Astrid Zekić
University of Zadar, Maritime Department, Zadar, Croatia
E-mail: azekic22@unizd.hr

Ana Gundić
University of Zadar, Maritime Department, Zadar, Croatia
E-mail: agundic@unizd.hr

Lucija Županović
Zadar, Croatia
E-mail: lucija.zupanovic@gmail.com

Martina Antunović
KIP - Intermodal Transport Cluster, Rijeka, Croatia
E-mail: antunovic@shortsea.hr
UDK 656.085:338.484

Abstract

Scuttling is the act of intentionally sinking a ship by allowing water to flow into its hull. Over time, sunken ships have become a new habitat for marine organisms, which enriches biodiversity and makes the diving destination more attractive. A special underwater attraction for professional and recreational scuba divers are the locations of sunken ships. This paper examines the level of scuttling development in the world. In the case of intentional sinking of ships, environmental impact analysis studies are also included. The authors emphasize the importance of the ecosystem approach in the implementation of scuttling. Furthermore, the authors cite scuttling in Malta as an example of good practice. The special contribution of the article is reflected in the importance of understanding scuttling as a form of tourist offer which has a positive impact on marine environment protection. The locations of the sunken ships contribute to the sustainable development of the tourist destination, since fishing and especially trawling are strictly prohibited in these areas.

Keywords: scuttling, diving tourism, scuba divers, marine environment ecosystem approach, Malta

1. INTRODUCTION

Tourist diving is an increasingly popular tourist activity. Man's desire to descend below the surface of the sea goes back to ancient times, whether the purpose of diving was hunting, rescuing, recreation or some military reasons [14]. In international tourism trends, diving tourism has currently the greatest upward trajectory. Scuba diving is an important and growing component of the adventure tourism market and is a significant part of international and domestic travel around the world [13]. Diving enthusiasts are recognized for their dedication to the sport and willingness to both travel to and spend money on new and unique experiences [17]. World trends show that this type of tourism is a rapidly growing activity that generates significant income, and along these lines maritime countries are trying to make the most of this potential, creating additional prerequisites for its development [12]. There is great potential held by the scuba diving industry to carry out and encourage conservation, attract tourism, generate revenue, improve people's quality of life and promote community pride [15].

In Croatia, interest in this form of selective tourism began to grow rapidly in 1996 after the termination of the war [11]. According to the data of the Croatian Chamber of Economy, more than 150 diving centers are currently registered, but it is unofficially estimated (because there is no official statistical monitoring by competent services) that between 75,000 and 100,000 tourists dive annually in the Croatian part of the Adriatic [8].

Many maritime countries have been sinking ships for years in order to develop and expand the offer of diving tourism. Ships are sunk in the immediate vicinity of tourist centers and at shallower depths that are accessible to recreational divers. They are sunk carefully, primarily on a sandy bottom with poor marine life, so as not to harm the marine environment. This activity also got its name - scuttling. Over time, the sunken ship becomes a new habitat for marine organisms, which makes the diving destination even more attractive.

Countries such as the USA, Australia and Malta have recognized the divers' interest in sunken objects, so they initiated deliberate sinking of ships in order to increase the advantage of a tourist destination. The USA leads the way in the development of scuttling for tourist purposes. The State of New Jersey has 129 scuttled ships; Carolina - 100; and New York - 65 [11]. Australia launched a national scuttling project, within which six ships were sunk for diving purposes in the period from 1997 to 2011. The sinking of the Ex-HMAS Adelaide that took place in 2011 was attended by more than 18,000 people with more than 600 vessels on the water [7]. Sinking of ships for tourist purposes is particularly active in Malta, followed by New Zealand, Thailand and Turkey. Numerous underwater parks have been built in Turkey with replicas of amphorae and sunken Hellenistic statues that attract a large number of divers. For the purpose of developing diving tourism, Montenegro sank the m/v Split, while in 2016, the admiral ship Vis was sunk in the Republic of Croatia. Owing to its diversity and natural beauty, along with many attractive underwater sites created by human activity (sunken ships, airplanes), the Adriatic Sea is listed among the most attractive seas. According to some estimates, more than two thousand ships have been sunk along the eastern coast of the Adriatic in the past three thousand years [9]. Each wreck is a time capsule containing elements of the time in which it was created and its technological achievements, but also of personal destinies of the people connected to it [10].

The paper is structurally divided into five main parts. After the introduction, the second part of the paper gives a definition of scuttling and the reasons for its application, both in the past and today. The third part analyzes the impact of scuttling on the environment and shows potential mitigation measures by emphasizing the importance of the ecosystem approach. Given that scuttling has made Malta one of the most popular scuba diving destinations, the fourth part of the paper describes the scuttling project in this country. The final, fifth part, consists of concluding remarks.

2. SCUTTLING

Scuttling is the act of deliberately sinking a ship by allowing water to flow into its hull. The term scuttling refers to the process of deliberately sinking ships for various reasons or for various purposes.

In wartime, scuttling was used for military purposes to prevent ships from falling into enemy hands. It is also performed on old and abandoned ships to prevent them from sinking by themselves due to dilapidation and neglect and thus cause an environmental or safety hazard if this occurs at a shallow depth of the sea, in a port or on a waterway. Scuttling is also performed on ships that have been damaged in an accident or those whose damage is too great to repair or economically unprofitable. Ships are deliberately sunk also with the purpose of preventing or reducing navigation in sea passages, channels or ports.

Nowadays, ships are deliberately sunk mostly for fishing, tourist and sports-recreational purposes. Ships that reach the seabed become artificial reefs and underwater oases for the development of special biocenoses and habitats of marine organisms including various fish taxa, which makes them very interesting destinations for the development of diving tourism, as a significant addition to the overall tourist offer of a country. Such undersea oases can be of great importance from the point of view of undersea protection if they represent areas where fishing is strictly prohibited.

Scuttling, or the intentional sinking of ships, is done in such a way that water is injected into the vessel hull using various techniques. It can be done by just opening the existing ship valves (Kingston) or by making holes on the hull (plating) of the ship, either on its surface or underwater part. Sinking a ship usually involves explosives placed in specific locations, which requires a special study. Improper immersion can cause damage to people, property and the environment. Risks involved with such improper placement include [3]:

- "Injuries to personnel handling reef materials;
- Damage to vessels transporting reef materials;
- Improper location causing damage to fishing gear;
- Damage to buried pipelines and cables;
- Injury to recreational divers;
- Decomposition or movement of the reef material to an unauthorized location;
- Environmental hazards caused guide by incomplete cleaning/leaching of used materials;
- Damage to existing natural resources; and
- Costs involved with total removal of the reefs (if so instructed)".

  [12]:
- Waterways;
- Port areas and their approaches;
- Isolated parts of port areas (anchorages);
- Submarine infrastructure protection zones;
- Protection zones of biologically valuable parts of the seabed (coraligenous biocenoses and biocenoses of posidonia oceanica settlements);
- Fishing zones and areas for mariculture;
- Zones for active sports and recreation (gliding, jet skiing, etc.);
- Seaplane landing surfaces and the like;
- Protected natural areas;
- Natural areas proposed for protection (planned protection measures);
- Archaeological heritage in the sea;
- Endangered parts of the sea (areas of application of special management and protection measures); and
- Areas around protected sunken ships/objects.

When preparing the vessel for diver opportunities, careful consideration should also be given to vessel stability (for transport and sinking operations) as well as vessel integrity (for the life of the vessel once placed at the reef site) [18]. Therefore, before sinking the ship, it is necessary to thoroughly clean it and remove and dispose of all chemicals, oils, lubricants and crude oil.

During sinking, the ship is positioned so that it lies flat on the bottom. For large ships, a special study is made to determine the method of sinking it, while sinking of smaller ships is much simpler. In any case, special care should be taken of the relief (the morphology and slope of the bottom) as well as of the existing sea currents.

The conditions that artificial reefs must meet are stability in storms, durability, biological suitability, and harmlessness to the environment. Therefore, the sinking of a ship on the seabed must neither interfere with the safety of navigation nor pollute the environment.

3. LOCATION SELECTION AND THE IMPACT OF SCUTTLING ON THE ENVIRONMENT

Locations where objects may be sunk must be determined by spatial plans. These locations are important for the development of diving tourism.

Each proposed location requires an assessment of the impact of the sunken ship on the existing habitat of the seabed, especially on the geological composition of the bottom, and on the existing biocenoses and benthic communities that live there. A flat, sandy bottom is the most suitable place for sinking a ship because fish have no hiding place on such a bottom. Places inhabited by *Posidonia* or a colony of *Pina nobilis* are to be avoided, as these taxa are protected as endangered andrare endemic species.

Requirements related to diving activities must be met, and ships are sunk to sea depths of up to 40 metres, the maximum depth allowed for recreational divers. Before sinking, sharp edges, badly attached parts and cables must be removed from the ship so as not to injure the diver. In adittion, several openings must be left on the ship through which it is possible to enter and exit easily and safely, while narrow passages and gaps through which divers are not allowed to enter must be closed by welding for safety reasons.

Impacts on the environment are assessed by an authorized expert who prepares the study. The participation of a hydrobiologist is mandatory, as is the diving survey of the seabed. No deliberate sinking is allowed on locations in which protected species live. The study contains data on the operator of the project, data on the project location and its description, data on the project and a description of the characteristics of the project, a description of the possible significant impacts of the project on the environment and considered environmental protection measures, a summary of the possible impacts of the project on the environment, applied regulations, rules and documentation and attachments. Ultimately, the study must be approved by the competent authority.

Ships that are deliberately sunk must be completely cleaned of any pollutants, oil, fuel oil, other petroleum products and the like. The approval of the competent authority for environmental protection is required, as well as an inspection of the object itself before sinking. When preparing the vessel, all solid and liquid materials that pollute the environment or are dangerous for divers who will visit the location must be removed. Materials that must be removed from the ship are: PCBs in a concentration equal to or greater than 50 ppm, all asbestos or materials containing asbestos, all hydraulic materials, oils, lubricating oils, batteries and accumulators, floating materials that are separated from the ship and can enter the water column, all gases from the device, all peeling paint from the surface, pyrotechnics, black and gray water as well as ballast water [3]. In the shipyard, tanks are pumped out, the ship is cleaned and prepared for sinking.

It is also necessary to mention the impact of tractors on the environment. Namely, as a result of towing the ship to its sinking position, there are certain noise emissions and emissions of exhaust gases from the ship's tugboat engines. However, these impacts are temporary and can be ignored.

Important impacts that can occur as a result of submersion refer to [2,4]:

- Lost habitats under the sunken ship;
- Possible localized and short-term impact on sea quality;
- Changes in current and sediment movements;
- Potential damage or disruption of the habitat/species, including the creation of new habitat, food or shelter;
- Attraction of new species and changes in ecological relations; and
- Damage from increased human activity in the area.

Most organisms that are not moved from the ship sinking site to another will die. However, this impact can be avoided by manually moving the organisms from the bottom before sinking the ship.

The sunken ship will have a significant impact on the conversion of habitats and types of biocenosis of the micro-location. Namely, it may enable the re-settlement of species that previously lived there and settlement of new species which were previously absent due to lack of habitat, thus increasing the biodiversity of the entire area.

Sunken ships first attract algae, and subsequently other marine organisms (sponges, anemones, molluscs and fish) and become their shelter. It should be noted that fishing, i.e. the use of any kind of fishing tools, is usually prohibited in the area of a sunken ship, which in turn enables the survival of all organisms and communities inhabiting a sunken ship.

In order to minimize impacts and achieve the greatest possible preservation of the environmental quality, potential mitigation measures could include [3]:

- "careful attention to the preparation of the vessel, including the proper cleaning and certification of the end-of-life vessel;
- Careful waste management procedures during cleaning and preparation, including handling by licensed operators and disposal at properly licensed facilities and compilation of waste inventories;
- Careful attention to the deployment of the vessel on the seabed, through controlled scuttling to ensure that it is lowered onto a bare sand bottom, including ensuring the use of the appropriate methodologies, craft, and trained personnel for the towing, securing, and scuttling of the vessel; and
- Careful attention to post-deployment mitigation measures, including the maintenance and proper enforcement of the no fishing zone around the wrecks and the implementation of proper monitoring programs to determine how the wreck is developing and to measure any deterioration in the structure".

Depending on the extent of the environmental impact identified, these impacts can be avoided or reduced to a level where they are no longer negative through the application of effective mitigation measures. It should be noted that an ecosystem approach is applied in scuttling, which involves maintaining ecosystem integrity, functioning and health to ensure the sustainable use of marine resources for current and future generations [19].

4. SCUTTLING IN MALTA, AN EXAMPLE OF GOOD PRACTICE

As a destination, Malta enjoys a good reputation for excellent shore and wreck diving. The diving master plan concluded that Malta is highly attractive as a diving destination due to its warm waters, good visibility and underwater scenery [1]. Over 45 dive centers existed in the Maltese Islands, a number which has been growing steadily since the 1970s, when the first dive center was set up on the Island [3]. An analysis document by the Malta Tourism Authority notes that 5.2 % of total inbound tourism were motivated to visit Malta for diving, whereas 6.8 % of total tourists participated in diving activities during their trip [6]. A strategy for the sustainable development of the diving industry is timely, with the launch of Malta's new Tourism Strategy for the period 2021 - 2030. The Tourism Strategy aims to manage and formulate the future development of tourism in Malta in line with sustainability principles, including through strategies aimed at making the best use of the islands' natural attractions and enhancing those tourism market segments where Malta possesses a competitive advantage, such as diving tourism [5].

The contribution of the diving segment to the Tourism Sector had also increased substantially due to the popularity of Maltese waters with both local recreational divers and leisure and fanatic divers from overseas. There are currently 12 dive wrecks that have been purposely scuttled for diving off the coast of the Maltese Islands [4]. The scuttling of wrecks and the construction of artificial reefs has been shown to attract fish life and, as long as the fish are not molested by fishermen and spear hunters, they would further enhance the value of these dive sites. Through scuba diving as a sports industry, local citizens have the opportunity to preserve their heritage by scuttling deliberate wrecks to create dive sites and artificial reefs for the protection of local and migrating marine life [16].

There are two bodies in Malta that have requirements related to scuttling. These are Environment Protection Department (Ministry for the Environment) and Planning Authority. Requirements for scuttling of the former AFM patrol boat „P33" to consolidate the existing dive site at Żonqor Point, Marsaskala shown in Table 1.

Table 1 Requirements for scuttling, patrol boat „P33"

Authority	Requirements for scuttling
Environment Protection Department	No objection in principle as long as the following conditions are adhered to: - Engine should be removed; - Fuel tanks and bilges should be steam cleaned; - Scuttling to avoid Posidonia fields and reefs.
Planning Authority	Request for the applicant to provide a report providing the following: - Description of the Vessel (plans, dimensions and major 20 features); - Cleaning methodology and provision of a certificate confirming the vessel is free of hazardous substances; - Method of towing and scuttling of vessel and details of mooring - Description of the choice of sites and alternatives considered; - Description of the existing environment (site map, land and sea uses, sources of pollution, bathymetric map) - Marine environment survey (habitats and biological communities, geomorphological features, archaeological remains, other relevant features); - Details on the management of the wreck, including a monitoring programme.

Source: [3]

The timing of the scuttling is dependent on the cleaning and preparation phase (including the availability of the necessary certificates), as well as on the issuing of the Full Development Permit.

The Master Plan to Support a Sustainable Diving Industry in Malta by the Malta Tourism Authority provides an analysis of the dive industry in Malta as well as identifies a strategy for the development of the industry. The Master Plan recognizes the importance of scuttled wrecks/artificial reefs in enhancing Malta's competitiveness in the dive market. The Master Plan advocates preparation of a Diving Subject Plan, which would identify broad areas best suited for future wrecks/artificial reef structures, as well as that the Malta Tourism Authority works with the dive industry to actively seek opportunities for the scuttling of new wreck attractions and the creation of artificial reefs [2].

A strategy for the sustainable development of the diving industry is timely, with the launch of Malta's new Tourism Strategy for the period 2021-2030. The Tourism Strategy aims to manage and formulate the future development of tourism to Malta in line with sustainability principles, including through strategies aimed at making the best use of the islands' natural attractions and enhancing those tourism market segments in which Malta possesses a competitive advantage, such as diving tourism.

The diving industry needs to innovate and create new services through a creative approach to diving. Ideas could include the promotion of specific themed diving packages linked to, for example, history, culture and folklore. Also the promotion of eco-dives, with the help of specialized tour guides and provision of detailed information on the subject [1].

It should be noted that the Association of Professional Divers, with the support of the Ministry of Tourism of Malta, successfully promotes the wrecks around Maltese islands deliberately sunk in order to increase the attractiveness of the seabed for divers. In Malta, it is a project of national importance.

5. CONCLUSION

Possible key impacts of scuttling are related to loss of habitat under the wreck, possible local and short-term impacts on water quality, changes in sea currents and sedimentation, damage to natural habitat and flora and fauna, including search for new habitat, food and shelter, attraction of new species, changes in ecological relationships, damage from excessive human activities, and possible damage to archaeological sites (if any).

Measures to mitigate the impact must be taken at all stages of the sinking process. Particular attention should be paid to proper cleaning, documentation and control of the sinking so that the ship rests properly on the seabed. The loss of habitat will be insignificant and temporary in nature, the bottom currents and sediment will change only slightly.

Seabeds that have neither a particularly rich flora nor a particularly rich fauna are suitable for scuttling. In fact, sunken ships enrich life in such localities and thus also become underwater attractions for recreational and professional divers.

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