https://doi.org/10.53656/str2023-3-3-saf

Education in the Information Society
Образованието в информационното общество

SAFETY THROUGH ARTIFICIAL INTELLIGENCE IN THE MARITIME INDUSTRY

Assoc. Prof. Petya Biolcheva
University of National and World Economy
Evgeni Valchev, PhD student
University of Plovdiv

Abstract. Artificial intelligence is entering the maritime industry at a rapid pace. There is talk about intelligent ships and autonomous solutions. According to the authors of this study, autonomous technologies should be introduced in gradually so as to guarantee peace of mind for marine experts and offer maximum accuracy in their functionalities. The purpose of this paper is to reveal a methodology for intelligent (based on artificial intelligence) safety in the maritime industry. A gradual process has been revealed in which, with the help of various intelligent tools, multi-faceted analyzes can be carried out and conclusions and alternative solutions can be drawn, on the basis of which maritime experts can make an informed decision and significantly increase safety. The combination of technology and expertise, outlines the necessary transition for creating a new type of competitive advantage.

Keywords: Maritime Industry; Intelligent Safety; Artificial Intelligence

1. Introduction

Introduction of Industry 4.0 and the drive for achieving a high level of digitization and automation of processes, including the use of various artificial intelligence (AI) tools, is a topic that arouses many scientific and business interests. Some autors are relating it to management of efficiency, productivity and human resources (Christenko et al. 2022), others to management of marketing (Jarek and Mazurek 2019); financial audits (Ayling and Chapman 2022); risk management (Naim 2022). Wide range of management activities currently falls under the scope and capabilities of AI. Approaching the era of artificial intelligence is also a fact for the maritime industry. A prerequisite for this can also be sought in the importance of international trade. Nearly 50% of goods are transported through it (Sanchez-Gonzalez et al. 2019). The dynamics of the environment require the maritime industry to be sufficiently flexible, adaptive to changes and at the same time safe. These are among the main reasons that in recent years there has been more and more talk about the entry of various AI tools into it. AI increases the

efficiency of primary services, including vessel tracking, emissions control, predictive maintenance, safety and welfare (Plaza-Hernández et al. 2022). A research objective of this paper is to reveal a methodology by which safety in the maritime industry could be significantly enhanced by applying the capabilities of various artificial intelligence tools. The posed research question is aimed at how to develop a methodology that combines the multifaceted analyzes and findings from various intelligent tools and human expertise, so as to significantly increase the effect of the various maritime safety systems, into a comprehensive integrated system. To by obtained an objective decision, the following sections are presented below. A literature review revealing research trends regarding the application of AI in the maritime industry; The main directions for application of AI in the marine industry, representing the main directions in which the efforts in the field are concentrated; A Methodology for Applying AI in the Maritime Safety Assurance Process (MAIS); Discussion, discussing the merits of the methodology; and conclusion.

2. Literature review

For greater clarity regarding the application of AI in the maritime industry together with the progress of science in this field, it is first necessary to reveal its essence. According to Chassignol and his team (2018), AI is defined as a theoretical framework guiding the development and the use of computer systems to implement the capabilities of human beings. The main human qualities they emphasize are: ability to perform tasks that require human intelligence; visual perception, including speech recognition, decision making; translation between languages. In a synthesized form, AI can be formulated as: software and/or hardware systems that, alike human's brain, are capable to interpret and analyse the acquired data and make a decision in achievmen of a certain goal (Christenko et al. 2022). The interesting thing about it is its abilities to learn and improve from its own experience (Kunnathur 2020). The claim that in the upcoming years it will become a key competitive advantage (Tamilchelvan 2020) for every business is also gaining momentum. This is also true for the maritime industry. AI, as a machine-based technique with algorithmic power, applicable for predictions, recommendations and decisions, is gaining increasing importance and development potential (Chen 2022). According to Pokrivcakova (2019), AI in the maritime industry can be defined as an intelligent system capable of performing various functionalities, including assisting maritime experts in developing their knowledge and flexible skills. In 2020, US legislation introduced AI as part of the training of key experts. According to it, for successful implementation of digital transformation and transition to AI technologies, an appropriate competence aside of experts is required (DoD AI Education Strategy 2020).

As it clear the "Smart Transformation" in maritime industry provides opportunities for improvement of its productivity, efficiency and sustainability.

AI systems are emerging in Aautonomous Ships that can operate independently without a direct human interaction, and their rate of error is lower than that of manned ships (Munim et al. 2020). Maritime operations enhanced with Big Data and AI can contribute for the economic and environmental aspects of the maritime business (Sanchez-Gonzalez et al. 2019). The ways in which shipping companies are making decisions are also changing. The application of AI is gaining increasing importance in various segments of shipping craft, and it is expanding the productive efficiency of maritime companies (Yuen et al. 2020).

3. Main directions in the application of AI in the maritime industry

The synthesis and analysis of scientific literature outlines several main areas where AI is contributing to the maritime industry: digital transformation; energy efficiency; forecasts and analyses; maritime safety and accident prevention.

Digital Transformation – Digital transformation is at a stage where it is changing all shipping-related activities (Ma 2020). Systems are being automated, monitoring of navigation systems and engines are being increased to automate on-board tasks, even using control without human intervention (Ichimura et al. 2022). The Digital Transformation predetermines the functional dependency of conventional models and tools for implementation of an approach with models, generated with Machine Learning (ML). The main contributions of AI, aimed at digitalization are also related to the possibility for complete change of the business model, by generating new revenues and creating value (Munim et al. 2020). The lack of stability and the sudden changes in the requirements of the business environment force the maritime industry to look for alternatives for efficient management with low costs and high standards of service quality. The implementation of Machine Learning, ontological analysis, neural networks and artificial intelligence, help to solve extremely complex algorithmic tasks based on unlimited count of complex parameters, supporting the selection of effective business models.

Energy efficiency – Air pollution from maritime transport has a strong negative impact on the environment. 3.3% of global carbon dioxide (CO2) emissions are due to maritime transport (Issa et al. 2022). In accordance with the requirements to reduce the total emissions of greenhouse gases from international maritime transport (Jimenez et al. 2022), optimization of the maritime industry is necessary. Its framework includes parameters such as: the optimization of the speed of the vessel; route planning; vessel crane control; optimization of sailing in case of changes in weather conditions; ship performance and navigation systems. These parameters depend on weather conditions, routes, other shipping routes, cargo, stability, etc. Artificial intelligence helps with dynamic analysis, calculating fuel consumption, safety, sea currents, etc. Based on the overall input, machine-learned programs and tools can take proactive actions based on predictions and expected results. Neural networks have the capacity to fully process the arrays of different

databases and "play" complex combinatorics, ultimately offering the optimized solution for choosing a specific route.

Forecasts and Analytics – Forecasts and analytics are an effective part of any system. It is essential to carry out analyses over the operational efficiency of vessels for the needs of shipping companies (Mirović et al. 2018); pricing analyses, delivery times; the analysis for the selection of the most suitable vessels against available goods to be shipped, etc. The analysis provides information based on historical and current data. These data are compared with future development analyses, which includes parameters from the entire maritime sector and other economic sectors, geopolitical factors and other relevant external factors. Based on the overall concept and rationale, current ML and AI technologies are extremely useful in making exploratory conclusions for future time periods.

Maritime safety and accident prevention – To achieve maximum levels of safety, a number of technologies and sensor networks are used to monitor both the internal and external parameters of each ship. The sensors continuously feed up-to-date information to central stations and controllers that take the appropriate proactive actions to reduce the risk of certain threatening events. Using end-to-end purpose-built sensors, as well as sensor network technology along with ML-based analytics systems, managers and experts are enabled to predicatively monitor and visualize events. Example input parameters can be: preventive analyses for the state of wind, waves, visibility; analysis and early notification in case of potential technical malfunction; analysis of nearby vessels and prevention of pirate attacks; guaranteed connectivity to a shore control Centre. Sensor networks detect the prerequisites for potential risk events and compare them with results from past events. This enables preventive actions and reduction of safety risks.

4. Methodology for Maritime Safety, Aided by Artificial Intelligence (MAIS)

Various safety management methodologies are used in the maritime industry. Most often, they are based on integrated systems aimed at developing, monitoring, controlling, and improving the basic operations in shipping (Banda et al. 2016). Their analysis during the last decade shows the presence of growing interests from various researchers. In 2014 (Zhang et.al. 2014) a methodology for the Maritime Safety Administration (MSA) is emerging. It is aimed at the safety and efficiency of water transport and the reduction of environmental pollution. 2016 (Banda et al. 2016) presents a model for safety management through key performance indicators. In 2017 (Tu et al. 2017) proposed an automatic identification system (AIS) with the ability to track the movement of ships, through electronic exchange of navigation data between vessels, with satellite base stations. Through this methodology, anomalies in traffic and route planning of marine vessels can be detected. Towards the end of the researched period, there is also talk of digitization and the entry of various artificial intelligence tools into maritime safety (Sanchez-Gonzalez et al.

2019). On this basis in 2023 a methodology working with an algorithm that predicts future sea traffic conditions and improving the performance of autonomous ships is being developed (Lee et al. 2023).

The growing interest in the subject is due to the need to transform the maritime industry in line with Industry 4.0. The literature analysis shows that safety management is a complex process (Sanchez-Gonzalez et al. 2019). Although there are developed methods and models for its improvement, they do not offer a high degree of digitization of the sector. The methodology proposed here reveals an integrated approach based on the application of various AI tools that will significantly increase efficiency and autonomy in maritime safety through the achievement of intelligent safety. The methodology is entitled (MAIS) Maritime Safety, with the help of artificial intelligence. With the aim of smooth transformation and reducing stress levels in maritime professionals (caused by the fear of replacing humans by machines), (MAIS) combines the role of smart tools with the expertise of maritime experts. In this collaboration, the functions of the AI tools are rather helpful in performing analyzes and offering intelligent inferences and alternatives to objective possibilities, and the concrete solutions are left in the hands of the authorized experts. In this way, the intelligent system will have the opportunity to improve and self-train over time to the point of achieving high results, and the experts will have the opportunity to get used to it and trust it.

The choice of intelligent tools in MAIS is determined by the types of activities related to maritime safety. They have overview (overlapping the entire aspect of incoming information), analyzing current and future events based on incoming information and drawing conclusions functions. The logic of the methodology is diagrammed in Fig.1.

A sample of major key activities related to maritime safety are used as input parameters driving the MAIS engine. In the specific case, they are reduced to various exemplary safety systems: fire safety; technical safety; early warning systems; behavioural analysis; analysis of external factors.

Fire safety – data from various sensor networks (reporting smoke, temperature, flame) are used to provide a flow of incoming information related to potential risk events. In addition to them, historical databases of personnel actions related to similar events, as well as databases based on expert analysis relating to specific risk situations, are applied. In the same direction, data are collected on key factors of the external environment that are relevant to fire safety, for example the presence of a thunderstorm.

Technical safety – to provide input data, this system uses sensors and corresponding sensor networks monitoring the surrounding technical environment for risks related to potential damage, inconsistencies with the normal operation of the technical equipment and the mechanical integrity of the vessel. They monitor for violations of operational and technical processes. Another source of data is

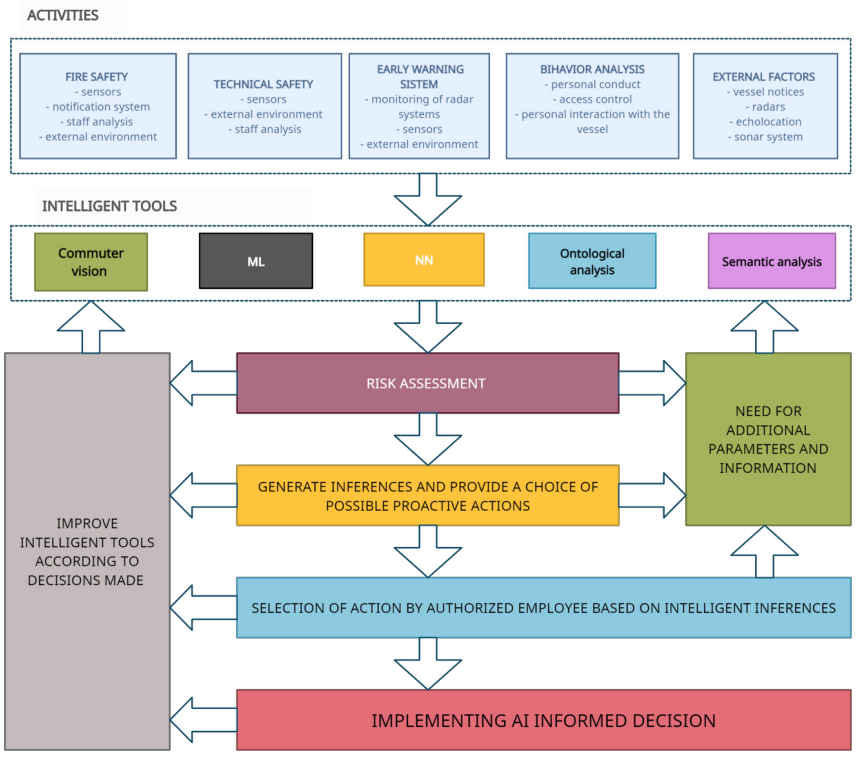

Figure 1. Methodology for Maritime Safety, Aided by Artificial Intelligence (MAIS)

the information received from the external environment that has a direct impact on the vessel (sea swell, weather conditions and data on their change). Data is also provided by security systems, access control, intelligent video surveillance, through which the risk of intentional abuse by ship personnel is reduced.

Early warning systems – with them, the incoming data is provided and guaranteed by historical information (databases and analyses) as well as current information, collected and processed in real time. Data sources are radar, sonar and other means available on the particular vessel. Similar to technical safety, data from the external environment related to the security of the vessel (meteorological data, various economic and geopolitical factors, etc.) also fall into the incoming information flow.

Behavioural analysis – here the data on the behaviour of each individual person of the ship's personnel is important. Their collection is necessary to monitor habits, reactions, norms of behaviour, illogical changes in the behaviour of the staff. The

goal is to reduce the risk of malicious actions related to ship safety, provoked by various psychological conditions. Access control systems, video surveillance systems, systems monitoring the personal interaction of personnel with the vessel are used as sources of incoming information.

External factors – in this safety system, the interaction of the ship with the external environment is important. Here, the data source may be external in nature, for example meteorological data, sea swell data, currents that have a direct effect on the vessel. Various economic and geopolitical factors, international agreements, and regulations, etc. are important. The data source can also be internal, i.e. inputs from various radars and radar systems, nearby vessel notifications, echo sounders, sonar systems and others relevant to the particular vessel are used.

All the input data collected in real-time, combined with data on its historical manifestation in the past period of time, form a knowledge base, which is necessary as input information to trigger the operation of the AI tools. This leads to the second step of MAIS. For the purpose of intelligent analysis, the following AI tools are applied here: computer vision; machine learning (ML); Neural Networks; ontological analysis and semantic analysis. Computer vision encompasses all systems, hardware and software, through which machines acquire real-world knowledge of the world around them. These are navigation systems, cameras, sensors and sensors, sensor networks and many others. Through their use, machines gain proven up-to-date information and perspective. The identification of potential events that may go out or go out of their usual parameters and norms are based on the applied long-term machine learning. ML processes and synthesizes historical and current information. Based on specific algorithms selected for the specific subject area ML constantly increases its functionality, correctness, and percentage of truth of the derived conclusions. Neural networks are directly related to this process. Through their ability to process 'n' number of input parameters, network topology, as well as 'n' number of output parameters with a certain percentage of truth, inferences are generated and specified. The process is complemented by ontological and semantic analysis, which help to correctly perceive and understand the surrounding physical world by intelligent tools. Thus, the various AI tools in complementary roles, in real-time and with impartiality conduct proactive intelligent analysis for the presence of potential risks threatening maritime safety.

For added accuracy, the generated list of potential risks should go through the next iteration of MAIS. It is related to risk analysis. The goal is to evaluate the various alternatives of potential solutions in a given situation and propose those with the lowest risk factor. In the case that additional information is needed, the procedure goes back a step and the intelligent tools conduct additional analysis based on the newly available real-time information.

At the next stage of MAIS, the system generates potential solutions and conclusions. On this basis, an authorized expert has the opportunity to take relevant

actions. With this property of the methodology, the role of a man and his importance become visible, i.e. smart tools assist in preparing various solutions to deal with a specific situation, but this stage, the final decision is taken by the experts. In the event that proposed alternatives provide a solution that matches the expert's choice, then he selects the particular alternative for application. Under conditions that there is a need for different alternatives, or the decision-making period is related to a rapid change in the circumstances of the environment, or there is another solution, the expert can update and supplement input parameters, according to his own observations, and request additional alternatives from the system. In this case, the AI tools are triggered again, the procedure is repeated, and the expert has the opportunity to get new alternatives and that too in real time. The procedure may have as many iterations as the expert judges until he makes an informed choice and makes the appropriate decision to address the particular safety situation. With each iteration between the expert and the system, the intelligent tools increase their level of efficiency and correctness in making decisions.

For the continuous improvement of the intelligent safety system, the processes related to the evaluation of proactive decisions serve as a source of training for the artificial intelligence. The expert's decisions are a source of information, and so are their consequences. MAIS thus improves over time and develops the potential to offer the best possible solutions using a broad knowledge base and significantly reducing response times. In this way, adequate and timely preventive actions can be taken. All this increases security and safety in the maritime industry.

5. Discussion

While the maritime industry has powerful software solutions that offer a high level of protection and they operate in a highly integrated manner, the application of AI can significantly improve processes. Incoming data from various security sources and processing it through complementary AI tools makes the analysis multifaceted. The effect of a change in parameters of one system on the functioning of another or others, as well as the potential consequences thereof, is considered. Various intelligent AI tools can establish these interrelationships and show potential threats. Another advantage of this type of analysis is the comparison of incoming data with data from past periods. Conclusions from past events are analysed in relation to their effect and their applicability to the specific circumstances, the dynamics of the environment and other factors.

The use of the intelligent safety system, where decisions are made by **experts**, is related to people's attitudes towards artificial intelligence. The fear of marine personnel that they will be displaced by machines is still a fact. **Expertise** is not neglected here, which reduces the initial negative attitude towards the intelligent safety system. Providing potential actionable solutions in real-time enables **experts** to avoid initial stress from the ongoing situation; decisions are multifaceted and consider multiple

factors and potential effects on all safety systems. Moreover, early diagnosis gives predicative information about potential danger, i.e. decisions are made proactively.

The gradual entry of AI into the maritime industry, in this case through the safety system, will promote the optimization of processes, to synchronize and integrate all operational safety systems. This will increase the overall level of security and give new competitive advantages in the maritime industry.

6. Conclusion

This paper examines the topic related to the introduction of artificial intelligence into the maritime industry. It outlines the main directions in which the most diligent work is being done to implement various intelligent tools. These are the areas related to digital transformation: energy efficiency, analysis and forecasting, maritime safety and accident prevention. The added value of the research is related to the author's development of a methodology for increasing safety in the maritime industry. This methodology envisages the application of various intelligent tools, with the aim of obtaining more precise analyses, providing real-time information, multi-faceted and unbiased analyses, providing conclusions for potential solutions to maritime **experts**. Methodology combines the power and accuracy of AI computational mechanisms, the accuracy of coalition dependencies, and advancing combinatorics algorithms with the expertise of maritime experts.

Acknowledgements

This work was financially supported by the NNWE Research Programme (Research Grand No 5/2023).

NOTES

1. Tamilchelvan, T., 2020. AI-Powered Solutions to Level Up Your Project Management. Available at: https://medium.com/project-managers-planet/ai-powered-solutions-to-level-up-your-project-management-4dddeeddc4cd.
2. DoD AI Education Strategy, 2020. Department of Defense Artificial Intelligence Education Strategy Delivered in Fulfillment of the Requirements outlined in Section 256 of the National Defense Authorization Act for Fiscal (Public Law 116-92). Available at: https://www.ai.mil/docs/2020_DoD_AI_Training_and_Education_Strategy_and_Infographic_10_27_20.pdf.

REFERENCES

AYLING, J., CHAPMAN, A., 2022. Putting AI ethics to work: are the tools fit for purpose?. *AI Ethics*. vol. 2, pp. 405 – 429.

BANDA, O., HÄNNINEN, M., LAPPALAINEN, J., KUJALA, P. GOERLANDT, F., 2016. A method for extracting key performance

indicators from maritime safety management norms. *WMU Journal of Maritime Affairs*, vol. 15, pp. 237 – 265, DOI: 10.1007/s13437-015-0095-z.

CHASSIGNOL, M. KHOROSHAVIN, A. KLIMOVA, A., BILYATDINOVA, A., 2018. Artificial intelligence trends in education: A narrative overview. *Procedia Comput. Sci*. vol. 136, pp.16 – 24.

CHEN, X., ZOU, D., XIE, H., CHENG, G., & LIU, C., 2022. Two Decades of Artificial Intelligence in Education: Contributors, Collaborations, Research Topics, Challenges, and Future Directions. *Educational Technology & Society*, Vol. 25 no.1, pp. 28 – 47.

CHRISTENKO, A., JANKAUSKAITĖ, V., PALIOKAITĖ, A., BROEK, E., REINHOLD, K., JÄRVIS, M., 2022, Artificial intelligence for worker management: an overview. *European Agency for Safety and Health at Work*. DOI: 10.2802/76354.

ICHIMURA, Y., DALAKLIS, D., KITADA, M., CHRISTODOULOU, A., 2022. Shipping in the era of digitalization: Mapping the future strategic plansof major maritime commercial actors. *Digital Business*, vol. 2, pp. 1 – 11. DOI: 10.1016/j.digbus.2022.100022.

ISSA, M.; ILINCA, A.; MARTINI, F., 2022. Ship Energy Efficiency and Maritime Sector Initiatives to Reduce Carbon Emissions. *Energies* , vol. 15, DOI: 10.3390/en15217910.

JAREK, K., MAZUREK, G., 2019. Marketing and Artificial Intelligence. *Central European Business Review*, vol. 8 no. 2. DOI: 10.18267/j.cebr.213.

JIMENEZ, V., KIM, H., MUNIM, Z., 2022. A review of ship energy efficiency research and directions towards emission reduction in the maritime industry, *Journal of Cleaner Production*, vol. 366, no.132888.

KUNNATHUR, M., 2020. Applying Artificial Intelligence techniques in Project Management. *Masters in Engineering and Management*, DOI: 10.13140/RG.2.2.15113.39526.

LAM, J., WONG, H., 2018. Analysing business models of liner shipping companies. *International Journal of Shipping and Transport Logistics*, vol. 10, no. 2, pp. 237 – 256. DOI: 10.1504/IJSTL.2018.090078.

LEE, E., KHAN, J., SON, W., KIM, K. 2023. An Efficient Feature Augmentation and LSTM-Based Method to Predict Maritime Traffic Conditions. *Applied Sciences*, vol. 13, DOI: 10.3390/app13042556.

MA, S., 2020. *Economics of maritime business*. Routledge. ISBN: 9781315658124.

MIROVIĆ, M., MILIČEVIĆ, M., INES, O., 2018. Big Data in the Maritime Industry. *NAŠE MORE: Znanstveno-strucni Casopis Za More I Pomorstvo*, vol. 65 no.1, pp. 56 – 62. DOI: 10.17818/NM/2018/1.8.

MUNIM, Z., DUSHENKOA, M., JIMENEZA, V., SHAKILB, M., IMSET M., 2020. Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions. *Maritime Policy & Management*, vol. 47, no.5, pp. 577 – 559. DOI: 10.1080/03088839.2020.1788731.

NAIM, A., 2022. Role of Artificial Intelligence in Business Risk Management. *American Journal of Business Management, Economics and Banking*, vol. 1, pp. 55 – 66.

PLAZA-HERNÁNDEZ, M., GIL-GONZÁLEZ, A., RODRÍGUEZ-GONZÁLEZ, S., PRIETO-TEJEDOR, J., CORCHADO-RODRÍGUEZ, J., 2021. Integration of IoT Technologies in the Maritime Industry. In: , et al. Distributed Computing and Artificial Intelligence, Special Sessions, 17th International Conference. DCAI 2020. *Advances in Intelligent Systems and Computing*, 1242. Springer, DOI:10.1007/978-3-030-53829-3_10.

POKRIVCAKOVA, S. 2019. Preparing teachers for the application of AI-powered technologies in foreign language education. *J. Lang. Cultural Edu*., vol. 7, no. 3, pp.135 – 153.

SANCHEZ-GONZALEZ, P., DÍAZ-GUTIÉRREZ, D., LEO, T., NÚÑEZ-RIVAS, L. 2019. Toward Digitalization of Maritime Transport? *Sensors,* vol.19, no.4. DOI:10.3390/s19040926.

Tu, E., Zhang, G., Rachmawati, L., Rajabally, E., Huang, G. 2017. Exploiting AIS Data for Intelligent Maritime Navigation: A Comprehensive Survey, *IEEE*. Vo.19, no.5, pp. 1559 – 1582, DOI: 10.1109/TITS.2017.2724551.

YUEN, K., XU, G., LAM, J., 2020. Special issue on 'Artificial Intelligence & big data in shipping. *Maritime Policy & Management*, vol.47, no. 5, pp. 575 – 576. DOI: 10.1080/03088839.2020.1790052.

ZHANG, J., X., ZHANG, D., HAUGEN, S., YANG, X. 2014. Safety management performance assessment for Maritime Safety Administration (MSA) by using generalized belief rule base methodology. *Safety Science*, vol. 63, pp. 157 – 167. DOI: 10.1016/j.ssci.2013.10.021.

✉ **Assoc. Prof. Dr. Petya Biolcheva**
ORCID iD: 0000-0001-9430-773X
Department Industrial Business
University of National and World Economy,
E-mail: p.biolcheva@unwe.bg

✉ **Evgeni Valchev, PhD student**
Faculty of Mathematics and Informatics
University of Plovdiv
E-mail: evgeni.valchev@gmail.com