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Introduction | *Uvod*

Dear Readers and Friends,

We are pleased to announce the publication of Volume 26, No. 1/2025 of the Časopis Pomorskog fakulteta Kotor - Journal of Maritime Sciences (JMS). For this publication, the invited paper titled "Science and Technology Park of Montenegro: Center for Innovation and Entrepreneurship Development" discusses the origins and development of the Science and Technology Park of Montenegro as a driver of innovation, entrepreneurship, and technological development through support for startups, international projects, and the connection between science and industry.

In addition to the invited paper, this edition includes four contributions: two original paper, one review paper, and a short report. The second paper, titled "Accumulation of metals in hake (Merluccius merluccius) from the Montenegrin coast", assesses the potential health risks from the consumption of hake from the Montenegrin coast and concludes that the metal concentrations are within safe limits, posing no health risk.

The following paper is titled "Innovative Cross-Border Risk Management for Hazardous Cargo Transportation: Enhancing Safety and Sustainability in the South Adriatic". The authors explore how the expanding maritime transport between Albania, Italy, and Montenegro increases disaster risks, and how an innovative Decision Support System could improve cross-border management of hazardous cargo, enhance safety, and promote environmental sustainability in the South Adriatic region.

The fourth paper, titled "Burnout sydrome among seafarers: risk factors, consequences and strategies", addresses burnout syndrome among seafarers as a growing issue caused by long shifts, isolation, harsh working conditions, and further exacerbated by the COVID-19 pandemic; this paper explores its causes, consequences, and prevention strategies to improve health and work efficiency.

The final paper in this volume, titled "The Kotor Fraternity of Seafarers in Naval-Military Operations" emphasizes the historical development and military contributions of the Kotor Fraternity of Seafarers, highlighting its role in naval warfare and its impact on Kotor's maritime heritage.

In conclusion, we would like to express our sincere gratitude to all the authors for their invaluable contributions to this edition. We also extend our thanks to our dedicated reviewers for their unwavering support and efforts in improving the quality of our publications.

Editor-in-Chief:
Senka Šekularac-Ivošević, Associate Professor

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Invited paper

Science and Technology Park of Montenegro: Center for Innovation and Entrepreneurship Development

Radivoje Drobnjak, Valentina Radulović, Tanja Rakonjac

Abstract: The Science and Technology Park of Montenegro (STP MNE) is a key accelerator of innovation, entrepreneurship, and technological progress in the country. As a bridge between the academic community, industry, and the financial sector, STP MNE creates a dynamic environment for startups, small and medium-sized enterprises, and researchers, providing them with access to incubation programs, mentorship, and global innovation ecosystems. Through strategic partnerships and participation in international projects such as HORIZON Europe and Interreg DANUBE, the park fosters technology transfer, the development of circular and blue economies, and the strengthening of Montenegro's innovation capacities. The Technology Transfer Office (TTO) serves as a catalyst for collaboration between science and industry, while programs such as SkillsUp and BoostMeUp empower young entrepreneurs. With 31 established partnerships, 9 international projects, and 22 tenants, STP MNE positions itself as a leader in innovation, advancing a sustainable and competitive economy based on knowledge and advanced technologies.

Keywords: Innovation, Entrepreneurship, Science and Technology Park, Technology transfer, Startups, Research and development

1. Introduction

Science and technology parks play a key role in connecting knowledge, innovation and the economy. Their primary function lies in fostering technological entrepreneurship, developing startup ecosystems, and strengthening cooperation between universities, research centers, and the business sector.

The concept of science and technology parks (STPs) was developed in the 1950s in the United States when the first such park was established at Stanford University. The Stanford Industrial Park, later renamed the

Stanford Research Park, represented the first university business park focused on research and development, with the aim to enhance cooperation between the academic sector, industry, and the local community, as well as to generate additional revenue for the university and the region [1]. This model became the foundation for the development of numerous science and technology parks worldwide. The Cambridge Science Park was the first example of such a park in Europe, established as early as in the 1960s. In Europe, the concept of science and technology parks began to develop more intensively from the 1980s, particularly within the framework of the European Union's innovation development policies [2].

Science parks are situated near or on the campus of a university, functioning as an organisational and legal vehicle for innovative change, as stated in [3]. This proximity enables the park to make effective use of academic resources while facilitating the commercialisation of scientific research.

According to IASP's definition "A science park is an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities"[4].

Science parks have proven to be effective instruments for fostering innovation and technological advancement on a global scale. They play a pivotal role in the formation of global innovation networks, facilitate technology transfer, and commercialise scientific research, thereby becoming indispensable participants in the development strategies of regional and national economies, as stated in [3]. The role of science and technology parks is to stimulate domestic industry in order to make it competitive in the era of the globalisation process [5].

UNESCO's definition state that "Science and Technology Parks are physical spaces for interaction between research institutions, universities and private enterprises aiming to encourage innovation, technology transfer and the development of new businesses" [6].

Science parks influence the fact that more attention is given to the realization of the project in laboratory research, all the way through to the commercial exploitation phase of the research results [7]. In many developing countries, including Montenegro, such institutions are recognized as drivers of economic transformation and the development of a knowledge-based economy.

The Science and Technology Park of Montenegro (STP MNE) was established on September 20, 2019, and its primary goal is to stimulate and enhance the economic growth of Montenegro through support for innovation and development.

In a world where innovation drives the economy and society, the Science and Technology Park of Montenegro (STP MNE) serves as a key engine for the development of high-tech entrepreneurship and research. Established as a strategic project of the Government of Montenegro, with the support of the Ministry of Science and the University of Montenegro, STP MNE has positioned itself as a platform connecting science, industry, and investors.

Its mission is to create a dynamic environment where innovative individuals and companies receive the necessary support for growth and global competitiveness. This text provides an overview of completed activities and future plans, highlighting key initiatives that shape the future of innovation in Montenegro.

The Science and Technology Park of Montenegro (STP MNE) is not just an institution – it is a hub for visionaries, pioneers, and creators of the future. As a fundamental pillar of the innovation and entrepreneurial ecosystem, STP MNE leads the revolution in technology and research, combining knowledge, creativity, and ambition into a powerful force for development.

Established in partnership with the Government of Montenegro, the Ministry of Science, and the University of Montenegro, STP MNE serves as a bridge between the academic community, the business sector, and financial institutions, enabling the creation of innovations that change the world [8]. Through its work, this park becomes a catalyst for change, a platform for transforming ideas into concrete technological and business successes.

2. STP MNE – A Driver of innovation and technological progress in Montenegro

The mission of STP MNE is clear and ambitious – to create a dynamic, stimulating environment that fosters technological innovation, empowers entrepreneurs, and connects science with industry.

Through its programs and resources, STP MNE provides support to innovative startups, small and medium-sized enterprises (SMEs), researchers, and entrepreneurs, giving them access to incubation, mentorship, education, and global innovation ecosystems. Here, ideas are not only developed – they get the opportunity to conquer the world market.

The vision of STP MNE goes beyond borders – it aims for Montenegro to become recognized as a center of innovation and technological development in the region. Through strong support for researchers and entrepreneurs, STP MNE shapes a sustainable and competitive economy based on knowledge, creativity, and high technology.

STP MNE is not just a place where innovations emerge – it is a space where new rules of the game are created, where dreams transform into reality, and where ideas become drivers of global change. Every entrepreneur, researcher, and innovator who becomes part of this community joins a story that changes the future of Montenegro.

2.1. Infrastructure and functionality: Creating a home for innovation

After years of planning and intensive work, the Science and Technology Park of Montenegro has finally opened its doors to innovators, entrepreneurs, and researchers. With the completion of infrastructure projects, Montenegro has gained a modern space where revolutionary ideas develop and new technological solutions are encouraged. This significant event was marked by an official opening ceremony attended by high-ranking government officials, representatives of the academic community, and the business sector. Panel discussions and presentations of innovative projects further emphasized STP MNE's role as a key player in developing the country's innovation ecosystem. This moment is not just a symbol of the park's operational launch but also a driving force for Montenegro's technological renaissance.

Fig. 1 – *The first science and technology park of Montenegro* [15].

2.2. Technology Transfer Office (TTO): A bridge between science and industry

To ensure that scientific achievements do not remain confined to laboratories but find real-world applications, the Technology Transfer Office (TTO) was established within STP MNE. This office plays a crucial role in connecting the academic community with the business sector, enabling researchers and innovators to turn their ideas into commercial products and services [9].

TTO was founded with the mission of facilitating the transformation of scientific discoveries into marketable innovations, thereby not only increasing the competitiveness of the Montenegrin economy but also fostering the development of new knowledge-based industries.

Key activities of TTO include:

- **Support for researchers and innovators** – Providing expert assistance to researchers in protecting intellectual property, commercializing patents, and developing startups based on scientific research.
- **Connecting science and industry** – Organizing events, workshops, and meetings with business representatives to identify potential innovations with wide market applications.
- **Technology transfer and licensing** – Facilitating the transfer of technology between universities and industries through licensing processes and partnerships with companies ready to implement innovative solutions.
- **Entrepreneurial ecosystem development** – In collaboration with STP MNE and relevant partners, TTO supports the development of startups by helping them define business models, secure financial support, and connect with international investors.
- **Education and mentorship** – Organizing professional training and advisory sessions for researchers and entrepreneurs on key aspects of technology transfer, intellectual property, and market validation of innovations.

In its first year of operation, TTO has established significant partnerships with leading academic institutions and business entities, laying a strong foundation for the long-term sustainability and efficiency of this innovation support model.

2.3. Coworking space as a Creative HUB

One of the most dynamic segments of STP MNE is its modern coworking space, designed as a center of creativity and collaboration. With flexible work areas, this space provides the perfect environment for researchers, startups, and entrepreneurs. Its open and dynamic structure allows for easy networking between experts from various fields, creating fertile ground for the development of interdisciplinary projects. The coworking space is not just a workplace – it is an innovation center where ideas are exchanged daily, and new solutions to global challenges are born.

2.4. Projects driving change

Through active participation in international projects, STP MNE has significantly contributed to the development of the innovation ecosystem and the strengthening of Montenegro's scientific and technological capacities. The key projects in 2024 include:

- **HORIZON 2020 and HORIZON Europe** – Through participation in these prestigious European Union programs, STP MNE has become part of a broad network of research institutions, technology parks, and entrepreneurial centers across Europe. These projects have enabled access to cutting-edge research, knowledge exchange with leading experts, and the implementation of innovative models for supporting entrepreneurs and startups in Montenegro. Through Horizon projects, STP MNE has helped build a bridge between science and industry, creating opportunities for knowledge and technology transfer. As part of the HORIZON Europe program, STP MNE organized numerous trainings on circular economy, aimed at supporting innovation and sustainable business practices. These trainings focus on the development of environmentally friendly ideas and the application of circular principles, contributing to the creation of a more competitive and sustainable business environment in Montenegro.
- **Circular Innovation Hub (Interreg DANUBE)** – Through the implementation of this project, STP MNE has become a key player in the development of the circular economy in the region [10]. The focus is on encouraging companies to adopt sustainable business models based on more efficient resource use, recycling, and reuse of materials. Through a series of workshops, education, and mentoring, local entrepreneurs have had the opportunity to develop innovative solutions that contribute to waste reduction and optimization of production processes, thus achieving long-term economic and environmental sustainability.
- **STORE MORE (Interreg DANUBE)** – Through its participation in the StoreMore project, STP MNE actively contributes to the development and promotion of innovative energy storage solutions, aimed at

facilitating the transition to renewable energy sources [11]. The developed tools and approaches play a key role in supporting partner countries in the region in integrating renewable sources into energy systems, enabling a long-term shift to sustainable and environmentally friendly energy sources.

- **Adriatic-Ionian Sustainable Blue Economy Alliance for Upscaling SMEs (ABBA)** – This ambitious project is dedicated to the development of the blue economy, with the goal of improving the sustainable use of marine resources and promoting innovation in the sectors of aquaculture, maritime technologies, and coastal ecosystem management [12]. Through cooperation with international partners, STP MNE has enabled the connection of local businesses and researchers with leading institutions in this field, creating a new dimension of economic growth through environmentally sustainable innovations.
- **RuBIO to Boost Innovation and Competitiveness of Entrepreneurs** – Innovations for the Sustainability of Rural Areas – This project aims to strengthen rural communities through the implementation of biotechnological innovations [13]. The focus is on the development of new agricultural production models, the use of sustainable biomaterials, and the digitization of the agricultural sector. Through the RuBIO initiative, agricultural entrepreneurs have the opportunity to improve their businesses, reduce their ecological footprint, and create competitive products that meet the standards of the modern market.

2.5. Entrepreneur empowerment programs

Entrepreneur empowerment programs represent a key component in the development of the innovation community, enabling young entrepreneurs to transform their creativity and ideas into sustainable business models. Through pre-incubation and pre-acceleration programs such as SkillsUp and BoostMeUp, entrepreneurs receive essential support in the early stages of development, including mentorship, access to investors, and education. This enables them to identify and capitalize on market opportunities. Additionally, competitions and innovation workshops provide opportunities for idea exchange and the creation of socially impactful solutions, further fostering the development of both local and global communities.

- **SkillsUp** – A pre-incubation program that gathered dozens of young startups throughout the year, providing them with crucial support through mentorship, education, and financial resources, helping them develop their ideas and prepare for further growth.

- **BoostMeUp** – A pre-acceleration program that enabled young entrepreneurs to fast-track their startup development through intensive training, mentorship, and access to investors, empowering them for market entry.
- **Hackathons and Innovation Workshops** – Competitions such as "Equal Hack: Code for Equality" brought together young developers, designers, and entrepreneurs who worked on developing solutions with a strong social impact, creating innovations that promote equality and social responsibility.
- **Support for the Academic Community** – Collaboration with the University of Montenegro resulted in a series of programs that allow students and researchers to transform their innovations into concrete business projects, bridging the gap between academia and the business sector.

3. Promotion and networking

Promotion and networking are vital for strengthening the innovation community as they enable the connection of entrepreneurs, investors, and other key stakeholders in the ecosystem. Global visibility and participation in international conferences allow organizations such as STP MNE to position themselves as leaders in regional and global innovations. Through these activities, startups and innovators not only gain new knowledge and contacts but also directly influence the development of their industries. The digital breakthrough, through redesigned websites and social media activity, facilitates easier communication with partners and investors, thus accelerating their growth and internationalization process.

3.1. Key Performance Indicators (KPI) and STP results

In line with its mission and strategic objectives, STP MNE has achieved significant results that are measurable through the following key performance indicators.

Table 1. – *Overview of Key Performance Indicators (KPI) – STP MNE.*

KPI	No	Description
Number of established partnerships	31	Partnerships with domestic and international institutions, universities, research centers, and industrial partners.
Number of domestic and international projects	9	Participation in donor-funded or European projects
Number of support programs	5	Specialized programs like SkillsUp and BoostMeUp offering mentorship, funding, and education.
Total number of employees/engaged associates	15	A team of experts in the fields of technology, business and research.
Total number of tenants	22	Companies and organizations with access to infrastructure, R&D support, and networking opportunities.
Number of Start-up / Spin-off companies	14	Companies created through STP MNE programs, developing disruptive technologies.
Number of legal entities engaged in innovation activities.	4	Number of entities involved in R&D projects within STP MNE.
Number of complementary organizations	4	Organizations that complement STP MNE's resources and expertise in science, technology, and entrepreneurship.

(Source: STP Montenegro, author's internal research, 2024)

- **Number of established partnerships (31)** – Establishing strong partnerships with domestic and international institutions, universities, research centers, and industrial partners has enabled STP MNE to become a central point for connecting science and industry. These partnerships contribute to the development of new projects, knowledge exchange, and technology transfer, creating new opportunities for innovation and entrepreneurship.

- **Number of domestic and international projects (9)** – Participation in nine strategic projects has enabled STP MNE to strengthen its impact in the regional and European innovation ecosystem. Projects such as HORIZON Europe, Interreg DANUBE, and other initiatives bring additional resources and expertise needed for the development of advanced technologies and innovative solutions.
- **Number of support programs (5)** – Through five specialized support programs, STP MNE provides startups, SMEs, and researchers with access to mentorship, financial assistance, and education. Programs like SkillsUp and BoostMeUp offer a platform for the growth and development of innovative businesses, enabling them to position themselves in the market.
- **Total number of employees/engaged associates (15)** – The STP MNE team consists of highly educated professionals with experience in various areas of technology, business, and research. Their role is crucial in implementing programs, supporting startups, and developing strategic initiatives that strengthen the innovation ecosystem in Montenegro.
- **Total number of tenants (22)** – The science and technology park currently hosts 22 companies and organizations operating within its innovative environment. These tenants have access to modern infrastructure, research and development support, as well as networking with global technology leaders. Progressive firms and other industry representatives residing in the science and technology park will contribute to the achievement of most of the park's objectives [14].
- **Number of Start-up/Spin-off companies (14)** – According to the presented key performance indicators, NTP Montenegro has achieved significant results in its initial phase. Start-up and spin-off companies represent 63.64% of the total number of tenants, indicating a strong entrepreneurial orientation and the park's role as a key player in developing innovative technologies. Through its incubation and acceleration programs, STP MNE has helped establish and grow 14 innovative start-ups and spin-off companies, developing disruptive technologies and solutions. This success not only contributes to strengthening the local entrepreneurial ecosystem, but it also plays a vital role in attracting new investments, positively impacting the overall innovation potential of Montenegro.
- **Number of legal entities engaged in innovation activities (4)** – Four legal entities are actively participating in research and development projects within STP MNE, providing expertise and

support in the development of new technologies. Representing 18.18% of the total number of tenants, these entities play a crucial role in the dynamics of the innovation environment, fostering synergy between academia and industry. Their presence not only contributes to the development of new technologies but also strengthens collaboration with the academic and business sectors, further enhancing the innovative infrastructure of STP Montenegro.

- **Number of complementary organizations (4)** – STP MNE collaborates with four key organizations that provide additional resources and expertise in the fields of science, technology, and entrepreneurship. These complementary organizations represent 18.18% of the total number of tenants and play a significant role in enhancing research infrastructure, fostering synergy between academia and industry, and creating new opportunities for the development of innovative projects. Their presence not only strengthens the park's innovative capacity but also contributes to the dynamics of the innovation environment, further supporting the development of new technologies and fostering collaboration across various sectors.

In line with its strategic objectives, the future activities of STP MNE will be directed, through both programmatic and project-based initiatives, towards encouraging the development of digital solutions with a focus on the blue economy, sustainable growth, and environmental protection. In this regard, special emphasis will be placed on strengthening collaboration with key stakeholders of the blue growth sector in Montenegro, fostering synergistic actions among research institutions, businesses, governmental bodies, and civil society organizations. The aim of this approach is to facilitate the creation of innovative technological solutions that contribute to the sustainable management of marine and coastal resources, as well as to the enhancement of the overall innovation ecosystem in Montenegro. This approach will also particularly encourage collaboration with maritime higher education institutions in Montenegro, the region, and beyond, further strengthening the knowledge exchange and innovation capacity in the field of blue growth. The first steps towards encouraging innovative solutions will be supported through the organization of hackathons focused on blue growth. In addition, an Open Call will be announced within the ABBA project, with the aim of supporting and developing ideas that provide advanced solutions in the field of blue growth

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4. Conclusion: STP MNE as a leader in innovation development

The Science and Technology Park of Montenegro (STP MNE) represents much more than just an infrastructure – it is a key driver of innovation, a bridge between the academic and business communities, and the epicentre of the country's technological progress. Through continuous support for young entrepreneurs, startups, and researchers, STP MNE not only strengthens existing capacities but also lays the foundation for the development of new projects and programs that will further stimulate innovative dynamics and economic growth.

STP MNE enhances its services and resources to support tenants and stakeholders, helping entrepreneurs grow and compete globally. Support through pre-incubation and pre-acceleration programs, along with continuous networking and promotion on international platforms, allows startups to recognize opportunities, overcome challenges, and achieve their business goals more quickly.

Special emphasis should be placed on further strengthening the collaboration between the academic and business communities, as this is key to the long-term sustainability of Montenegro's innovation ecosystem. Through initiatives that enable technology transfer, the commercialization of research, and the practical application of academic innovations in the real sector, STP MNE creates a bridge between science and the market, contributing to the development of sustainable business models and the growth of knowledge in the country.

STP MNE, as a leader in innovation, remains dedicated to enhancing its capabilities and developing innovative solutions that address current challenges while also establishing the foundation for Montenegro's future technological and economic progress.

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Original scientific paper

Accumulation of metals in hake (*Merluccius merluccius*) from the Montenegrin coast

Neda Bošković, Danijela Joksimović

Abstract: This study presents the results of the content of metals (Cr, Ni, Cu, Zn, Fe and Mn) in hake (*Merluccius merluccius*) from the Montenegrin coast, as well as the risk assessment and hazard index for human health caused by the consumption of hake. The examined hake samples were taken from the open sea on the Montenegrin coast in the period from spring 2019 to autumn 2020. During the entire research period, the mean concentrations of the examined metals in hake muscle tissue moved in the following decreasing order: Zn > Fe > Mn > Cu > Ni > Cr. The results of this research indicate that the concentrations of the tested metals in the hake samples were within or below the permitted limit values. Values of risk assessment and hazard index for all tested metals in hake muscle tissue were below unity, so the hazard index was also low. There are no health risks from the intake of Cr, Ni, Mn, Fe, Cu and Zn by consuming hake. However, further monitoring and analysis of the presence of non-essential metals in fish are recommended, as well as assessing the risks and dangers to human health caused by the consumption of fish.

Keywords: Hake, Metals, Risk assessment, Montenegrin coast

1. Introduction

Based on their biological role, metals can be divided into essential (with known biological function), such as Cu, Cr, Fe, Mn, Zn, and non-essential (with unknown biological function), such as Pb, Cd, Hg, As [1]. Essential metals regulate a number of physiological mechanisms crucial to the functioning and development of organs in humans, so their deficiency can lead to various diseases in humans [2]. Concentrations in which metal ions can be considered dangerous vary, so some of the essential metals in higher concentrations than the prescribed values are toxic [3].

In the marine environment, metals are naturally present in lower concentrations [4]. However, various anthropogenic activities lead to an increase in the available concentrations of metals in the environment and in marine ecosystems. Metals are considered one of the main polluting substances of anthropogenic origin in the marine environment [5]. The presence of metals in marine ecosystems above the maximum allowed concentration (MAC) directly threatens the life of plants, animals and even humans [6]. Metals, due to their toxicity and ability to accumulate in living organisms, represent a potential danger for the living world, both for plants and animals, and for humans [6, 7].

Fish, like other marine organisms, can contain various polluting substances as a result of seawater pollution. Fish is a valuable source of protein in the human diet. To ensure that its consumption does not pose a health risk, a continuous monitoring for harmful substances in fish is essential [6, 8]. Fish are considered important bioindicators in aquatic ecosystems for pollution assessment [9-11], where they can accumulate organic and inorganic pollutants and are good indicators of long-term effects [12]. Fish accumulate metals through food, water and sediment [13]. Apart from habitat, nutrition is an equally important and decisive factor for the accumulation of metals and therefore for the presence of metals in fish tissues [6]. Metals accumulated in fish can impair the beneficial nutritional value of fish, and through the food chain reach humans, which can lead to health risks. Due to all of the above, determining the concentration of metals in marine organisms and assessing the potential impact on human health is a very important aspect [14-16].

In this research, hake (*Merluccius merluccius*), which represents a benthopelagic bottom species in the Montenegrin sea, was selected as a bioindicator of metal pollution. This species has already been used as ecotoxicological bioindicators in the Mediterranean Sea due to its commercial value, ecological implications and different feeding habits [6, 17], which enables comparison with literature data from the region and beyond. The research represents a part of the unpublished results and research of the doctoral dissertation [6].

2. Materials and methods

The Adriatic Sea is susceptible to pollution as a relatively small and closed water area and is greatly influenced by various anthropogenic factors and activities that take place immediately along the coast, as well as at sea [6].

Fish samples were collected during the spring and fall of 2019 and 2020. Fig. 1 shows the fish sampling area. Fish sampling was done by trawling, i.e. bottom demersal nets, mesh size 40 mm (square shape), length about 50 m [6]. After sampling, 10 fish with similar parameters (length, weight) were selected.

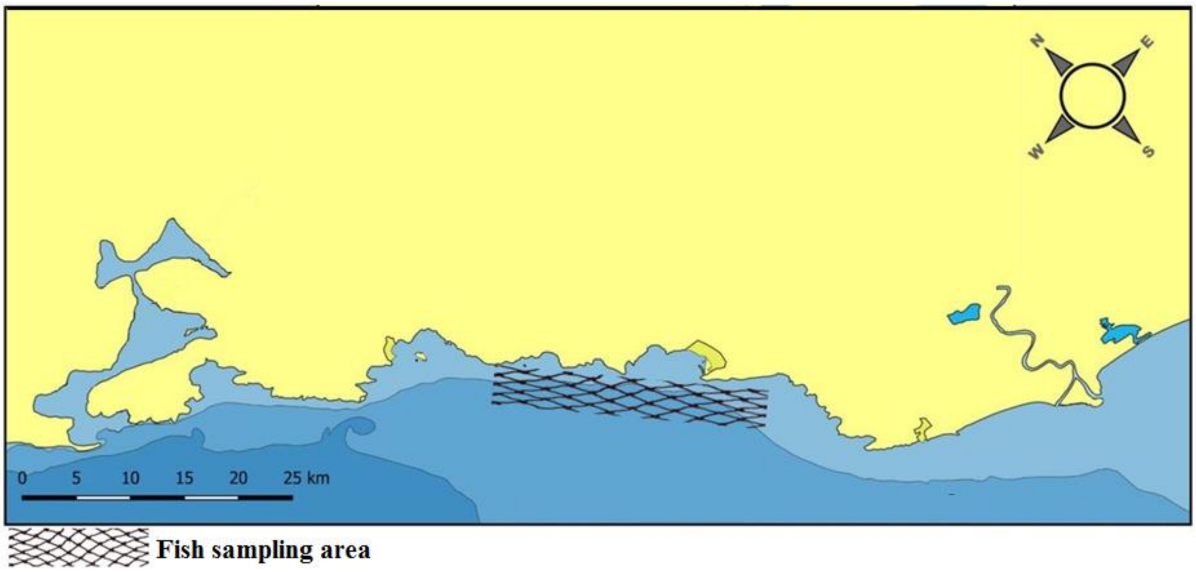

Fig. 1 – *Map of the fish sampling area* [6].

The preparation of the samples, as well as the analysis of metals in hake muscle tissue, was performed in the laboratory of the Centre for Ecotoxicological Research (CETI) in Podgorica according to the standard methods MEST EN 14084:2009 and according to the laboratory of the IAEA agency (International Atomic Energy Agency) and Marine Ecosystem Laboratory from Monaco [6]. In this study, hake muscle tissue was analysed for the presence of metals. Homogenized fish muscle tissues were digested in a microwave digestion device (Speedwave Xpert, Berghof). Concentrations of Fe, Mn, Zn, Cu, Cr, Ni in hake muscle tissue were determined using Inductively coupled plasma – optical emission spectrometry ICP-OES. Along with each batch of fish samples, the concentration was determined in certified reference materials (IAEA 407, 436) [6].

2.1. Hazard quotient risk (THQ) and hazard index (HI)

The risk to human health caused by the introduction of metals through the consumption of hake on the Montenegrin coast was assessed using the Target hazard quotient (THQ) [6]. The THQ represents the relationship between the Reference Dose (RfD) and the measured concentration, depending on the length and time frequency of exposure, amount of intake and body weight [18]. It is calculated using the equation [19]:

$$\mathrm{THQ} = \frac{EF \cdot ED \cdot MS \cdot C}{RfDo \cdot BW \cdot AT} \cdot 10^{-3} \tag{1}$$

EF – frequency of exposure (365 days per year);

ED – duration of exposure, average human lifespan (70 years);

MS – fish portion size (standard fish consumption rate is 17.5 g/day for the general population) [20];

C – concentration of the tested element in fish (mg/kg wet sample);

RfDo - Reference dose (RfD) is an estimate of the daily exposure of the human population to a certain agent without a significant risk of adverse effects during the lifetime (USEPA, 1993). Oral reference doses (RfDo) of metals (mg/kg·day): Cr 0.003; Ni 0.02; Mn 0.14; Zn 0.3; Fe 0.7; Cu 0.04 [20, 21].

BW – body mass of an adult (70 kg);

AT – average exposure time (EF · ED).

Hazard index (HI) was used to assess the risk to human health, by means of which the joint impact of a number of elements is evaluated (Bošković, 2022). The hazard index is calculated by summing the THQ values for all individual elements [19]:

$$HI = THQ_1 + THQ_2 + THQ_3 + \ldots\ldots\ldots\ldots + THQ_n \quad (2)$$

where THQ1 is the risk coefficient of an individual element, and n is the number of examined elements. When the value of HI < 1, there is no apparent risk from the substance during lifetime exposure, however if the value of HI > 1, there may be a hazard or adverse effect on human health [18].

3. Results and discussion

The concentrations of the tested metals in hake muscle tissue during the entire research period are presented in Fig. 2. During the entire research period (2019-2020), the mean concentrations of the tested metals in the muscle tissue of the hake moved in the following decreasing sequence: Zn > Fe > Mn > Cu > Ni > Cr.

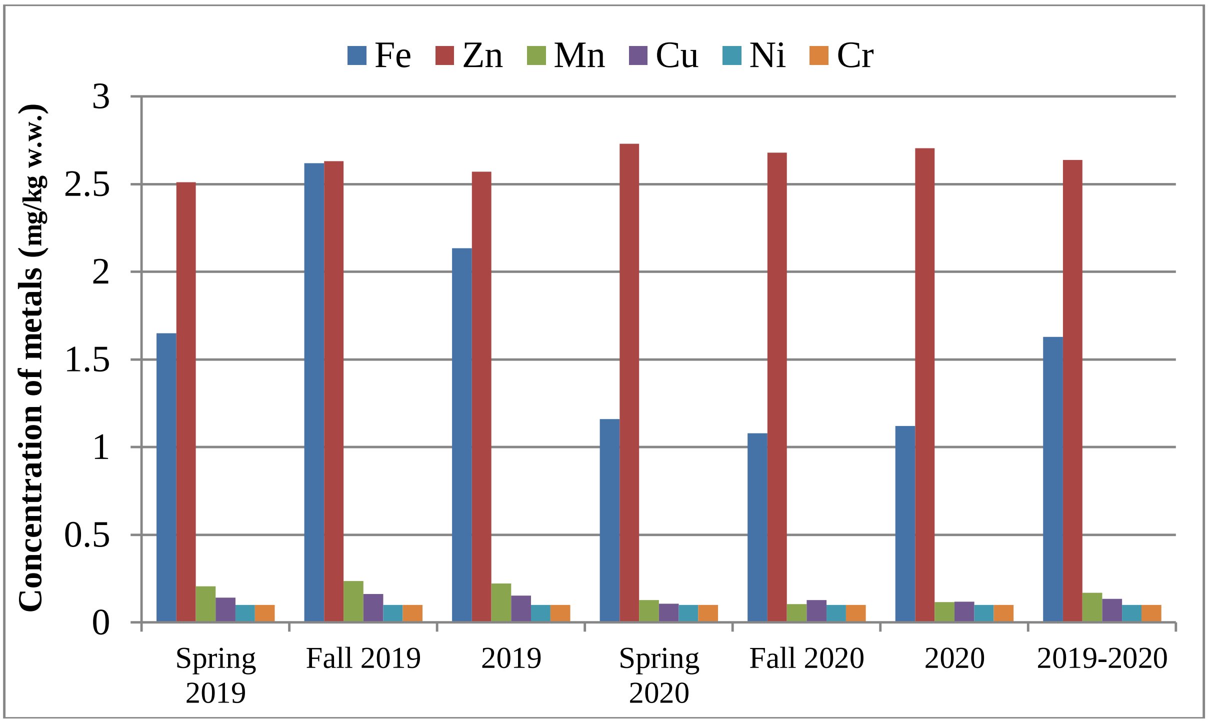

Fig. 2 – *Concentrations of metals in hake muscle tissue sampled in 2019 and 2020 (mg/kg wet weight - w.w.)* [6].

During 2019, slightly higher Fe concentrations were recorded in hake samples compared to 2020, while the sampling season did not have a significant impact on the Fe concentration in hake muscle tissue, Fig. 2. Fe is an essential trace element and one of the most widespread metallic elements in the Earth's crust, so its presence in the analysed fish from the Montenegrin coast is not surprising [22]. The range of Fe concentrations in hake muscle tissue during this study was within the range of values found in hake from the Mediterranean coast of Turkey and higher than the values recorded on the Adriatic coast of Montenegro [23, 24]. On the other hand, Fe concentrations in hake muscle tissue from the Mediterranean and Tyrrhenian seas were significantly higher than the values recorded in this study [25, 26].

Higher concentrations of Zn in hake samples were recorded during the 2020 sampling year, compared to 2019. Although Zn is an essential metal, necessary for the growth and development of living organisms, naturally present in the environment, mining and processing of ores, burning of coal and waste, disposal of waste, wastewater and the use of fertilizers and pesticides containing Zn are some of the anthropogenic sources of Zn in the environment [27]. The concentration of Zn in the hake muscle tissue during the entire research period did not vary significantly in the hake samples, Fig. 2. There were no significant differences in the Zn concentrations in the hake muscle tissue depending on the sampling season. In hake muscle tissue from the Montenegrin coast, Zn concentrations were lower than the values obtained in the Adriatic, Mediterranean and Tyrrhenian seas [25, 26, 28]. Also, the recorded values of Zn in hake were close to the values found in hake from the Adriatic and Mediterranean coasts and higher than the values recorded in the Ionian Sea [17, 23, 24].

In hake samples, there was no noticeable difference in Mn concentration depending on the sampling area. Concentrations of Mn in hake muscle tissue varied slightly depending on the season and the year of sampling. As Mn is an essential element, its concentrations in the analysed fish were expected, Fig. 2. The concentrations of Mn in hake muscle tissue were similar than the literature data recorded in the Adriatic, Mediterranean and Tyrrhenian seas and within the range of values recorded in the Adriatic Sea [23,24,26,28]. Lower Mn concentrations were recorded on the Adriatic and Ionian coasts than in hake muscle tissue in this study [17, 24].

It can be said that the concentration of Cu in hake muscle tissue during the entire study was quite uniform, without significant differences depending on the season and year of the study, Fig. 2. The concentrations of Cu in hake muscle tissue were lower than the literature data recorded in the Adriatic, Mediterranean and Tyrrhenian seas and within the range of values recorded in the Adriatic Sea [23, 24, 26, 28].

The concentrations of Cr and Ni in hake muscle tissue during the entire study were below the detection limits, Fig. 2. Ni concentrations in hake muscle tissue from the Montenegrin littoral were lower or within the range of values found in hake from the coast of the Adriatic, Ionian and Tyrrhenian seas [17, 24, 26]. In the Adriatic Sea in Montenegro, the measured concentrations of Cr in hake muscle tissue were very low, below the detection limits, as well as the values obtained in this study, while in the Ionian Sea, higher concentrations of Cr were measured in hake, compared to the values of the research in this study [17, 24].

In general, the examined metals in hake muscle tissue were mostly in the range or lower than the values recorded in hake muscle tissue from the Adriatic, Mediterranean, Ionian and Tyrrhenian seas.

Based on the above, it can be concluded that the mean concentrations of Fe, and Mn in hake muscle tissue were higher during the 2019 sampling year, while the mean concentration of Zn was higher during the year 2020. Also, during 2019, higher Cu concentrations were recorded in hake muscle tissue. The higher concentrations of examined metals in 2019 compared to 2020, the year of fish sampling, can be explained by the greater influence of anthropogenic factors such as the greater number of vessels, exhaust gases and the greater impact of tourism [29].

Differences in the concentrations of the tested metals in fish samples depending on the sampling season (spring-fall) were observed for Fe, whose concentrations were higher during the autumn sampling period, and from Zn and Mn, whose concentrations were higher during the spring sampling period of the analysed fish. At higher temperatures, metabolic activity increases, which can contribute to a higher level of metal accumulation in fish, and at lower temperatures, fish store energy reserves to a greater extent, before the period of reproduction [29, 30]. Also, the seasonal variability of the concentration of metals suggests that environmental factors such as the seasonal cycle of element absorption/dissolution in specific areas, local physicochemical parameters such as temperature, salinity and the nature of sediments can influence the bioaccumulation of metals by marine organisms [29, 31, 32].

Threshold values are not prescribed for all metals examined in this research, but only for Cu and Zn. Concentrations of Cu and Zn in hake muscle tissue from the Montenegrin coast were lower than the values prescribed by the FAO [33].

3.1. Risk assessment

The calculated values of the target hazard quotient risk (THQ) for the tested metals in hake, as well as the hazard index (HI), which assesses the joint impact of all tested elements, are given in Table 1. To calculate the THQ value, the mean concentrations of the tested elements during the two-year test period (2019/2020) were used.

Table 1 - *Target hazard quotient (THQ) and hazard index (HI) for the tested metals in hake for the general population, during the two-year study period [6]*

Metals	**THQ**
Cr	0.0083
Cu	0.0008
Fe	0.0006
Mn	0.0003
Ni	0.0013
Zn	0.0022
HI	0.0135

THQ values for all examined metals in hake muscle tissue were below unity, so the hazard index was also low (HI < 1). The results indicate that there are no health risks from the intake of Cr, Ni, Mn, Fe, Cu and Zn by consuming hake from the Montenegrin coast (THQ < 1). However, further monitoring and analysis of the presence of non-essential metals in fish are recommended, as is the assessment of risks and dangers to human health caused by the consumption of fish.

4. Conclusion

The results of this study showed that the concentrations of Cr, Ni, Cu, Zn, Fe and Mn in hake from the Montenegrin coast were within or below the permitted limit values and mostly within the range or lower than the values recorded in hake muscle tissue from the Adriatic, Mediterranean, Ionian and Tyrrhenian Seas. During the entire study period, the mean concentrations of the tested metals in hake muscle tissue followed a decreasing order: Zn > Fe > Mn > Cu > Ni > Cr. The risk assessment and hazard index values for all tested metals in hake muscle tissue were below unity, therefore the hazard index was low, indicating that there are no health risks from the intake of Cr, Ni, Mn, Fe, Cu and Zn through the consumption of hake. However, further monitoring and analysis of the presence of non-essential metals in fish, as well as the assessment of the risks and hazards to human health caused by fish consumption, are recommended.

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Original scientific paper

Innovative Cross-Border Risk Management for Hazardous Cargo Transportation: Enhancing Safety and Sustainability in the South Adriatic

Danilo Martino, Emilio Cimino, Nexhat Kapidani, Elizabeta Mrnjačević, Domenico Satalino, Cloridano Bellocchio

Abstract: The maritime transportation between Albania, Italy, and Montenegro is expanding, bringing economic benefits but also increasing the risk of disasters, particularly concerning the transportation of hazardous cargo. The Interreg IPA CBC Italy-Albania-Montenegro 2014-2020 CRISIS Project N.465 addresses these risks within the South Adriatic region and its ports, introducing an innovative Decision Support System (DSS) aimed at enhancing cross-border management of hazardous materials. This system focuses on preventing fatal accidents and promoting environmental sustainability by minimizing pollutant dispersion. It incorporates several factors, including weather forecasts (wind and wave conditions), port infrastructure, ship design, marine protected areas, and traffic flow to optimize Berth Allocation towards safer solutions. The solution developed within the project prioritizes safety by not only defining advanced algorithms but also ensuring that optimal solutions are applied throughout operations. The experience matured during the project execution led us to the formulation of a novel approach for solving Berth Allocation Problem, starting from evidence found in literature and evolving one of the most popular approaches towards the inclusion of sustainability-related parameters.

Keywords: Berth Allocation Algorithm (BAP), Hazardous Cargo Transportation, Risk Management, Cross-Border Cooperation & Innovative approach, Environmental Sustainability.

1. Introduction

1.1. The CRISIS Project

The Cross-border RISk management of hazardous material transportation (CRISIS) project is a European co-funded project involving partners from Italy, Albania and Montenegro. CRISIS aims to investigate these specific risks by analyzing data and evidence from the Italian, Albanian, and Montenegrin territories, along with road transportation in the surrounding regions. Its main objective was the development of an Information and Communication Technology (ICT) Platform to monitor hazardous materials transportation in the Adriatic Sea. This platform integrates two DSS Modules to enhance cross-border management of hazardous materials. The first module is focused on providing an enhanced berth allocation service, creating prioritized schedules based on ship features, transported cargo and weather condition; the second module focuses on open-sea transportation and aims to minimize navigation by including aspects related to Marine Protected Areas (MPA). The ICT platform, therefore, acts as a coordinator and monitoring tool for monitoring the transportation of such materials and support stakeholders in scheduling berth allocation plans. Based on the challenges identified during the project execution, the present article focuses on the development and implementation of an innovative algorithm for the second module with the aim of optimizing port operation under environmental and safety constraints.

1.2. Background and Motivations

Transportation by sea has been a cornerstone of global trade for centuries, facilitating the movement of raw materials, finished products, and commodities across vast distances [1]. As international trade has expanded and evolved, so too have the complexities and challenges associated with maritime transportation and cargo handling. One of the most pressing concerns is the safe and efficient management of ships carrying hazardous or dangerous cargo on board. Hazardous substances include gases (IMO Class 2), flammable liquids (IMO Class 3), toxic substances (IMO Class 6), and radioactive materials (IMO Class 7). These materials are vital to various industries, from manufacturing and energy production to agriculture and healthcare. While their transportation is crucial to sustaining modern economies, this also introduces unique risks that demand meticulous planning and execution.

The primary objectives when transporting dangerous materials via maritime routes are to ensure the safety of human life, protect vessels and cargo, and prevent environmental harm. The potential consequences of accidents involving hazardous materials are severe, encompassing immediate threats to crew members, long-term health risks, and environmental degradation. With its delicate balance of flora and fauna, the marine ecosystem is particularly vulnerable to contamination from spills or leaks from ships.

Alongside transportation in open seas, an important topic is the management of ports and traffic near shores. This task, with its challenges and complexity, grows in importance when transportation of hazardous materials is involved. Effective berth allocation is crucial in any port management system, but when hazardous materials are in transit, the stakes are significantly higher [2].

Typical operational and service level indicators, such as berth allocation waiting time, are particularly important for port performance intensity of port asset utilization [3]. Usually, waiting times between arrival and the allocation of berths have been decreasing. The world's largest ports, like Antwerp and Hamburg, recorded a reduction in the port-to berth time. However, less positive performances were recorded elsewhere, while in some ports port-to-berth waiting times have increased like in India and some African countries [1].

Traditional algorithms for berth allocation focus on various operational objectives such as minimizing wait times, optimizing resource usage, and maximizing throughput. However, these objectives, although critical, are not sufficient to guarantee environmental and human safety, especially when hazardous materials are involved. Factors such as safety regulations, environmental risks, proximity to protected areas, and the potential for catastrophic events demand a more specialized approach to these problems.

The proposed algorithm evolution is designed to integrate multiple layers of complexity into a cohesive system that aligns with both operational goals and safety protocols. By leveraging a combination of technology and methodologies, the proposed algorithms aim to provide both time-optimized and safety-optimized planning solutions.

The article is structured as follows: Section 2 presents a review of the existing literature on berth allocation algorithms. Section 3 details the theoretical foundation and implementation of the proposed algorithmic modifications. Section 4 reports and discusses the results obtained from laboratory benchmarks, evaluating the effectiveness of the proposed approach.

2. Berth Allocation Algorithm

2.1. Literature Review

The Berth Allocation Problem (BAP) is a critical challenge in the domain of maritime logistics, particularly in the context of container port operations. The primary objective of BAP is to efficiently assign berths to incoming vessels based on various constraints and optimization criteria. This problem involves several considerations such as vessel characteristics, arrival times, berth availability, and compatibility with neighboring vessels. The complexity of BAP arises from the need to balance conflicting objectives, such as maximizing berth utilization while minimizing vessel waiting times and operational costs. In most cases, real-world factors like uncertainties in arrival schedules and dynamic berth availability further contribute to the intricacy of the problem. As a result, finding an optimal solution to the Berth Allocation Problem often requires advanced optimization algorithms and heuristics due to its NP-hard nature, making it a challenging and crucial area of research in maritime logistics.

The study of BAPs features a rich literature of methodologies and algorithms aimed at optimizing the allocation of berths in port terminals. Within this literature, researchers have explored various approaches tailored to different BAP classifications, such as static versus dynamic scenarios or continuous versus discrete layouts. Literature evidence shows that BAP is often solved with methodologies such as exact algorithms, heuristics, and metaheuristics, each offering unique benefits and trade-offs. The choice of methodology often depends on factors such as problem size, required accuracy, and available computational resources, with hybrid approaches often offering the most effective solutions by combining elements of different methodologies.

Among the solutions that have significantly contributed to BAP is the non-linear mixed integer programming model together with the stochastic beam search algorithm, proposed by [4] with the aim to minimize the costs of delay and asset reallocation on the terminal.

Efficient terminal management requires reducing the time of ships spent in the port on the loading/unloading and other services, and therefore, the "Port Collaborative Decision Making (PortCDM)" concept is introduced in [5]. The main contribution of this concept is the intelligent system that will improve port call data sharing and enable high-precision calculations of ships **Estimated Time of Arrival (ETA)** and **Expected Time of Departure (ETD)**, which is of great significance for berthing operations and reducing the ship time in port in waiting queues at anchorage, as well as other bottlenecks related to berthing/unberthing and servicing on the docks.

An interesting approach was proposed in [6], conceptualizing the "Bi-objective Robust Berth Allocation Model (BRBAM)", which aims to determine a ship berthing program that minimizes operating costs and maximizes customer satisfaction. The focus is on economic performance and customer satisfaction, with the goal of optimizing the robustness of the berth assignment policy. In the field of metaheuristic algorithms, notable efforts have been made in [7] with the use of the Chemical Reaction Optimization (CRO) inspired by the thermodynamics law of chemical reaction and in [8] with the development of a novel evolutionary algorithm with the aim of assisting berthing scheduling at container terminals. In [9], one of the most recent studies in this field, the authors proposed a solution methodology involving the **Cuckoo Search Algorithm (CSA)** to minimize terminal costs, demonstrating its higher effectiveness compared to other metaheuristic algorithms [9,10] .

The above-mentioned studies focused on minimizing costs, times or maximizing satisfaction, hence putting particular emphasis on the economic aspects of the BAP. In literature, fewer studies highlighted the sustainability aspects of such dangerous operation, especially when dealing with hazardous cargo or unsafe operational conditions. In [11] the authors studied BAP including tidal constraints. One of the most advanced literature evidence found was [12] where the authors focused their efforts on designing a "Risk Assessment for berthing of hazardous cargo vessels", however the paper focused primarily on finding the causes of accidents in handling cargo vessels more than solving a BAP problem.

This article focuses on finding an optimal solution to improve with a more complex problem formulation that includes the above-mentioned risk factors in a solution which includes cargo risk levels, wharf structure and weather variables in the algorithmic solution. CSA was selected as the candidate algorithm based on the literature findings, due to its capability of finding optimal solutions in low computational times. Major effort was put into minimizing loading/unloading risks, hence increasing the complexity of the problem itself with respect to the classical formulation.

3. Risk-Aware Berth Allocation Algorithm

3.1. Modified Problem Formulation

This article is primarily focused on the hybrid berthing layout with dynamic vessel arrivals, hence it will be referred to as DH-BAP, which is more complex with respect to the scenario with static arrivals. The choice of hybrid berthing layout is taken due to the need to assign a safety score to pre-determined berthing point in the whole quay which is difficult if applied with a high level of granularity. Hence, the hybrid layout comes from the division of the dock in a fixed number of berthing points, even if long ships are allowed to occupy more than one, if necessary.

For formulation simplicity, the Maritime Container Terminal (MCT) is considered to possess one berthing layout with known length to accommodate vessels arriving at various time points dynamically. The set of all potential berthing positions on the wharf is denoted as $B = \{1, 2, \dots, M\}$. This simple case is extendable for each berth, even with wharfs with particular berthing configuration, with minimal effort.

Typically, the BAP is tailored to a specific time frame for vessel arrivals, in this specific case a focus is placed on the upcoming 24 hours (next day). This period is hence divided into a set of 30-minute time intervals denoted as $T = \{1, 2, \dots, K\}$. Each interval is accompanied by a weather assessment, detailing both wind and sea conditions expected during that specific time segment.

The set $S = \{1, 2, \dots, N\}$ encompasses all ships scheduled to arrive at the terminal on the following day. Crucial information is available in advance for each ship, including ETA, PBP (Preferred Berthing Point), ship length, estimated (or required) ETD, and an estimate of cargo risk based on the pollution risk posed by the products transported and their potential impact on marine species. In addition, the estimated handling times for each ship were considered known in advance based on previous agreements between the MCT and the incoming ships, such as the number of quay cranes chartered by the ship or the number of containers to be loaded/unloaded during the handling period.

In an ideal scenario (free wharf and mild weather conditions), as soon as a ship arrives it is allocated at the safest spot in the quay, fastly handled and depart, respecting the handling times. If more ships arrive in the same interval, priority must be given to ships with higher cargo risk, reserving them the safest spots in wharf. Other ships are then allocated in less safe spots (if available) or have to wait for a safe spot to be available, based on weather conditions, wharf availability and cargo risk assessment. In the end, in case of severe weather conditions, the algorithm should be able to trade off handling speed and safety by delaying unsafe operations.

Total risk cost for a ship arriving at the MCT is split into three different terms, two of which have the most impact:

Waiting Costs (WC) influenced by the total time a ship has to wait before being served (Waiting Time or WT), the average wave risk assessment for the WT and the ship's cargo risk level. For waiting costs only wave risk is considered due to waiting areas often exposed to higher marine currents. Equation for waiting costs, expressed as [risk/hour] is the following:

$$WC = W_w * [(CRS_s + 1)^2 * W_{WAS}] * WT_s \tag{1}$$

Where:

- W_w is the waiting weight, expressed as cost per unit time, indicating how waiting is considered high on cost impacts on the overall cost.
- CRS_s is the Cargo Risk Score of ship s.
- W_{WAS} is the average *Waiting WAve Score* for that wharf in the waiting times.
- $WT_s = BT_s - ETA_s$; BT_s is the berthing time for the ship.

Handling Costs (HC) are influenced by the time necessary for a ship to be served once docked (Handling Time, HT), the average wind risk assessment for the whole period in which the ship is served, the ship's cargo risk level and the berthing point safety assessment score. Since wharfs are usually protected from strong marine currents, only wind scores are considered for handling costs, being quay cranes operations riskier under severe wind conditions. Equation for handling costs is the following:

$$HC = H_w * \left[(CRS_s + 1)^{H_{WIS}/BSS}\right] * HT_s \tag{2}$$

Where:

- H_w is the handling weight, expressed as cost per unit time, the index on how handling costs impact on total cost.
- H_{WIS} is the average *Handling WInd Score* for that wharf during the whole handling period of the ship.
- BSS is the Berth Safety Score, assigned to a berthing point based on its positioning on wharf and its exposure to sea and winds.

- **Late Departure Costs (LDC)** are influenced only by the amount of time a ship exceeds its ETD. This difference is computable as: $LDT = ETD - (ETA + WT + HT)$ and it can assume also negative values, resulting in an incentive towards fast ship handling. The equation is the following one:

$$LDC = LD_w * LDT_s \tag{3}$$

Where LD_w is the late departure weight expressed as cost per unit time indicating how early or late departure impacts on the total cost.

Hence, the overall cost equation for a single ship can be expressed as following, considering a ship s, berthed at time BT_s and in berthing position BP_s, waiting under average wave conditions W_{WAS} and being served under average wind conditions H_{WIS}:

$$Cost(s, BP_s, BT_s, W_{WAS}, H_{WIS}) = WC + HC + LDC \tag{4}$$

The goal of the berth allocation problem is to find the optimal berthing position and times for all ships coming at the planning horizon such as the overall cost is minimized:

$$minimize \sum_{s \in S} \sum_{b \in B} \sum_{t \in T} x_{sbt} * Cost(s, BP_s, BT_s, W_{WAS}, H_{WIS})$$

subject to[9]:

$$[C1]\ x_{sbt} \in 0,1 \qquad \forall s \in S, b \in B, t \in T$$

$$[C2] \sum_{b \in B} \sum_{t \in T} x\_\{sbt\} = 1 \qquad \forall s \in S$$

$$[C3]\ BT_s \geq ETA_s \qquad \forall s \in S$$

$$[C4]\ |BT_s - BT_{s'}| \geq SET \qquad \forall s, s' \in S$$

$$[C5]\ BP_s + L_s \leq W \qquad \forall s \in S$$

$$[C6] \textstyle\sum_{s' \neq s \in S} \sum_{b = BP_s - Ls' + 1}^{BP_s + L_s} \sum_{t = BT_s - HT_{s'} + 1}^{BT_s + HT_s} x_{s'bt} = 0 \qquad \forall s \in S \tag{5}$$

[1] x_{sbt} is a binary variable which takes value 1 if a ship s is assigned to berthing position b at berthing time t, 0 otherwise.

[2] This constraint ensures that any ship is berthed only once during the planning horizon.

[3] Third constraint ensures that ships cannot be served before their arrival.

[4] **Safety Entrance Time (SET)** constraint ensures that two ships cannot be berthed simultaneously. Safety Entrance Time is included in the problem formulation and implementation since most ports welcome one ship at a time due to physical constraints at their entrance.

[5] Length constraint is applied on the whole wharf, ensuring that all ships are allocated inside the physical dimension of the quay.

[6] The last constraint ensures that, during planning, two ships cannot even partially overlap in both space and time: two ships cannot coexist in the same berthing point if they share the same handling time slots.

3.2. Chosen algorithm: CSA.

CSA is a powerful nature-inspired optimization technique that derives its inspiration from the unique reproductive behavior of cuckoo birds. The inspiration for CSA comes from the brood parasitism strategy employed by certain species of cuckoo birds. These birds lay their eggs in the nests of other bird species, shifting the responsibility for incubating and caring for their offspring onto unwitting host birds. To survive, the cuckoo chicks must outcompete the host birds' own chicks for food and care. This concept of laying eggs in other birds' nests, combined with the need for cuckoo chicks to thrive in a competitive environment, served as the foundation for the CSA. In optimization terms, the "eggs" represent potential solutions to a problem, while the "nests" are the solution spaces. The objective is to find the best-fit solution by continually improving and replacing eggs in suitable nests.

Introduced in 2009 by Xin-She Yang and Suash Deb, CSA has gained widespread recognition and adoption in the field of optimization. Its appeal lies in its ability to effectively address complex optimization problems [9,13], particularly those characterized by multi-modal and non-linear search spaces. CSA operates as a population-based optimization algorithm. It starts by initializing a population of "nests" or potential solutions to the optimization problem. Each nest represents a potential solution, and the quality of these solutions is evaluated based on an objective function. The algorithm then proceeds through a series of iterations, where cuckoos (representing new potential solutions) are introduced into the population. These cuckoos lay eggs (representing potential solutions) in nests, with the quality of the eggs determined by their fitness. If an egg is of higher quality than the nest it is placed in, it replaces the previous content of that nest. CSA also incorporates mechanisms to maintain diversity in the population. It identifies the "worst" nests and either replaces them with new random nests or abandons them altogether. Simultaneously, the "best" nests are retained to ensure that the algorithm does not lose promising solutions. The process continues for a predefined number of iterations or until a termination condition is met. Throughout these iterations, CSA explores the solution space, gradually improving the quality of solutions, and eventually converging to an optimal or near-optimal solution.

The time complexity of the CSA is a topic of interest, as it influences its practical applicability. CSA's time complexity depends on a range of factors, including problem size, the choice of parameters, and the complexity of the objective function. In general, CSA exhibits a moderate time complexity, often comparable to other metaheuristic optimization algorithms such as genetic algorithms and particle swarm optimization [9]. The primary computational burden arises from the evaluation of the objective function for each nest (potential solution) and cuckoo (new potential solution). The algorithm's performance can vary significantly based on the problem's characteristics. In cases where the objective function is computationally expensive, CSA may require longer to converge. Additionally, the number of iterations and the size of the population influence the overall runtime. Efforts have been made to enhance CSA's efficiency, such as parallel implementations and hybridization with other optimization techniques. These adaptations aim to reduce the time complexity and accelerate convergence, especially for large-scale and computationally intensive problems.

CSA offers several notable advantages that make it a valuable tool in the realm of optimization:

- **Global Search Capability**: CSA's ability to explore extensive search spaces and locate global optima is one of its primary strengths. It excels in scenarios where the optimization landscape is complex and multi-modal, ensuring that it does not get trapped in local optima.
- **Simple Implementation:** The algorithm's simplicity is a significant advantage. CSA's minimal parameter requirements and straightforward structure make it accessible to both researchers and practitioners. It can be readily implemented and customized to address a wide range of optimization problems.
- **Diversity Maintenance:** CSA incorporates mechanisms for maintaining diversity within the population. By identifying and replacing the worst nests while preserving the best ones, the algorithm strikes a balance between exploration and exploitation. This feature reduces the risk of premature convergence and promotes the discovery of high-quality solutions.
- **Parallelization Potential:** CSA's population-based approach lends itself well to parallelization. This means that it can harness the computational power of modern hardware, making it suitable for addressing computationally intensive optimization problems efficiently.

While CSA offers several advantages, it is essential to consider its limitations:

- **Parameter Sensitivity:** CSA's performance is extremely sensitive to the choice of parameters, including the population size, the termination criteria and parameters related to random generation of new solutions or deletion of less important ones. Tuning these parameters to achieve optimal results can be a non-trivial task and may require extensive experimentation.
- **Limited Scalability:** CSA may encounter challenges when applied to very large-scale optimization problems. The population-based nature of the algorithm implies that it requires maintaining and updating a considerable number of nests, which can be computationally demanding and resource-intensive for massive problem instances.
- **Convergence Rate:** CSA, while effective at global exploration, may exhibit a slower convergence rate compared to some other optimization algorithms for certain problem instances. Achieving convergence to an optimal solution might require more iterations, making it less suitable for time-sensitive applications.

```
Objective function f(X), X = (f(x1, x2, ..., xd) T
Generate initial population of n host nests Xi (i=1, 2, …, n)
While t < Max_itertions do
    Get a cuckoo randomly by Levy flights
    Evaluate its quality/ fitness Fi
    Choose a nest among n (say, j) randomly
    If Fi > Fj then
        replace j by the new solution;
    End If
    A fraction (Pa) of worse nests are abandoned and
    new ones are built;
    Keep the best solutions
    Rank the solutions and find the current best
End While
Postprocess results and visualization
```

Fig. 1 – *Example of pseudocode for CSA* [14].

CSA proved to be a more effective algorithm compared to Mixed Integer Linear Programming (MILP) or Genetic Algorithms (GAs) in [8], giving both faster responses and converging to better optimal solutions than other metaheuristic algorithms. CSA implements a series of mechanisms to improve exploration, such as the use of random walks or replacements of a portion of worst nests with the aim to generate new solutions. While random walks (Lévy Flights) help improve the solutions in the neighborhood of previous ones, nest replacement abandons worst solutions to explore new ones in the solution space.

CSA proved its effectiveness in searching acceptable local optima, often near the global ones, even with multi-objective functions, and a highly constrained search space like the one imposed by the berth allocation problem [9].

3.3. Modified CSA: design and implementation details

CSA was implemented using **python 3.10.4** and deployed as an independent and scalable module. It acts as a service on calls, accepting an input and returning the planning. The code was organized in classes, modeling both the inputs and the solution. While implementing it, several aspects were taken into account, such as:

- **Egg and Nest definitions:** it was important to define, pragmatically speaking, the characteristic of an egg, i.e., the shape of the solution. In the algorithm an egg was strictly related to a single ship, meaning that a nest is composed of N eggs, where N is the number of vessels taken into account in an execution. For each ship, both berthing time BT_s and berthing position BP_s were taken in account, as depicted by the cost function defined in Section 3.1. Hence, an egg is represented by a berthing point depending on the wharf and a time slot from those defined in the problem formulation. This adaptation to the specific discrete use case led to an egg structure similar to a hash map, basing the search space on the integer indexes of both the berthing points and the time slots.
- **Constraints definition:** two major types of constraints were identified while developing the solution, namely *egg-domain constraints* and *nest-domain constraints.* The former are related to the placing of a single ship in the wharf, so constraints C1, C2, C3 and C5; constraints C4 and C6, instead, involve more than one ship in a solution. Defining constraint types was useful to control operations while executing the planning algorithm, avoiding unfeasible solutions.
- **Starting conditions:** starting conditions are necessary for every evolutionary algorithm and adopting strategies allows them to converge as soon as possible. In the design of the CSA, it was impossible to set a fixed starting condition due to the variable nature of weather, ship arrivals and port structures. However, to avoid

unfeasibility, the starting population was forced to respect both nest and egg constraints.

- **Evolutionary strategy:** as depicted in [9], using levy flights led to a fast-convergence algorithm. The same strategy was adopted here, further details will be provided later in this chapter.
- **Replacement strategy:** two replacement strategies for CSA were designed for algorithm execution. The first one consisted of simply replacing the worst nests with new randomly generated ones. The second replacement strategy implements a *crossing over* mechanisms where the resulting new nests are bred from two random nests in the whole solution space.
- **Hyperparameters tuning:** once the problem definition was set, one of the most important parts for CSA execution is defining its working mechanisms by setting algorithm hyperparameters. CSA convergence speed is highly influenced by its settings and finding an optimal configuration is often a trial-and-error workflow. The following list is a comprehensive set of hyperparameters already tuned to provide a high convergence speed:
    - **N_nest = 100:** size of the solution space, namely the total number of nests generated as population sample. The higher the number of nests, the higher are the chances to find an optimal solution but also the execution times.
    - **N_iterations = 100:** max number of iterations of the algorithm. The higher the iterations, the higher the execution times but generally the lower the global fitness score reached. To avoid reaching the maximum number of iterations with no improvement, an early stopping mechanism was designed to stop the algorithm if it does not improve overall fitness after 10 iterations.
    - **pa = 0.65:** fraction of worst nests to be deleted. Usually, in this algorithm, this number fixes at 0.25. The higher the fraction, the higher the chances of finding an optimal solution and the execution times. A too high value, however, can lead to convergence problems depending on the strategy used to replace abandoned nests. The value was set so high due to the trade-off between execution times and constraint compliance.
    - **max_tries = 2:** maximum number tries for iteration to avoid generation operations to stuck in endless loops. This could happen if the nest is not able to produce a new solution due to constraints and the number of ships.

- **levy_beta = 1.5, sigma_u = 0.6966, sigma_v = 1, c_multiplier = 1:** set of hyperparameters for the levy flight operations from literature. Noteworthy the *c_multiplier* parameter which decides how much the levy flight step influences the new solution, usually set to a fraction, but being set to 1 in this use-case due to the particular solution structure.

Here, the following pseudo-code to document the most important modifications apported to CSA for solving the DH-SBAP. Operation on eggs were mainly performed on two-element arrays, containing the indexes of berthing points and time slot of the current solution. When the egg indices are modified by the algorithm, the resulting object field for berthing point and time slot is also filled. Each egg has the responsibility to compute its fitness score, based on the BAP environment (weather variables included in the time slots list). Nests' fitness and all constraints, instead, are handled by the berth allocation solver.

Start

Given the following objective function:
$min \sum_{s \in S} \sum_{b \in B} \sum_{t \in T} x_{sbt} * Cost\,(s, BP_s, BT_s, W_{WAS}, H_{WIS})$
Generate Random Population
While t $< n_{iterations}$ **do**:
  Get Best Nest
  for each nest **do**:
    Perform Nest Levy Flight (nest, bestnest)
  Sort Nests by Fitness
  for each nest **do**:
    Perform Egg Elimination(nest)
  Reduce current $c_{multiplier}$ by $\frac{1}{100}$ its current value
End

Fig. 2 – *CSA, CRISIS version.*

Start

$levy_\beta = 1.5$
$\sigma_u = 0.6966$
$\sigma_v = 1$
Get current nest fitness score
while n < max tries **do**:
  for each egg in nest **do**:
    Get the same ship egg in the best nest
    Compute levy flight step toward a better solution using indices:
      u = array of 2 values normally distributed with mean 0 and std σ_v
      $s = \frac{u}{|v^{\frac{1}{levy_\beta}}|}$
      new egg = $c_{multiplier} * s * (egg - bestegg)$
    if new egg respects egg-contraints **then:**
      Compute new egg fitness score
      if new egg is better than the previous one **then:**
        Swap eggs
  if new nest respects nest-contraints **then:**
    return new nest
End

Fig. 3 – *CRISIS CSA's modified levy flight step.*

Start

Get the p_a fraction of worst nests
for each nest in worst nest list **do**:
  while t < max tries **do**:
    Generate two different random number between 0 and $n_{nests} - 1$
    Pick $nests_1, nest_2$ in solution space using these two numbers
    for each egg in current selected nest **do**:
      select egg_1, egg_2 from $nest_1, nest_2$ using the related egg indices
      new egg = egg + N[0, 1) * $(egg_1 - egg_2)$
      if new egg respects egg-contraints **then:**
        Compute new egg fitness score
        if new egg is better than the previous one **then:**
          Swap new egg with old egg
    if new nest **do not** respects nest-contraints **then** repeat attempt
Swap worst nests with new nests
End

Fig. 4 – *CRISIS Mixing Replacement Strategy. Egg operations are treated as vector elementwise operations.*

Start

Get the p_a fraction of worst nests
for each nest in worst nest list **do**:
  while t < max tries **do**:
    for each egg in current selected nest **do**:
      Generate random egg
      if new egg respects egg-contraints **then:**
        Compute new egg fitness score
        if new egg is better than the previous one **then:**
          Swap new egg with old egg
    if new nest **do not** respects nest-contraints **then** repeat attempt
Swap worst nests with new nests
End

Fig. 5 – *CSA Replacement Strategy.*

Among the two above-mentioned replacement strategies, the first one was kept, since it resulted in a better convergence rate and slightly lower execution times. Each time a new egg is generated or evolved from other ones, its fitness is evaluated against that of the whole nest: if the nest with the new egg has an overall fitness score lower than the previous one, the new egg is kept. The use of more nests ensures the algorithm to check for different optima in the solution space, trying different combinations.

```
computeFitness(egg, ship)
Start

Get the ship related to the current egg
Get all time slots included in waiting time period of the related ship
Compute mean wave risk score for the selected waiting time slots
Get all time slots included in handling time period of the related ship
Compute mean wind risk score for the selected handling time slots
Compute waiting times, handling times and late departure times in seconds
Compute waiting costs using the average wave risk
Compute handling costs based on the average wind risk
Compute late departure costs
Sum all costs
End
```

Fig. 6 – *Egg fitness score computing pseudocode, based on the fitness function formula above.*

4. Results and Discussion

The implemented BAP algorithm described in Section 3.1 was evaluated against synthetic data. These synthetic data represent a set of realistic values from weather variables, cargo risk score and berth safety scores, each included in an integer variable in interval [1,10]. The idea behind these tests was to assess the behavior of our approach against simulated environments, evaluating if CSA can perform berth allocation following the cost function. During these experiments, both wind and wave indicators were simulated through a constrained random walk, while CRS scores and BSS scores were randomly sampled within the given set of values. Other variables were randomly sampled from a random distribution, like the ship ETA and ETD, handling time for each ship and ship length.

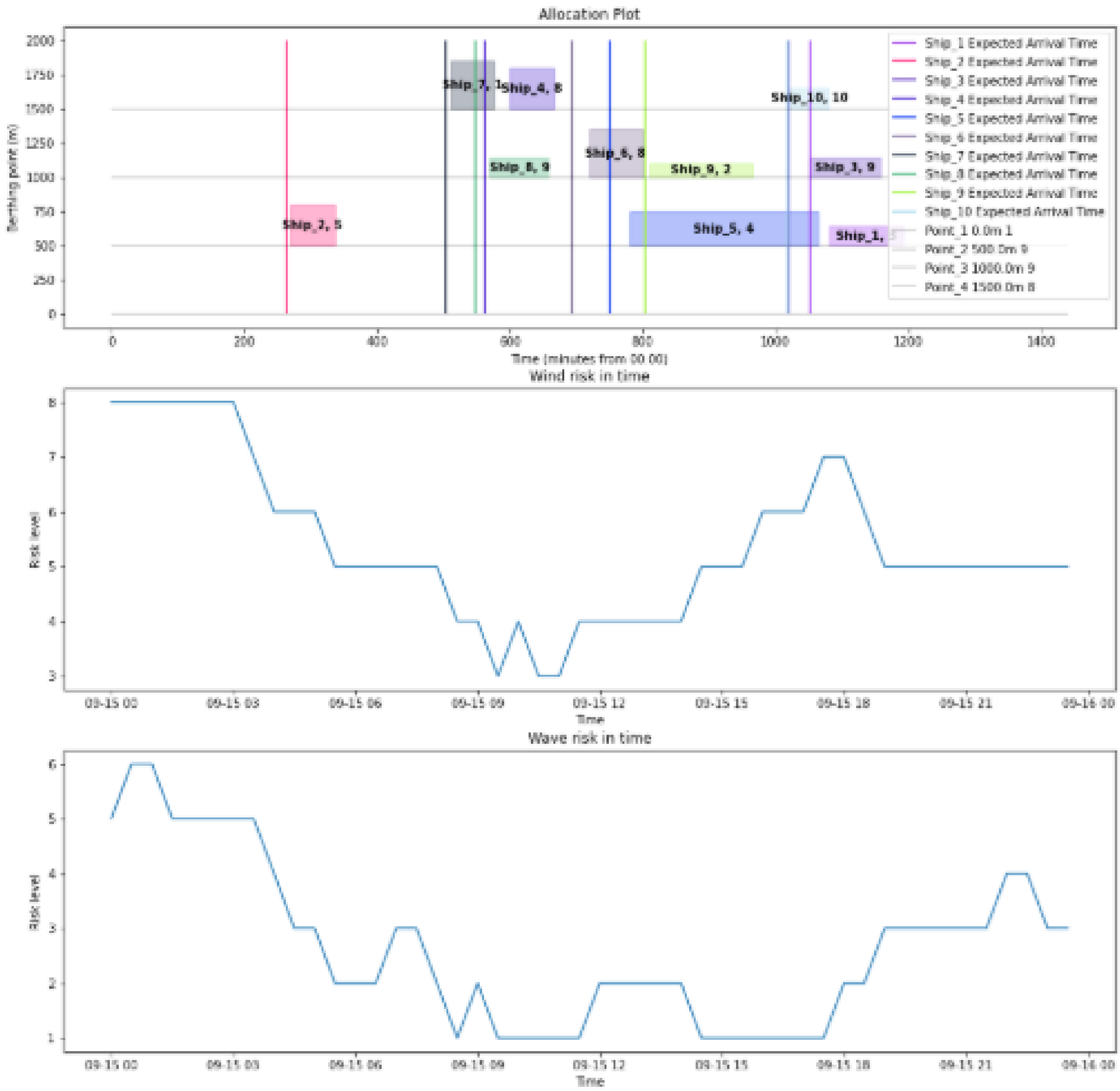

Fig. 7 – *Example BAP testing environment. Reading from above to below:* ***A)*** *Ship placing plot.* ***B)*** *Wind intensity simulation plot* ***C)*** *Wave intensity simulation plot.*

In Fig. 7 there is a plot depicting the content of the typically used BAP testing environment, comprehending information about ship placement and weather simulation.

The upper graph represents the positioning of the ship in a spatial and temporal graph: the x-axis represents time (in minutes) while the y-axis represents the length of the wharf. The horizontal gray lines starting from the vertical axis represent the berthing points that are the starting point for the ship's position. Berthing points are also reported in plot legend for clarity. Ships are represented as colored boxes, which show the ship's name and cargo risk score. The length of the box (x-axis) represents the ship's handling time, while its height (y-axis) represents the length of the ship. The colored vertical lines, on the other hand, represent the ETA of each ship, and the color of the lines corresponds to the color of the ship. A ship can only be placed on berthing points, but can occupy more than one if necessary, provided it does not exceed the length of the dock. Moreover, x-axis is divided into timeslots of pre-defined length.

The middle and lower plots, instead, represent the random walk simulation of wind and wave variables, respectively. The x-axis is aligned with the upper plot while the y-axis represents the intensity of the specific weather phenomena.

4.1. Laboratory Benchmark and Sustainability Evaluation

Given the experiment setup, it is necessary to assess if berthing schedules produced by the algorithm effectively contribute to improving the sustainability and safety of operations. The following statements represent the desired behavioral outcomes:

1. In the case of severe sea conditions, ships should be served promptly, giving priority to high-risk cargoes, regardless of the berthing point. This is based on the simplified assumption that docks are protected from sea currents and waves, so loading/unloading operations can be conducted even under the presence of poor outer sea conditions.
2. In heavy winds, high-risk cargo ships have two options:
    a. If berthing points with high safety scores are available, handling operations are allowed and ships can be served as soon as possible, reserving the highest safety points for the highest risk cargoes.
    b. If safe mooring points are not available and the wind is expected to decrease in intensity, it is preferable to wait.
3. In the event of both adverse sea and wind conditions, a trade-off must be made. High-risk cargo should be handled promptly if safe docking points are available, otherwise it is preferable to wait until conditions are better.
4. In case of mild weather data, the problem turns into a simple schedule optimization problem.

These conditions are encapsulated in the mathematical formulation proposed in the previous sections. However, by exploiting only the cost function, it is difficult to estimate the effectiveness of the results themselves. Therefore, an evaluation approach based on a sustainability index is formulated.

Sustainability considers different metrics and KPIs based on the case study: in context of logistics and transportation, a recent study [15] identified a set of useful sustainability-related KPIs, assessing both economic, environmental and social dimensions. This article's focus on sustainability is based on preservation of marine ecosystem. For these reasons, the modified CSA is built on a hazard-mitigation cost function, considering several risk factors and penalizing unsafe cargo operations. However, quantifying the risk of pollution based on the BAP-produced schedule is a challenging task to perform without a rich set of field data.

Therefore, a custom comparative evaluation approach was proposed to validate results obtained from these algorithms. The comparison involves comparing two versions for each algorithm with their respective results:

- **Sustainable version:** considers risk factors such as weather assessment, cargo risk assessment, wharf security assessment and marine protected areas, producing a **sustainable-optimal result.** In this context, sustainability is measured by the respective cost functions of each modified version of the algorithm.
- **Base version:** is the base version of each algorithm, explicitly formulated to exclude weather data, wharf security assessment and cargo risk assessment, optimizing only service times. The base version produces a **time-optimal result** or **unsustainable result.**

The following values are computing by crossing algorithms and results obtained:

- **Sustainable Result over Sustainable Cost (SRSC):** The total cost obtained with a normal execution of the sustainable version of the algorithm.
- **Unsustainable Result over Unsustainable Cost (URUC):** The total cost obtained with a normal execution of the base version of the algorithm.
- **Unsustainable Result over Sustainable Cost (URSC):** Total cost obtained by applying the sustainable cost function over the results obtained by the execution of the unsustainable algorithm. It expresses how much the time-optimal solution costs in terms of sustainability.
- **Sustainable Result over Unsustainable Cost (SRUC):** Total cost obtained by applying the cost-optimal function over the results obtained by the execution of the sustainable algorithm. It expresses how much the sustainable-optimal solution costs in terms of efficiency.

In the end, from these three values, three indices are provided:

- **Sustainability Index (SI):** $\frac{URSC}{SRSC}$, where URSC >= SRSC, has a minimum value of 1 and no upper values. It indicates the improvement ratio in terms of sustainability brought by the sustainable solution against the cost-optimal one.
- **Effectiveness Index (EI):** $\frac{URUC}{SRUC} * 100$ where URUC <= SRUC, has a maximum value of 100% and asymptotes towards 0%. It defines the percentage of effectiveness of the sustainable solution against the cost-optimal one.
- **Sustainability to Effectiveness Ratio:** $SI * EI$, asymptotically touches 0 and grows to infinity. It defines how much improvements in terms of sustainability there are against the loss in terms of efficiency.

4.2. Test Results

BAP experiments were conducted in two stages to ensure thorough testing and evaluation of the system's performance. The first stage, conducted in a development environment, aimed to develop a correct algorithm, and visualize how the algorithm reacts to objective function minimization. In this environment, weather variables, wharf structure, and ships were simulated and/or forced to specific values.

The first experiment was conducted with two ships, with the aim of testing scenarios involving simple concurrency. These ships had similar ETA but different cargo risk levels, so they must “compete” for the safest spot. The objective of the experiment was to test the algorithm's capability to allocate ships to the safest spot based on the cargo risk level they exhibit.

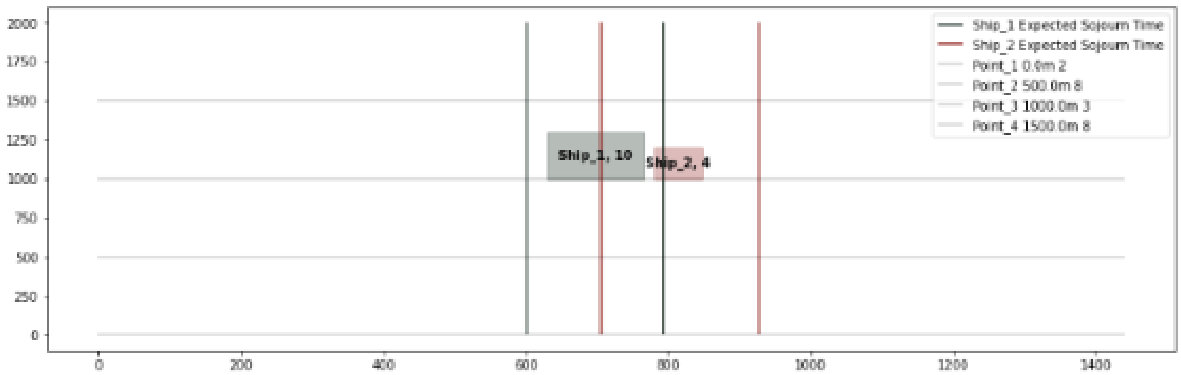

Fig. 8 – *Experiment 1 – Initial random placement.*

In this experiment, the wave and wind conditions were set to cross sharply. In the first half of the time horizon, the wind score was set high (9-

10) and then decreased to an average of 6 after noon. On the other hand, the waves were set to increase in intensity, starting from a low level and reaching severe conditions at noon (Fig. 9). This experimental setup should test the harsh weather trade-off, expecting ships to be served on safest berths and promptly. Time slots are set to be 30 minutes wide.

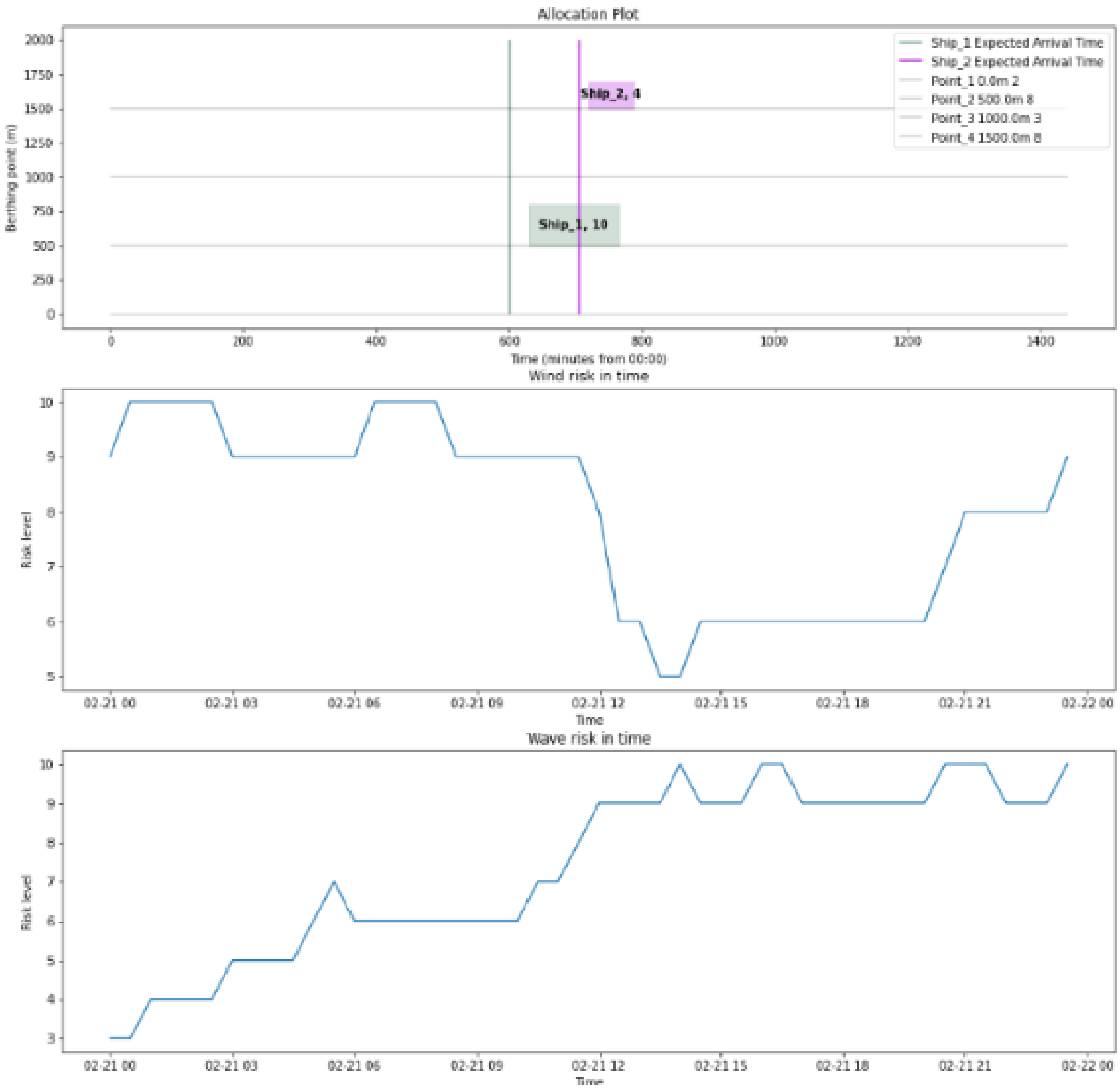

Fig. 9 – *Experiment 1 - Berthing schedule and weather variables.*

The test produced correct and valid results: since **Ship_1** had the highest risk **(10)**, it was allocated to one of the two berthing points with the highest safety score **(Point_2, 8)**. Moreover, it waited a time slot (30 minutes) before starting handling operations due to harsh wind conditions and since sea conditions were more permissive in the first half of the day. **Ship_2** with a medium cargo risk **(4)** was immediately allocated to the second safest spot available **(Point_4, 8)** instead of waiting for the first ship to finish. This was due to the increasing wave risk level, which impacts waiting times and to the lower cargo risk.

The second experiment focused on testing the algorithm in a busy environment and verifying its convergence to an optimal solution. In this experiment time slots are set to 60 minutes to decrease available slots and 8 different ships with different cargo risk level were placed randomly. Moreover, wind conditions were set to be severe, while sea conditions worsened during the time horizon, reaching their maximum intensity at the end of the day.

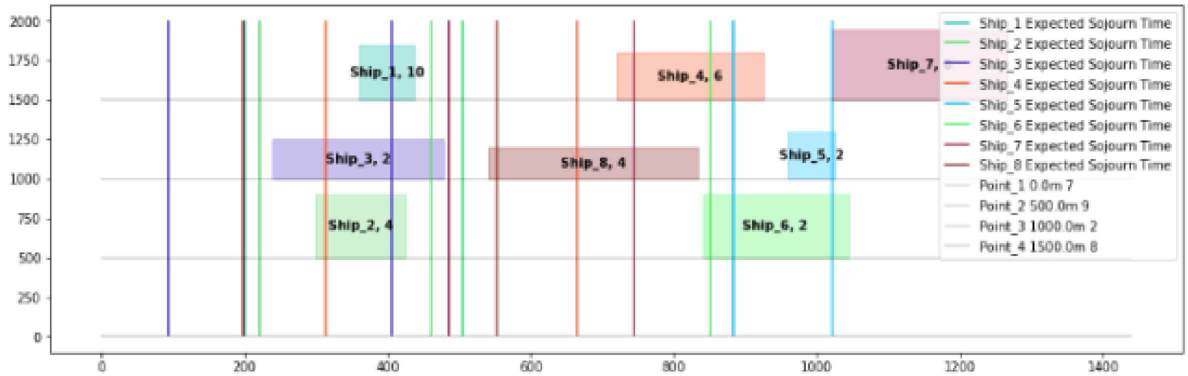

Fig. 10 – *Experiment 2 – Initial random placement.*

Based on the results shown in Fig. 11, it is possible to observe how the algorithm, starting from a random placement, converged to a better solution. It is also possible to see how ships with lower risk levels usually have more flexible scheduling. This test also showed improvement windows, for example, when there is the possibility to anticipate the allocation of low-risk cargo. For instance:

– **Point_3** which is the least safe with a safety score of **2** is not considered by the algorithm. This is a desirable outcome, since even low-risk cargo are untreatable under severe conditions and need to be handled in safer conditions.

– **Ship_1** has the highest risk score **(10)** was immediately handled in **Point_2** with the highest safety score **(9)**.

– **Ship_7** with a risk score of **8** was served at **Point_1** with a berth safety score of **7.** The plot exhibits a delay between the ETA line and the berthing point: this delay is caused by the time slot width of 60 minutes. The ship could be served at other berths by moving other ships, but other configurations are suboptimal. For example, moving this ship to **Point_2** would force both **Ship_6** and **Ship_4** to move to other berthing points. For example, both could swap points with **Ship_7**, but they would also have to delay their operations by one time slot.

- **Ship_4** with a risk score of **6** was slightly delayed before being served in **Point_2**. This allowed for operations under slightly better wind condition, well supported by berthing point safety score.
- Low-risk ships like **Ship_8** or **Ship_6** had a more flexible scheduling.
- **Ship_5** had no concurrence, so it is immediately served at the safest berth.

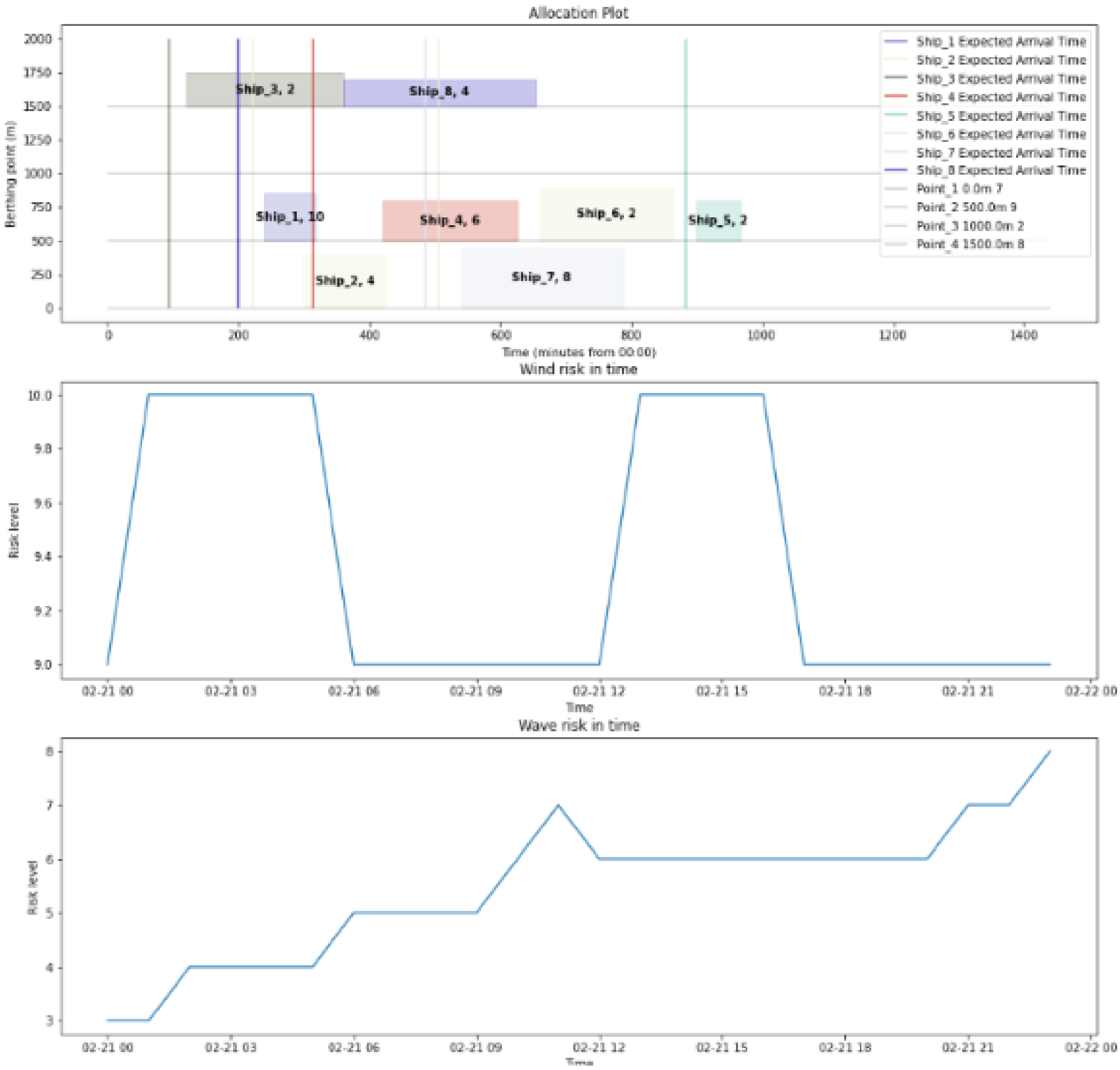

Fig. 11 – *Experiment 2 - Berthing schedule and weather variables.*

Concerning sustainability and efficiency preservation scoring, modified BAP showed appreciable performances. In the first test, for instance, our CSA approach correctly increased sustainability by reducing exposure to adverse weather conditions, still maintaining a prominent percentage of efficiency: ships were handled as soon as possible. In the second case, instead, it is possible to observe how some ships were delayed with respect to the time-optimal solution (it is sufficient to consider the third berthing point to imagine a better schedule). On the other hand, however, the choice of excluding the least safe part of the wharf increased safety in operations by several units, keeping the Sustainability to Effectiveness Ratio positive.

The sustainability scoring system, however, raised two major problems, due to the nature of the formulation itself, that are to be considered while reading the sustainability index:

- It is **sensitive to initial conditions:** when repeatedly tested on a small number of ships and berths under varying weather conditions, especially when handling time slots do not overlap, the results show high variance. In some runs, the cost-optimal and sustainability-optimal solutions may coincide, while in others, the sustainability index can be several orders of magnitude higher. This phenomenon is pronounced when the cost-optimal solution assigns high-risk cargo ships to one of the available low-safety berths under severe winds, since it prioritizes minimal service times.
- The sustainable version of the algorithm is based on exponential functions, which means that **sustainability scores can vary abruptly**, especially in high-risk situations. For this reason, a qualitative scale was provided to scale down the sustainability score and avoid basing the assessment on extremely large values.

5. Conclusion

This article presented a preliminary study aimed at proposing alternative versions of commonly used algorithms to address Berth Allocation. This algorithmic solution was developed during the execution of the CRISIS project, alongside a second solution for identifying the Shortest Safe Path, together addressing both open sea transportation and berthing operations. Overall, the proposed approach opened new roads for the exploration of sustainable algorithm design, yielding promising results in laboratory testing. Following initial tests, the solution was successfully deployed in a second stage testing environment: a fully functional platform where real-time weather data is collected from external services and applied to realistic scenarios input by operators. The tests produced positive outcomes, enhancing safety during cargo loading and unloading by adjusting berthing points and/or times to reduce overall operational risks.

Accordingly, the authors acknowledge the study’s limitations and identify directions for future research.

A primary limitation is the need to explore a broader range of algorithms. This article primarily focused on evolving the objective functions of CSA but did not investigate the possibility of applying the same cost functions to alternative algorithms.

Another limitation is the validation methodology, which is currently applicable only in a laboratory environment. The methodology is, in fact, purely theoretical and closely tied to the defined objective function. A suggested approach could be to create specific simulations that include ship features, transported goods, and weather conditions, allowing for the measurement of accident probability and related severity. These results could then be compared with classical approaches, enabling the definition of well-structured KPIs to assess how effectively the proposed modifications improve sustainability.

Finally, there is awareness of potential improvements to the proposed approach, which is currently based on value estimation. These improvements could be introduced by incorporating more accurate situational factors, including, but not limited to, a wider range of weather variables, operational efficiency factors, human risk factors, and the evaluation of possible violations of Collision Regulations, and defining a rigorous scoring method to correctly score cargo risk and berth safety.

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Pregledni rad

Sindrom sagorijevanja kod pomoraca: faktori rizika, posljedice i strategije

Filip Mihailović, Boris Ćorić

Sažetak: Sindrom sagorijevanja (*eng. burnout syndrome*) među pomorcima postaje sve prisutniji problem zbog dugotrajnih smjena, izolacije, velikog radnog opterećenja i drugih stresora. Pomorci su često izloženi nepovoljnim vremenskim uslovima, fizički napornom radu i dužem boravku na moru, što dodatno doprinosi razvoju sindroma sagorijevanja. Takođe, pandemija COVID-19 dodatno je otežala i usložila situaciju zbog restrikcija putovanja, produženih ugovora i ograničenog pristupa medicinskoj i psihološkoj pomoći. Doprinos ovog preglednog rada je u tome što na maternjem jeziku donosi definiciju i značenje profesionalnog sagorijevanja kod pomoraca koje u savremenom vremenu postaje sve relevantnije. Cilj ovog rada je da istraži uzroke *burnouta* kod pomoraca, njegove posljedice po mentalno i fizičko zdravlje te strategije prevencije koje bi mogle poboljšati njihovu dobrobit i radnu efikasnost. Korišćena literatura uključuje najnovije međunarodne studije i izvore dostupne putem relevantnih akademskih baza podataka, a analizirana su i konkretna empirijska istraživanja pomoraca koji su se suočili s ovim izazovom.

Ključne riječi: *Burnout* sindrom, Pomorci, Stres, Strategije.

1. Uvod

Međunarodnu klasifikaciju bolesti *(ICD – International Classification of Diseases*) donosi Svjetska zdravstvena organizacija (*SZO/WHO - World Health Organization),* koja je odgovorna za izradu, reviziju i ažuriranje ove klasifikacije, koja se koristi globalno kao standard za dijagnostiku bolesti i drugih zdravstvenih stanja. ICD pomaže u praćenju bolesti, prikupljanju statističkih podataka i kreiranju zdravstvenih politika. Trenutno važeća verzija je i ICD-11, koja je stupila na snagu 01. 01. 2022. godine, zamjenjujući prethodnu verziju ICD-10. Međutim, u Crnoj Gori se još uvijek koristi ICD-10, dok se u budućnosti planira prelazak na ICD-11, što će omogućiti precizniju dijagnostiku i bolje usklađivanje sa međunarodnim zdravstvenim standardima.

Sindrom sagorijevanja uključen je u 11. reviziju Međunarodne klasifikacije bolesti kao profesionalni fenomen. Nije klasifikovan kao medicinsko stanje. SZO ga je opisala u poglavlju „Faktori koji utiču na zdravstveno stanje ili kontakt sa zdravstvenim službama" – koje obuhvata razloge zbog kojih ljudi traže zdravstvenu pomoć, ali koji nisu klasifikovani kao bolesti ili zdravstvena stanja. ICD-11 je *burnout* definisalo na sledeći način: „Sagorijevanje je sindrom koji nastaje kao rezultat hroničnog stresa na radnom mjestu koji nije uspješno upravljan. Karakterišu ga tri dimenzije: osjećaj iscrpljenosti, povećana mentalna distanca od posla i cinizma u vezi sa poslom, smanjena profesionalna efikasnost.*"* [1].

Sagorijevanje narušava lično i društveno funkcionisanje pojedinca. Ovaj pad kvaliteta rada, fizičkog i psihičkog zdravlja može biti skup - ne samo za pojedinog radnika, već i za sve na koje ta osoba utiče. Intervencije za ublažavanje sagorijevanja i promovisanje njegove suprotnosti, angažovanja na poslu mogu se desiti i na organizacionom i na ličnom nivou. Društveni fokus sagorijevanja, čvrsta istraživačka osnova u vezi sa sindromom i njegove specifične veze sa domenom rada daju poseban i vrijedan doprinos zdravlju i dobrobiti ljudi [2].

Stres se definiše kao opšta reakcija, odnosno, skup nespecifičnih reakcija organizma, nastalih zbog potrebe za prilagođavanje izmijenjenim uslovima spoljašnje sredine. Stresori su nepovoljni činioci ili faktori psiho-socijalne i fizičke prirode koji remete ili ugrožavaju psihičko i opšte stanje osobe koja je pod dejstvom stresora [3]. S obzirom na navedeno, *burnout* predstavlja uže specifikovan hronični stres na radnom mjestu.

Iako postoje određena preklapanja, između *burnout*-a i depresije, kada su simptomi u pitanju, depresiju Američka psihijatrijska asocijacija (*APA – American psychiatric association*) definiše kao ozbiljno i često stanje koje utiče na emocije, misli i ponašanje osobe, narušava svakodnevno funkcionisanje, a manifestuje se kroz dugotrajnu tugu, gubitak interesa, promjene sna i apetita, umor i osjećaj bezvrijednosti [16]. Depresija je bolest koja nema jedan jasan i univerzalan uzrok, već je multifaktorijalni poremećaj, što znači da nastaje iz kombinacije različitih uzroka koji se međusobno prepliću i variraju od osobe do osobe. Kod *burnout* sindorma uzrok takođe možete biti multifaktorijalni, ali za razliku od depresije, ovdje je naglasak na radnom kontekstu i dugotrajnoj izloženosti stresu bez adekvatnog oporavka.

Zanimanje pomorca, često opisano izrekom: "Pomorstvo je hljeb sa sedam kora", simbolizuje težak i izazovan život ispunjen fizičkim, mentalnim i emotivnim naporima, što se prenosi generacijama kao dio tradicije i identiteta pomorskih zajednica.

Radni uslovi u pomorskoj industriji su izuzetno zahtjevni. Pomorci se često nalaze u situacijama u kojima su izloženi dugotrajnim smjenama, nepravilnom rasporedu rada, nepovoljnim vremenskim uslovima te ograničenim mogućnostima za socijalnu interakciju s porodicom i prijateljima [5].

Specifične karakteristike brodarskog radnog okruženja zasigurno doprinose razvoju sindroma sagorijevanja, koji se može manifestovati kao emocionalna iscrpljenost, depersonalizacija i smanjena radna učinkovitost. U ovom radu autori su analizirali uzroke *burnouta* kod pomoraca, njegove posljedice po mentalno i fizičko zdravlje te predložili strategije prevencije.

2. Metodologija

Ovaj rad koristi izvore podataka iz akademskih radova, članaka i izvještaja objavljenih u međunarodnim časopisima, ali i stručne literature. Podaci su prikupljeni iz internet baza podataka: *ScienceDirect*, *PubMed* i *SpringerLink*. Analizirani su faktori koji doprinose *burnoutu* kod pomoraca i efikasnost strategija prevencije. Takođe, razmatrani su izvještaji pomorskih organizacija i istraživanja sprovedena među pomorcima širom svijeta, čime se osigurava širi uvid u problematiku sagorijevanja. U radu su korišćeni relevantni izvori iz stručne medicinske i psihijatrijske literature, uključujući publikacije o mentalnom zdravlju pomoraca, dijagnostičkim kriterijumima *burnout* sindroma i terapijskim pristupima za njegovo ublažavanje.

3. Uzroci *burnouta* kod pomoraca

Opšti uzroci *burnouta* kod pomoraca uključuju kumulativni učinak dugotrajnih radnih zahtjeva od strane brodarskih kompanija, socijalne izolacije i nepovoljnih radnih uslova na brodu. Dugotrajne smjene, visoko radno opterećenje te izloženost teškim vremenskim uslovima doprinose razvoju hroničnog stresa kod pomoraca [4]. Dodatno, COVID-19 pandemija je ozbiljno narušila globalnu brodarsku industriju, uzrokujući zatvaranja luka, ograničenja putovanja i produžene smjene na brodovima, što je dodatno pojačalo stres i negativno uticalo na mentalno i fizičko zdravlje pomoraca.

Pomorci često rade u uslovima koji zahtijevaju kontinuirani rad, naročito tokom operacija u lukama gdje se obavljaju fizički zahtjevni poslovi poput utovara i istovara tereta. Takav intenzivan rad, bez adekvatnih perioda odmora, povećava rizik od hronične iscrpljenosti, fizičke i mentalne, samim tim i razvoja *burnouta*. Dugotrajne smjene doprinose nakupljanju stresa koji se, ako nije pravovremeno otklonjen, može manifestovati u psihološkim simptomima sagorijevanja [4].

Jedan od ključnih faktora rizika za *burnout* kod pomoraca je socijalna izolacija. Dugotrajna odsutnost od porodice i prijatelja dovodi do osjećaja usamljenosti, a nedostatak emocionalne podrške dodatno pogoršava stres [5]. Pomorska profesija, zbog svoje inherentne izolovanosti, zahtijeva razvoj novih strategija za održavanje socijalnih veza, što je ključno za prevenciju emocionalne iscrpljenosti.

Pomorci su svakodnevno izloženi nepovoljnim vremenskim uslovima, što zajedno sa fizički zahtjevnim poslovima doprinosi povećanom stresu. Dugotrajna izloženost ovim uslovima može imati negativan uticaj na fizičko zdravlje, što posredno utiče i na mentalno stanje pojedinca [4]. Ovaj faktor dodatno komplikuje mogućnosti regeneracije tokom perioda odmora na brodu.

Modernizacijom brodskih operacija, pomorci se sve više suočavaju s izazovima usljed visokih tehnoloških zahtjeva. Česta potreba za brzim prilagođavanjem novim sistemima i tehnologijama može dovesti do dodatnih izazova, što ujedno vodi dodatnom mentalnom opterećenju, a naročito u slučajevima kada nedostaje adekvatna obuka ili podrška. Time se povećava opasnost od razvoja *burnouta* kao posljedice hroničnog stresa na radnom mjestu.

Rad *Through restful waters and deep commotion: A study on burnout and health impairment of Italian seafarers from the JD-R model perspective* [6] istražuje kako *burnout* utiče na zdravstvene probleme italijanskih pomoraca koristeći teorijski okvir *Job Demands-Resources* (JD-R). Glavni rezultati pokazuju da visoki radni zahtjevi, posebno visoko radno i kognitivno opterećenje, značajno povećavaju *burnout*, koji potom negativno utiče na fizičko zdravlje (loš kvalitet sna i pojavu mišićno-koštanih tegoba). Rad koristi presječni dizajn, prikupljajući podatke putem onlajn upitnika (uzorak od 629 pomoraca, validan uzorak 239) i analizira podatke korišćenjem strukturnog modelovanja jednačina. Snage rada leže u dobroj teorijskoj osnovi i metodološkoj rigoroznosti, dok su glavna ograničenja vezana za presječni dizajn (što onemogućava utvrđivanje uzročno-posljedičnih veza), upotrebu samoprocjena koje mogu biti pristrasne, i ograničenu reprezentativnost uzorka zbog dobrovoljnog učešća. Takođe, u radu, postoji nejasnoća u razlikovanju *burnouta* i depresije.

4. Posljedice *burnouta* kod pomoraca

Burnout kod pomoraca ima višestruke negativne posljedice koje utiču na sve aspekte njihovog života. Osim što se manifestuje kroz smanjenje radne učinkovitosti i povećanje operativnih grešaka, sindrom sagorijevanja značajno narušava zdravlje pomoraca, kako mentalno, tako i emocionalno i fizičko zdravlje. Pomorci koji pate od *burnouta* često doživljavaju hroničnu anksioznost, depresiju i osjećaj bespomoćnosti, što dodatno smanjuje njihovu sposobnost da se efikasno nose sa stresom. Fizički simptomi, kao što su hronični umor i poremećaji sna, mogu dovesti do dugoročnih zdravstvenih problema, dok se socijalna izolacija produbljuje zbog povlačenja iz društvenih aktivnosti. Sve navedeno dodatno otežava emocionalni oporavak pomoraca [7,4].

Sagorijevanje kod pomoraca može dopinijeti povećanju rizika od razvoja depresije, anksioznosti i emocionalne nestabilnosti. Nadalje, iscrpljenost i depersonalizacija značajno umanjuju sposobnost pomoraca da se nose sa stresom, te mogu dovesti do smanjenja njihove profesionalne efikasnosti. Mentalni poremećaji povezani s *burnoutom* često utiču na opšti kvalitet života, što može imati dugoročne posljedice po psihičko zdravlje [7].

Hronični stres i *burnout* dovode do pada koncentracije i sporijih reakcija, što dodatno narušava radnu sposobnost kod pomoraca. U brodarskom okruženju, gdje svaka greška može imati ozbiljne posljedice, smanjena radna sposobnost i pad koncentracije značajno povećavaju rizik od nesreća na brodu. Time se direktno narušava sigurnost brodskih operacija.

Burnout nije jedini psihološki izazov kod pomoraca, već preživljeni stres, bilo akutni ili hronični, mogu biti uzrok i dugim zdravstvenim problemima poput: poremećaja spavanja, kardiovaskularnih oboljenja, dijabetesa i oslabljenog imunološkog sistema. Fizički naporan rad u nepovoljnim uslovima na brodu dodatno komplikuje proces oporavka, što povećava ukupni zdravstveni rizik, po život i zdravlje pomoraca [4].

5. Znakovi sagorijevanja i predložena rješenja

ShipUniverse je specijalizovana onlajn platforma za pomorske stručnjake, vlasnike brodova i operatere flota, koja povezuje stručno znanje s praktičnim rješenjima, s ciljem unapređenja operativne efikasnosti, održivosti i rasta u savremenoj pomorskoj industriji.

U svom vodiču pod nazivom *Izbjegavanje burnouta posade na velikom moru* predstavljeni su, između ostalog, znakovi i rješenja izgaranja posade na brodu.

Tabela 1 – *Znakovi i rješenja izgaranja posade na brodu.*

Znakovi sagorijevanja	Rješenja
Emocionalni simptomi:	Emocionalna rješenja: - Omogućiti pristup povjerljivom savjetovanju putem programa pomoći zaposlenima (EAP).

- Hronična anksioznost i briga oko radne performanse ili bezbijednosti. - Razdražljivost i frustracija prema kolegama ili radnim zadacima. - Osjećanja depresije, beznadežnosti i otuđenosti. - Emocionalno distanciranje od posla i kolega.	- Organizovati radionice za upravljanje stresom sa fokusom na *mindfulness* i tehnike opuštanja. - Podsticati podržavajuće radno okruženje gdje članovi posade mogu otvoreno da izraze svoja osjećanja. - Podsticati učešće u društvenim aktivnostima radi izgradnje zajedništva i smanjenja izolacije.
Fizički simptomi: - Hronični umor koji se ne poboljšava odmorom. - Poremećaji sna, uključujući poteškoće pri uspavljivanju ili održavanju sna. - Česte glavobolje, bolovi u mišićima i neobjašnjeni tjelesni bolovi. - Promjene u apetitu, bilo prejedanje ili gubitak apetita.	Fizička rješenja: - Osigurati redovne periode odmora i sprovođenje propisa o radnom vremenu prema MLC-u. - Poboljšati higijenu sna optimizacijom spavaćih prostorija za udobnost, uz smanjenje buke i svjetlosti. - Promovisati fizičku kondiciju putem brodskih programa vježbanja i pristupa opremi za vježbanje. - Obezbijediti uravnotežene i nutritivno bogate obroke koji podržavaju opšte zdravlje i nivo energije.
Ponašajne promjene: - Smanjena radna učinkovitost, uključujući greške i nedostatak fokusa. - Povlačenje iz društvenih aktivnosti i izolacija od posade. - Povećana upotreba alkohola, duvana ili drugih supstanci kao mehanizmi suočavanja. - Zanemarivanje lične higijene i izgleda.	Ponašajna rješenja: - Implementirati programe podrške među kolegama kako bi se članovi posade međusobno podržavali. - Organizovati edukativne sesije o opasnostima zloupotrebe supstanci i promovisati zdravije strategije suočavanja. - Organizovati redovne aktivnosti za timsko povezivanje radi jačanja odnosa i smanjenja izolacije. - Pratiti radnu učinkovitost posade uz pružanje konstruktivnih povratnih informacija i podrške pri promjenama u ponašanju.
Socijalni i psihološki stres: - Osjećaj usamljenosti i izolacije zbog dugih perioda odsustva od kuće. - Povećani konflikti ili tenzije među članovima posade. - Teškoće u upravljanju emocionalnim opterećenjem zbog odvojenosti od voljenih.	Socijalno i psihološko rješenje: - Omogućiti redovne prilike za komunikaciju članova posade sa porodicom putem interneta ili satelitskih telefona. - Organizovati radionice o rješavanju konflikata i komunikacijskim vještinama za poboljšanje međuljudskih odnosa.

- Smanjena motivacija i gubitak interesovanja za aktivnosti.	- Implementirati mentorski program kako bi se novim članovima posade pomoglo da se integrišu i osjećaju podržano. - Podsticati učešće u rekreativnim aktivnostima koje promovišu opuštanje i mentalno blagostanje.
Kognitivni problemi i teškoće u donošenju odluka: - Teškoće u koncentraciji i donošenju odluka. - Zaboravnost i propusti u pamćenju. - Sporije reakcije i narušeno rasuđivanje. - Povećane greške u rutinskim zadacima i operacijama.	Kognitivna rješenja: - Organizovati obuke o efektivnom upravljanju vremenom i prioritetnim zadacima. - Osigurati adekvatan odmor članovima posade radi održavanja kognitivnih funkcija. - Podsticati redovne pauze tokom radnog vremena kako bi se spriječio mentalni umor. - Implementirati sistem "drugara" gdje članovi posade međusobno provjeravaju svoj rad radi smanjenja grešaka.

(Izvor: *ShipUniverse* [8])

6. Strategije prevencije i intervencije

Na osnovu tabele 1 i predloženih rješenja, ovim radom se predlažu strategije za prevenciju *burnouta* kod pomoraca. Integracijom navedenih strategija–organizacionih promjena, jačanja socijalne podrške, kontinuirane edukacije i promocije zdravog načina života, moguće je kreirati sveobuhvatan sistem prevencije burnouta koji ne samo da smanjuje simptome sagorijevanja, već unapređuje opštu bezbijednost i efikasnost operacija na moru.

Prevencija burnouta kod pomoraca zahtijeva sistemske promjene u organizaciji rada. Optimizacija radnih ciklusa i osiguravanje redovnih odmora ključno je za smanjenje hroničnog stresa. Implementacija modela poput *Job Demands-Resources* može pomoći u identifikaciji i upravljanju radnim zadacima, te osiguravanju potrebnih resursa za efikasno suočavanje sa stresom [9].

Dodatno, istraživanja sugerišu da poboljšanje komunikacije između menadžmenta brodarske kompanije i posade broda, kao i participativni pristup u donošenju odluka, može dodatno smanjiti rizik od *burnouta* kod posade [10]. Takođe, organizacioni intervencijski programi koji uključuju redovno praćenje radnog opterećenja i povratne informacije od strane zaposlenih pomoraca mogu pomoći u pravovremenom otkrivanju problema [11].

Povećanje mogućnosti za održavanje komunikacije sa porodicom i prijateljima, čak i na daljinu, ključno je za ublažavanje osjećaja socijalne izolacije. Uvođenje redovnih komunikacionih programa i psihosocijalne podrške na brodu može značajno smanjiti emocionalni stres [5].

Osim toga, implementacija programa mentorstva i timskih sastanaka poboljšava međuljudske odnose i osigurava podršku unutar posade. Intervencije zasnovane na socijalnoj podršci pokazale su se efikasnim u smanjenju negativnih emocionalnih efekata burnouta [12].

Redovna obuka iz oblasti savladavanja tehnika upravljanja stresom, uključujući program *mindfulness*, vježbe opuštanja i treninge za prilagođavanje na nove tehnologije, može pomoći pomorcima u boljem suočavanju s izazovima radnog okruženja. Takva edukacija povećava svijest o simptomima *burnouta* i omogućava pravovremenu intervenciju.

Dodatno, integracija programa za lični razvoj i psihološku otpornost, može dodatno osnažiti pojedince da se suoče sa stresom kroz praktične strategije i tehnike suočavanja sa sindromom izgaranja [13].

Zdrav način života, koji uključuje uravnoteženu ishranu, redovnu fizičku aktivnost i adekvatan san, igra ključnu ulogu u prevenciji *burnouta*. Organizacione brodarske politike koje omogućavaju pristup zdravoj hrani i stvaranje uslova za fizičku aktivnost mogu značajno poboljšati fizičko i mentalno zdravlje posade [4].

Dodatna istraživanja pokazuju da kvalitetan san i pravilna ishrana smanjuju nivo stresa te poboljšavaju radnu efikasnost, što je presudno za održavanje visokog nivoa radne etike i performansi na brodu [14].

Uzimajući u obzir dodatne studije i date preporuke, važno je da brodarske kompanije kontinuirano prilagođavaju i unapređuju preventivne strategije kako bi se odgovorilo na dinamične izazove modernog pomorskog rada. Implementacijom ovih mjera osiguraće se da se posada osposobi za suočavanje sa sve većim radnim opterećenjima tokom plovidbe, čime se stvara održivo radno okruženje koje favorizuje dugoročnu profesionalnu i ličnu dobrobit.

U zaključku rada *Through restful waters and deep commotion: A study on burnout and health impairment of Italian seafarers from the JD-R model perspective* [6] naglašava se važnost smanjenja radnih zahtjeva, unapređenja podrške na brodu (npr. kroz trening transformacionog liderstva i tim-bilding aktivnosti) i sprovođenja daljih istraživanja kako bi se bolje razumjeli uzročno-posljedični odnosi u pomorskoj industriji.

Još jedan konkretan primjer koji se razmatra u ovom radu je empirijsko istraživanje *Stress and strain among merchant seafarers differs across the three voyage episodes of port stay, river passage and sea passage* [15]. U njihovom istraživanju, analizirani su nivoi stresa kod pomoraca tokom tri različita segmenta putovanja – boravak u luci, prelazak kroz riječne kanale i plovidba na otvorenom moru. Rezultati su pokazali da tokom morskog putovanja, kada je radno opterećenje znatno niže, posada ima više vremena za oporavak, što rezultira smanjenim simptomima stresa i potencijalno smanjenim rizikom od *burnouta*. Ovo sugeriše da se periodi plovidbe mogu koristiti za implementaciju preventivnih intervencija, poput radionica za relaksaciju i aktivnosti usmjerenih na unapređenje psihološke otpornosti pomoraca.

Ovaj primjer, u kombinaciji sa već navedenim studijama, dodatno potvrđuje značaj sveobuhvatnog pristupa u prevenciji burnouta kod pomoraca, pri čemu se prepoznaju specifični periodi u kojima se mogu efikasno implementirati strategije za smanjenje stresa i unapređenje radne efikasnosti posade.

Dosad navedeno naglašava važnost holističkog pristupa u prevenciji burnouta, gdje se uz organizacione mjere za optimizaciju radnih uslova, posebna pažnja posvećuje i emocionalnoj podršci i razvoju mehanizama suočavanja. Implementacijom ovakvih strategija ne samo da doprinosi zdravlju posade, već se i povećava bezbijednost i efikasnost operacija na moru, čime se stvara održivije radno okruženje.

7. Zaključak

Na osnovu sprovedene analize literature i empirijskih istraživanja, jasno je da sindrom sagorijevanja kod pomoraca predstavlja ozbiljan izazov u pomorskoj industriji, sa značajnim negativnim uticajem na mentalno zdravlje posade, bezbijednost brodskih operacija i operativnu efikasnost. Ključni faktori rizika uključuju dugotrajne smjene, stresne radne uslove i socijalnu izolaciju.

Najvažnije mjere prevencije uključuju optimizaciju radnih uslova, jačanje socijalne podrške, uvođenje redovnih edukacija o upravljanju stresom i promociju zdravog načina života. Implementacija modela poput *Job Demands-Resources* i psihosocijalnih programa može značajno smanjiti simptome *burnouta* i poboljšati opšte stanje posade, što vodi ka većoj efikasnosti i sigurnosti brodskih operacija.

Dalja istraživanja, naročito primarne studije na različitim tipovima brodova, biće ključna za dodatno razumijevanje i unapređenje strategija prevencije.

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Burnout sydrome among seafarers: risk factors, consequences and strategies

Filip Mihailović, Boris Ćorić

Abstract: Burnout syndrome among seafarers is becoming an increasingly prevalent issue due to long working shifts, isolation, heavy workloads, and other stressors. Seafarers are frequently exposed to adverse weather conditions, physically demanding tasks, and prolonged periods at sea, all of which further contribute to the development of the burnout syndrome. Moreover, the COVID-19 pandemic has exacerbated the situation by introducing travel restrictions, extended contracts, and limited access to medical and psychological support. The contribution of this review paper lies in presenting, in the native language, a comprehensive overview of the definition and significance of professional burnout among seafarers, a topic of growing relevance in the modern age. The aim of this paper is to explore the causes of burnout among seafarers, its effects on their mental and physical health, and preventive strategies that could improve their well-being and work performance. The literature used includes the latest international studies and sources available through relevant academic databases, along with an analysis of empirical research involving seafarers who have faced this challenge.

Keywords: Burnot syndrome, Seafarers, Stress, Strategies

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Short report

Kotorska bratovština pomoraca u vojno-pomorskim operacijama

Miroslav Vukičević, Slavko Dabinović, Zdravko Ikica

Abstract: Ovaj rad istražuje istorijsku ulogu Kotorske bratovštine pomoraca u vojno-pomorskim operacijama od doba Bizantije do venecijanskog perioda. Studija prikazuje kako se bratovština razvila od religijski potpomognutog udruženja do značajne pomorske sile, naglašavajući njen doprinos različitim vojnim sukobima, uključujući Prvi mletačko-turski rat i Opsadu Skadra. Rad takođe analizira administrativne i strukturne promjene unutar bratovštine tokom mletačke vlasti, ilustrujući njenu prilagodbu vojnim i ekonomskim zahtjevima tog vremena. Takođe se razmatra i doprinos nasljeđa bratovštine u oblikovanju pomorske istorije i kulturnog nasljedstva Kotora.

Ključne riječi: Kotorska bratovština pomoraca, vojno-pomorske operacije, Pomorska istorija, Kotor, Bokeljska mornarica Kotor

1. Uvod

Šturi podaci o vojnoj organizaciji Bratovštine kotorskih pomoraca iz predmletačkog perioda u vrijeme bizantijske uprave gradom ipak nam govore o ratnim brodovima spremnim za ratovanje još od IX vijeka. Za razliku od predmletačkog perioda, u vrijeme mletačke vladavine Kotorom, vojna fizionomija Bratovštine je u čisto vojničkoj strukturi jednog odreda mornara u njenom sastavu.

Ugled koji je Kotorska mornarica stekla u očima Venecije bazirao se prvenstveno na njenim izuzetnim ratnim zaslugama. Nije slučajno da je do reorganizacije, odnosno donošenja novog statuta Mornarice, došlo 1463. godine, dakle, baš one godine kada je počeo rat između Mletaka i Turske (Prvi mletačko-turski rat 1463-1479). Prvi poznati uspjesi u borbama protiv Turaka zabilježeni su kod opsade Skadra 1474. godine, kada je Bratovština dobila prvo veliko priznanje, a grad Kotor epitet „najdražeg".

Venecija je izjednačila pojam Bratovštine pomoraca (*Confraternitas nautarum*) sa mornaričkom vojnom organizacijom (*Marinarezza di Cattaro*) i taj se specifičan fenomen nije desio u drugim sredinama pod mletačkom upravom.

2. Početak osnivanja vojne organizacije kotorskih pomoraca

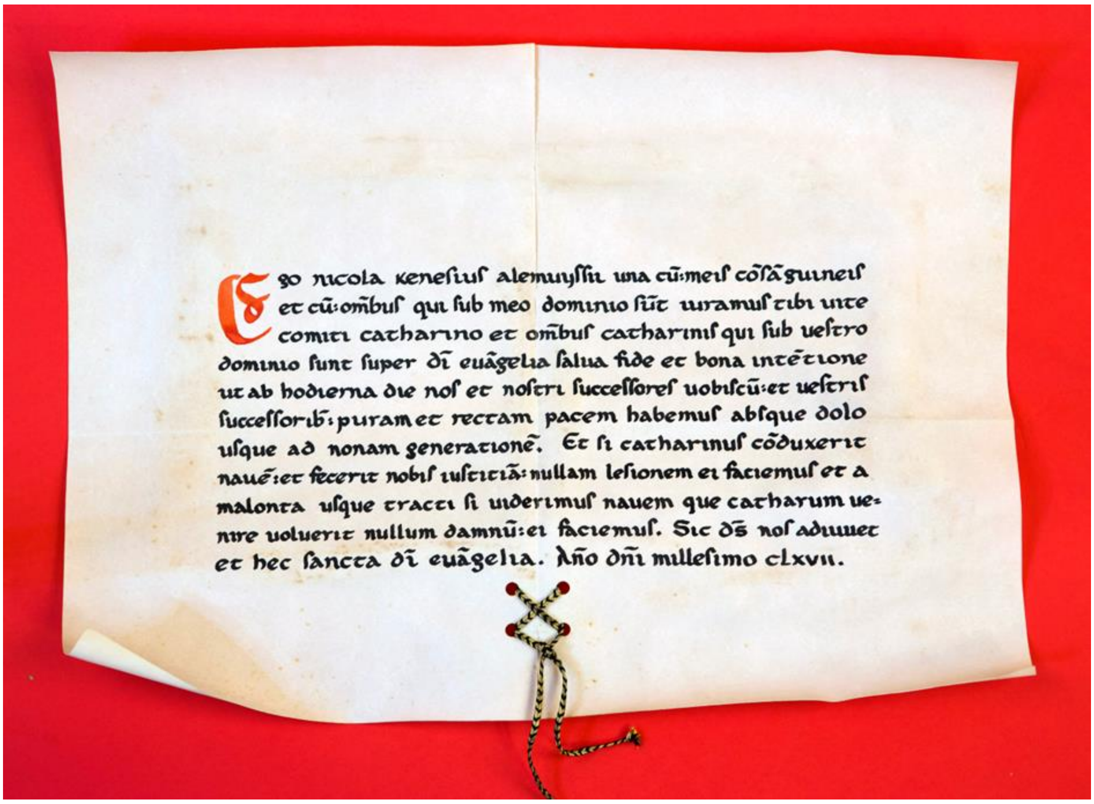
Pretpostavlja se, sa određenom sigurnošću, mogućnost veoma ranog postojanja jednog oblika vojne organizacije kotorskih pomoraca, koju je organizovala centralna bizantijska vlast početkom IX vijeka. Još u VII vijeku Bizant je, pored svoje centralne flote, u borbi protiv arapskih Saracena koristio i pomorske borbene jedinice gradova pod svojom upravom. Iz tog razloga je u tim gradovima već tada morao postojati neki oblik vojne organizacije pomoraca. U Raveni, koja je tada bila pod vlašću Bizanta, postojala su udruženja za odbranu ravenskog pristaništa u slučaju opasnosti s mora. Ta udruženja imala su konkretni zadatak vršiti regrutaciju za potrebe bizantske flote. Nakon gubitka Ravene, polovinom VIII vijeka, vrlo je moguće da su bizantske vlasti u Kotoru formirale organizaciju pomoraca za odbranu luke i zaliva od napada Saracena, s obzirom na to da je Kotor za Bizant bio vrlo značajan grad, kako u vojnom, tako i u trgovačkom pogledu.

Kotor, djelimično samostalan grad, kao i svi gradovi na istočnoj obali Jadrana pod bizantskom vlašću, daleko od centralne vlasti, morao se sam brinuti za odbranu od napada s kopna i mora. Međutim, u ratovima koje je vodio Bizant vjerovatno su postojali čvršći vojni kontakti za potrebe zajedničkih pomorsko-borbenih akcija, dok su u obezbjeđenju od piratskih napada gradovi bili prepušteni sami sebi. Gradovi pod bizantskom upravom, pa tako i Kotor, morali su raspolagati naoružanim brodovima pod komandom gradskih vlasti. Postoji više dokaza o ranom postojanju jakih flota na Jadranu, opasnim rivalima Veneciji, kao što je bila mornarica hrvatskih knezova sa svojim uspješnim akcijama tokom IX vijeka.

Kada govorimo o začecima Kotorske mornarice, koji sežu u rani Srednji vijek, potrebno je pozvati se na relevantne povijesne podatke koji govore o organizovanoj ratnoj i trgovačkoj mornarici toga vremena. Akademik Grga Novak u svom radu [1] „*Ratovi i bitke na Jadranskom moru*“ spominje ratne brodove Zadra, Splita, Dubrovnika i Kotora 867. godine, u sastavu bizantske flote koja je oslobodila Dubrovnik od petnaestomjesečne saracenske opsade. Bizantska flota, u kojoj su još uvijek bili brodovi gradova Zadra, Splita, Dubrovnika i Kotora, opsjedala je Bari u Apuliji 869. godine, s namjerom njegovog oslobađanja od saracenske okupacije.

Mavro Orbini u svom djelu *Kraljevstvo Slavena* [2] spominje dvije kotorske galije u 1155. godini. Te godine, kotorske galije prebacile su u Dubrovnik četiri stotine Kotorana, dvjesto Ulcinjana i sto pedeset Peraštana radi odbrane dubrovačke teritorije, kojega je napadao bosanski ban Borić.

Treći, vrlo značajan, podatak o postojanju kotorske mornarice svakako je onaj iz 1167. godine, kada su knezovi grada Kotora i Omiša potpisali ugovor o miru i slobodnoj trgovini Jadranskim morem s obavezom pridržavanja tokom devet generacija. Iz ovog ugovora između Kotora i Omiša o nenapadanju, mirnoj pomorskoj plovidbi i unapređenju pomorske trgovine može se prepoznati da su kotorski trgovački brodovi bili vrlo dobro borbeno opremljeni i da su postojale jake pomorske snage u Kotoru, koje su podjednako služile u trgovačke i ratne svrhe.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nauē: et fecerit nobis iusticiã: nullam lesionem ei faciemus et a
malonta usque tracti si uiderimus nauem que catharum ue-
nire uoluerit nullum damnū: ei faciemus. Sic ds nos adiuuet
et hec sancta dī euãgelia. Año dñi millesimo clxvii.

Slika 1. – *Ugovor o miru i slobodnoj trgovini Jadranskim morem (između Kotora i Omiša)* [17].

U ovom XII vijeku teško se može pretpostaviti postojanje cehovske bratovštine pomoraca, ali je moguće pretpostaviti postojanje jedne organizovane ratne mornarice. Osnivanje takve borbene, ratne organizacije kotorskih pomoraca sigurno se moralo dogoditi prije osnivanja cehovskih, odnosno staleško-stručnih udruženja. Iz ove borbene organizacije kotorskih pomoraca razvilo se u određenom momentu i cehovsko udruženje. Dolaskom Kotora pod vlast Mletačke Republike 1420. godine, novoj vlasti posebno je bilo važno da se kotorski pomorci i njihovi brodovi koriste za borbu protiv pirata, naročito ulcinjskih i sjevernoafričkih.

3. Bratovština kotorskih pomoraca

O postojanju organizovane Bratovštine kotorskih pomoraca govori nam dokument iz 1353. godine, u kojem se spominje Pobožno društvo kotorskih pomoraca, “*Pia sodalitas naviculatorum Catharensium*” [3]. Dokument predstavlja donacionu ispravu, tj. darovnicu, datiranu 27. aprila 1353.

godine, kojom Bratovština kotorskih pomoraca poklanja crkvu Sv. Nikole van zidina grada Kotora redovnicima franjevcima. Drugi, takođe vjerodostojan, dokument o pomenu Bratovštine kotorskih pomorca je iz godine 1453, deset godina prije donošenja Statuta Bratovštine, a odnosi se na ugovor sklopljen između Bratovštine kotorskih pomoraca i plemićke obitelji Buća (*Bucchia*), prema kojem Bratovština preuzima crkvu Sv. Nikole u zidinama grada Kotora i u kojoj će imati svoje sjedište.

Bratovština kotorskih pomoraca od osnivanja preuzima dužnosti organizovanja odbrane kotorskih teritorijalnih voda i popunjavanja ratnih brodova posadom, posebno kotorskih galija. Mletačka Republika od 1420. godine donosi propise organizovanja vojne i trgovačke mornarice jadranskih gradova pod njenom upravom. Da je Kotor tada bio vrlo jak centar sa razvijenom trgovačkom i ratnom mornaricom govori i bogata spomenička kulturna baština koja datira iz tog vremena, a koja ne bi mogla biti stvorena bez jake i organizovane trgovačke i ratne mornarice.

Uspostavljanjem mletačke vlasti u Kotoru 1420. godine osjeća se jak uticaj Venecije na Bratovštinu kotorskih pomoraca [4]. Tako mletački duždk Francesco Foscari 1. februara 1432. godine šalje u Kotor ratni brod, s obavezom da se naoruža i popuni veslačima, naoružanjem i ostalim potrepštinama. Slično naređenje mletački duždk daje kotorskom knezu 1. avgusta 1451. godine. Zapovjednik galije, tj. suprakomit, trebao je biti izabran iz redova kotorskih plemića. Mijušković S. u svom radu „Kotorski admirali“ [8], navodi dokument od 29. juna 1432. godine, koji spominje Bazilija Bizantija, a predstavlja prvi od sačuvanih pomena kotorskih zapovjednika (*supracomesa*) kotorske galije, dok iz predmletačkog perioda nema podataka o imenima zapovjednika kotorske galije. Pomoć kotorskog pomorstva Mletačkoj Republici bila je izuzetno dragocjena, posebno u bici kod Portoroža 1436. godine, gdje su Đenovežani pretrpjeli težak poraz, čemu je kotorska galija pod zapovjedništvom Bazilija Bizantija dala značajan doprinos. Kasnije će kotorska mornarica steći još veće zasluge prilikom opsade Skadra.

Bratovština kotorskih pomoraca 26. juna 1463. godine donosi svoj Statut pod nazivom Bratovština svetog Nikole mornara u Kotoru, *Liber fraternitatis divi Nicolai marinariorum de Catharo* [5].

Par godina nakon reorganizacije Kotorske mornarice iz 1463, ona učestvuje u odbrani Skadra od turske najezde i dobija 17. jula 1475. godine velike pohvale od mletačkog duždka Pjetra Močeniga (*Pietro Mocenigo*). U pohvali se kaže i stavlja do znanja kotorskim gradskim sucima i članovima Malog vijeća, da Sinjorija (*Signoria*) vrlo dobro zna koliko duguje hrabrosti, vjernosti i odanosti kotorskih odreda prilikom opsade Skadra [6]. Duždk je tom prigodom svečano i javno potvrdio kotorske povlastice i objelodanio da je Kotor najdragocjeniji među svim dragocjenim mletačkim gradovima. Kad je kapetan Skadra i guverner mletačke Albanije, Antonio Loredan, pozvan da preda Skadar Turcima, on je odlučno odbio, jer je raspolagao i vojskom i mornaricom [7]. U svom izvještaju, Loredan kaže da je imao malo pouzdanja u kolebljive albanske odrede, a iskazuje velike hvale u prilog kotorskoj mornarici. Tada je Kotorska mornarica požrtvovano doprinijela održavanju stalnih veza između opsjednutog Skadra i otvorenog mora. Mletačka flota ušla je u Bojanu u namjeri da zauzme Skadar, ali kad je neprijatelj mletačke flote blokirao ušće rijeke, nada za spas je bila vrlo mala. Zapovjednik mletačke flote obećao je nagradu onome koji bi protjerao neprijatelja s blokade. Marin Bizanti, suprakomes kotorske galije, napao je neprijateljske brodove i rastjerao ih, spasio mletačku flotu od uništenja i odbio da primi ponuđenu nagradu. Zapovjednici ostalih mletačkih brodova su se ustručavali da izvrše napad na neprijatelja. U dukalu[4] Pjetra Močeniga od 14. jula 1475. godine, koji govori o turskoj opsadi Skadra, pohvaljuje se držanje Kotorana pod komandom trećeg po redu poznatog suprakomesa, Marina Bizantija.

U kotorskom Statutu uvrštena je odredba kotorske opštine o pomorskom naoružanju. Nalazi se u prvom dijelu Statuta i pretpostavlja se da je donešena u predmletačko vrijeme, prije 1420. godine. Kotor je tada imao galiju u svom posjedu. U mletačkom periodu, galija je pripadala Mletačkoj Republici.

Kada se u Budvi oko 1465. g. dogodila pobuna, drugi po redu poznati suprakomit Đorđe Bizanti, brat Marina, upućen je iz Kotora sa velikim snagama da spasi grad od velike opasnosti, uspjevši da zarobi sve pobunjenike [8].

Četvrti poznati zapovjednik kotorske galije iz XV vijeka je Bernard Buća. Učestvovao je u sukobu mletačke i turske flote kod Krfa 1499. godine na kotorskoj galiji koja je bila dio flote od ukupno 17 galija. Tih godina navodi se i Luka Paskvali kao zapovjednik kotorske galije. Godine 1500, na položaju suprakomesa pominje se Tripun Buća, zapovjednik kotorske galije u odbrani luke Modon na Peloponezu u Grčkoj od Turaka [8].

4. Uloga kotorskih pomoraca za vrijeme mletačke vladavine

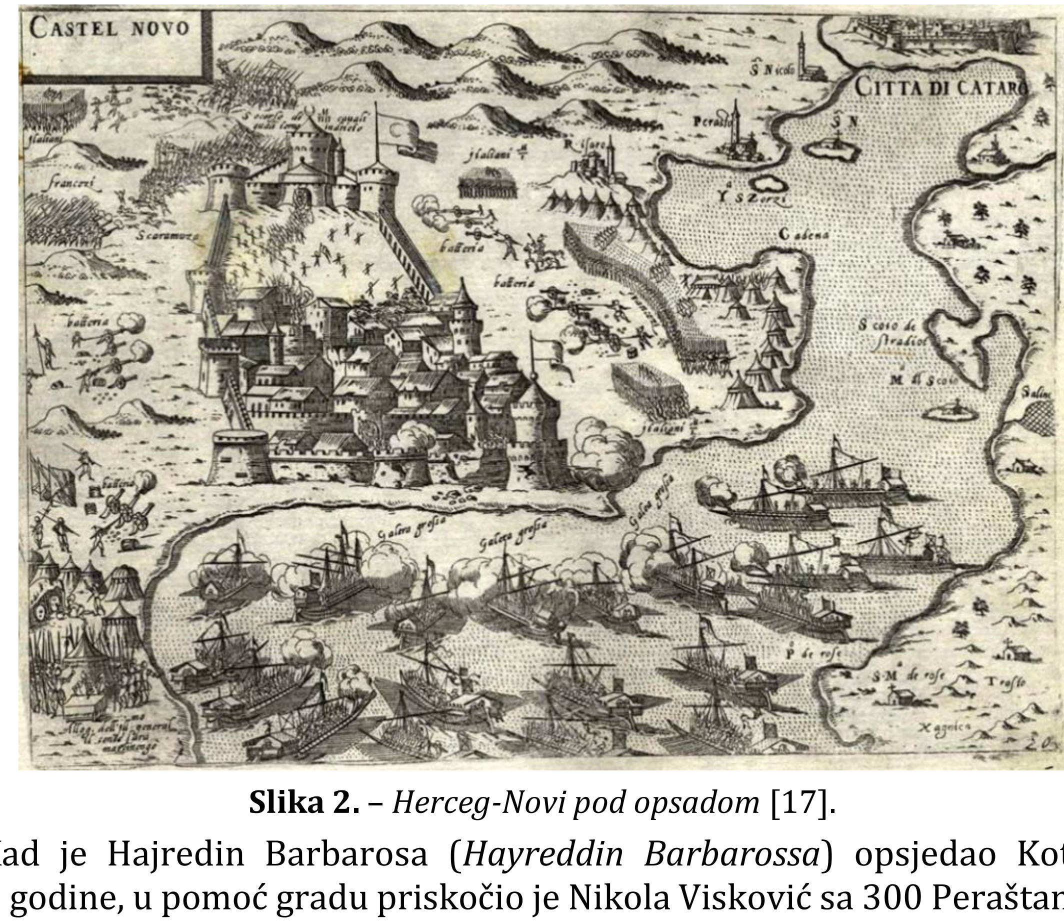
Za vrijeme mletačke vladavine, Bratovština kotorskih pomoraca, odnosno Kotorska mornarica, imala je i veoma značajnu borbenu ulogu u službi mletačkih pomorskih vojnih snaga. Tako kotorska galija 1571. godine

[4] *Dukal* je odluka ili naredba koju je centralna vlast iz Mletaka (Venecije) slala svojim gradovima na istočnoj obali Jadrana.

učestvuje u najvećoj pomorskoj bici do tada, koja se vodila između flote Svete lige i flote Turskog carstva kod Lepanta u Korintskom zalivu u Grčkoj [9]. U ovoj bici najznačajniju ulogu odigrala je mletačka mornarica, u čijem sastavu je bila i kotorska galija „Sv. Tripun“. Kotorska galija, iako na strani pobjednika, bila je opkoljena od četiri turske galije i stradala je sa suprakomitom, kotorskim plemićem Jeronimom Bizantijem i kompletnom posadom.

Nakon Jeronima Bizantija, poznati zapovjednici kotorske galije bili su iz uglednih kotorskih plemićkih porodica: Bolica, Vrakjen, Jakonja, Gregorina, Burović, Medin.

Peraštani, iako dosta rano odvojeni od Kotorske mornarice, dali su ogroman doprinos u borbama protiv gusara i pirata na Jadranskom moru, a po pozivu mletačkog generalnog i izvanrednog providura, morali su učestvovati u većim mletačkim vojnim operacijama, kako na moru tako i na kopnu. Primjer za to je iz maja 1687. godine, kod oslobađanja Herceg-Novog od Turaka, kada kotorski izvanredni providur Đovani Batista Kalbo (*Giovanni Battista Calbo*) naređuje okupljanje svih bokeljskih trgovačkih brodova u njihovim matičnim lukama [10].



Slika 2. – *Herceg-Novi pod opsadom* [17].

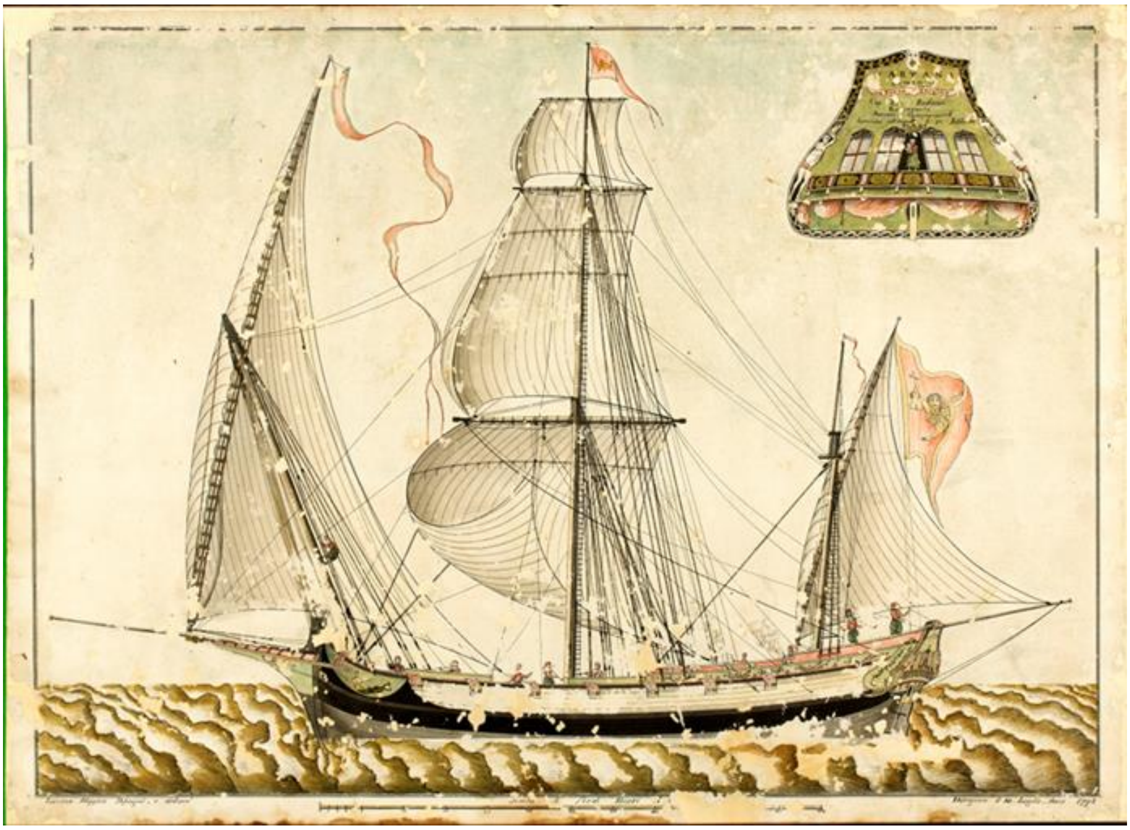
Kad je Hajredin Barbarosa (*Hayreddin Barbarossa*) opsjedao Kotor 1539. godine, u pomoć gradu priskočio je Nikola Visković sa 300 Peraštana i doprinio odvraćanju Barbarose od opsade grada. Zauzvrat, Peraštani od mletačkog Senata dobijaju godišnju pomoć od 200 dukata i oslobađanje od carine na robu prevezenu morem [11]. Bratstvo Mazarovića ističe se u pomorskim bitkama kod Valone 1638, kod Patrasa i Malvazije, te u blizini Mila 1645, prilikom osvajanja Risna 1649, i u borbi kod Herceg-Novog 1657. godine. Peraštanin, kapetan Vicko Bujović bio je veliki borac u borbama protiv Turaka na kopnu i protiv gusara na moru. Naročito se istakao u borbi prilikom osvajanja Herceg-Novog 1687. godine. Za uspješne borbe protiv gusara značajno je spomenuti Krsta Đoku i sina Nadala, koji se sukobio sa tripolitanskim šambekom[5]. Za uspješnu akciju i spašavanje tereta, dobio je 6. februara 1752. godine od duždа Frančeska Loredana (*Francesco Loredan*) titulu viteza (kavalijera, it. *cavaliere*) sv. Marka. Osobite zasluge stekao je u borbi protiv Turaka i gusara Frano konte Visković. Imao je čin pukovnika, a 11. juna 1695. godine [10,11] dobio je plemićku titulu (konte), dok je 1703. godine odlikovan kolajnom i redom viteza Sv. Marka. Iz peraške porodice Balović istakli su se u borbama protiv gusara i pirata Matija Andrijin, kapetan peraških čuvara zastave [12], Matija Krstov, koji je 1763. godine dobio titulu viteza i konta, te još osam istaknutih ratnika na moru. U borbama protiv pirata takođe su se posebno iskazali i Peraštani: kap. Matija Bronza, kap. Petar Bane, kap. Nikola Lazarević, kap. Krsto Martinović i kap. Tripo Čorko [17].

Slika 3. – *Kap. Đuro Bane u sukobu sa berberskom tartanom pred Dračom* [17].

Značajno je bilo učešće Dobroćana u bici za Bar od 16. do 22. oktobra 1717. godine. Posebno su se istakli pomorci bratstava Radimira i Kamenarovića,koji su dobili tri pohvalnice od samog komandanta mletačkih oružanih snaga, Alviza Močeniga (*Alvise Mocenigo*), i jednu pohvalnicu od kotorskog vanrednog providura, Marina da Molina [13]. Posebnu pohvalnicu

[5] Šebeka ili šambek – vrsta broda na jedra sa dva ili tri jarbola.

dobili su 20. decembra 1719. godine braća Ivanovići, Matija i Luka Petrov, koji su pod Barom učestvovali sa svojom tartanom *Santissimo Crocefisso e Madonna del Rosario* (Presveto raspelo i Gospa od Krunice).



Slika 4. – *Tartana La Beata Vergine kap. Ilija Radimiri* [17].

U bici za Ulcinj, tokom jula 1718, dobrotski pomorci takođe iz bratstava Radimir, Kamenarović i Ivanović potvrdili su ranije stečeni pomorski i ratnički ugled. Dobroćani su u bici za Ulcinj učestvovali sa osam velikih tartana iznad 1000 *stara*[6] nosivosti. U pohvalnici generalnog vojnog providura Moceniga, od 22. avgusta 1718, piše da su se Dobroćani poslije neuspjeha u osvajanju grada, posljednji povukli na brodove. Godine 1751. i 1756. dobrotski kapetani, braća Marko i Jozo Ivanović, izvojevali su dvije velike pobjede nad turskim gusarima. Kap. Marko 1751. godine pobjeđuje 150 tripolitanskih gusara kod Patrasa, a 1756. godine zajedno s bratom Jozom likvidiraju turski šambek od 360 tripolitanskih gusara. U tom sukobu poginuo je kap. Marko Ivanović. Mletačka Republika dodijelila je Jozu Ivanoviću titulu viteza sv. Marka sa zlatnom kolajnom.

[6] *Star* – stara jedinica za žito (oko 60 kg) ili ulje (zapremninu).

Slika 5. – *Bitka kap. Marka Ivanovića sa Berberskim piratima kod Patrasa 1751. godine* [17].

Slika 6. – *Kap. Marko i Jozo Ivanović u pirejskoj luci napadnuti od tripolitanskog šambeka 1756. godine* [17].

Svojevrstan je bio podvig kap. Petra Želalića iz Bijele 1760. godine, zarobljenog na brodu „Sultania“, koji je po dolasku u Rodos uspio da se oslobodi i, zajedno sa još dva člana posade i ostalim zarobljenicima, zatvori ulaz u unutrašnjost broda, tako da Turci, koji su bili na molitvi, nisu više mogli da izađu. Želalić je tada isplovio brodom i uputio se prema Malti, gdje je predao brod i za taj podvig dobio orden Reda Malteškog viteza [14].

Iz Prčanja se u mletačko-turskim okršajima ističu pomorski kapetani iz bratstava Đurović, Lazzari, Sbutega, Maras, Luković i Muzaća. Ivo Luković, kao opštinski glavar 1698. godine, zapovijedao je jedinicom od oko 50 Prčanjana u bitkama kod Bara, Grahova i Trebinja. Hrabrost prčanjskih pomoraca pri mletačkom zauzimanju Herceg-Novog posebno je istakao generalni providur Đirolamo Korner (*Girolamo Corner*) u pismu iz 1689. godine, izdvajajući ratničke vještine Vicka Petrova Lukovića kao predvodnika prčanjskih boraca.

Osvajanjem Herceg-Novog 1687. prestaju značajniji sukobi sa Turcima na kopnu, kao i hajdučke akcije u Crnoj Gori i Hercegovini, a zatim i borbe protiv gusara i pirata na moru [14].

Padom Mletačke Republike 1797. godine, Kotorska mornarica uglavnom gubi sve one atribute koje je imala nekoliko vjekova prije toga, tako da čak i njena djelatnost skoro potpuno zamire, osim što joj se dozvoljava pojavljivanje u uniformama prigodom gradskih svetkovina, posebno proslave zaštitnika grada Sv. Tripuna, 3. februara.

Slika 7. *Sveti Tripun kotorski* [17].

Za vrijeme ruske vladavine Bokom, 1806-1807. godine, nešto je liberalnija aktivnost Mornarice, pa čak određeni broj bokeljskih brodova učestvuju pod ruskom zastavom u borbama protiv Francuza [6].

Mornaricom je tada upravljao lučki kapetan, a ne više admiral. Teže prilike za Mornaricu dolaze poslije 1807. godine, dolaskom Francuza u Boku, koji zabranjuju Mornarici bilo kakvu djelatnost i oduzimaju joj svu imovinu.

Za vrijeme kratkotrajne crnogorsko-bokeljske vlade tzv. „Centralne komisije", tokom 1813. godine, Mornarici se dozvoljava njena javna aktivnost i ponovno uspostavljanje njenih organa.

Međutim, polovinom 1814. godine Austrijanci ponovo ulaze u Boku i ostaju sve do 1918. godine. U ovom dugom periodu od preko 100 godina, došlo je do reorganizacije Mornarice, tako da je 1833. godine austrijski namjesnik za Dalmaciju, grof Lilienberg, odobrio obnavljanje njenih aktivnosti [6]. Međutim zadržane su samo njene staleške, ali ne i vojne nadležnosti.

5. Zaključak

Cilj ovog rada je da se istakne vjerodostojnost vojnih aktivnosti Kotorske mornarice u kontinuitetu od devetog vijeka pa sve do pada Mletačke Republike 1797. godine. To nas navodi na zaključak da postoji neprekidna vojno odbrambena aktivnost mornarice od skoro hiljadu godina. Kontinuitet djelovanja kotorskih i bokeljskih pomoraca pratimo još iz vremena ravnopravnog učešća u Bizantskoj floti sa pomorcima Zadra, Splita i Dubrovnika, u ratovima protiv Saracena i takođe iz ugovora o nenapadanju i slobodnoj plovidbi Jadranom između gradova Kotora i Omiša iz 1167. godine. Ulaskom u sastav Mletačke Republike 1420. godine, nastavlja se kontinuitet vojnih aktivnosti u okviru mletačke flote, u borbama s agresivnim piratima, naročito ulcinjskim i sjevernoafričkim gusarima koji su ometali slobodnu plovidbu južnim Jadranom. Dokument iz 1353. godine potvrda je kontinuiteta organizovane Bratovštine pomoraca u popunjavanju ratnih brodova posadom radi odbrane kotorskih teritorijalnih voda, što je Mletačkoj Republici bilo izuzetno dragocjeno, a posebno kasnije prilikom opsade Skadra. Statut Bratovštine kotorskih pomoraca iz 1463. godine vjerodostojan je dokument o značaju ove pomorske organizacije u odbrani ovih obala. Kotorska galija 1571. godine učestvuje u najvećoj pomorskoj bici kod Lepanta u Korintskom zalivu koja se vodila između flote Svete lige i flote Turskog carstva. U ovoj bici najznačajniju ulogu odigrala je mletačka mornarica, u čijem sastavu je bila i kotorska galija „Sv. Tripun" pod zapovjedništvom Kotoranina Jeronima Bizantija.

Vojne aktivnosti ostalih mjesta Kotorskog zaliva pratimo djelovanjem Peraških pomoraca, u borbama protiv gusara i pirata na Jadranskom moru, i učešćem u većim mletačkim vojnim operacijama pored mora i na kopnu. Dobroćani učestvuju u bici za Bar 1717. i Ulcinj, 1718. godine. Dobrotski kapetani, braća Marko i Jozo Ivanović, izvojevali su dvije velike pobjede nad turskim gusarima. 1751. i 1756. godine. Takođe se ističu i Prčanjani u mletačko-turskim ratovima, iako pomorci, isto tako su vješti i na kopnu u bitkama kod Bara, Grahova i Trebinja.

Padom Mletačke Republike 1797. godine, Kotorska mornarica gubi sve vojno pomorske karakteristike, njena djelatnost skoro potpuno zamire, osim što joj se dozvoljava pojavljivanje u uniformama prigodom gradskih svetkovina, posebno proslave zaštitnika grada sv. Tripuna, 3. februara. Na kraju, rad prati djelovanje Bratovštine kotorskih pomoraca u 19. vijeku, kad je bila više puta i ukidana ali se uspjela održati i obnoviti svoje djelovanje samo kao Memorijalna organizacija.

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The Kotor Fraternity of Seafarers in Naval-Military Operations

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Abstract: This paper explores the historical role of the Kotor Fraternity of Seafarers in naval-military operations from the Byzantine era through the Venetian period. The study highlights the evolution of the fraternity from a religiously sponsored guild into a significant naval force, emphasizing its contributions to various military engagements, including the First Ottoman-Venetian War and the Siege of Shkodra. The paper also examines the administrative and structural changes within the fraternity under Venetian rule, illustrating how it adapted to the military and economic demands of the time. The fraternity's legacy in shaping the maritime history and cultural heritage of Kotor is also discussed.

Keywords: Kotor Fraternity of Seafarers, Naval-military operations, Maritime history, Kotor, Boka Navy Kotor

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