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Arab Academy for Science, Technology, and Maritime Transport, AASTMT
Abu Kir Campus, Alexandria, EGYPT
P.O. Box: Miami 1029
Tel: (+203) 5622366/88 – EXT 1069 and (+203) 5611818
Fax: (+203) 5611818
Web Site: http://apc.aast.edu
Email: apc@aast.edu

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The Influence of Computerized Simulation Techniques on Maritime Security Exercises: ISPS Code

Ahmed Mohy Ibrahim

Head of Quality Assurance Unit at Regional Maritime Security Institute, Arab Academy for Science, Technology and Maritime Transport (RMSI - AASTMT), Alexandria, Egypt.
ORCID: (0000-0001-5582-382X)

Emails: ahmedmohyyy@aast.edu, ahmedmohyy@gmail.com

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ABSTRACT

Purpose: *Maritime security necessitates adept collaboration among port facility security teams, seafarers, and governing authorities. Maritime Education and Training (MET), guided by international standards, conforms to their competence and proficiency, especially in security exercises, boosting understanding of roles and responsibilities in challenging security scenarios. The pivotal role of international maritime communities in shaping future MET by embracing computerized simulation techniques indicates a new era in maritime safety simulations but lacks insights into adopting security scenarios. Revolutionizing the use of computerized simulators for seafarers in maritime safety sectors is advancing, yet there is limited intervention in security exercises.*

Design/Methodology/Approach: *This study explores integrating immersive technologies into theoretical "tabletop exercises", aiming to enhance the strengthening of realistic exposure to high-risk scenarios. The research emphasizes the significance of MET guided by international standards and proposes leveraging computerized simulation techniques, aiming to revolutionize security exercises. Employing a descriptive and analytical exploration approach, this study offers a thorough examination of challenges within maritime security training. It provides a comprehensive overview by not only describing the current state but also critically analyzing the potential impacts and effectiveness of immersive technologies. This assessment focuses specifically on how these technologies enhance practical training for maritime security personnel.*

Key-words:
Computerized Simulation Immersive Technologies, ISPS Code, Maritime Security Exercises, MET

INTRODUCTION

The maritime industry's ongoing digital transformation is driving rapid change and is expected to persist as the maritime sector becomes more intelligent and automated, especially in Maritime Education and Training (MET) (Cicek et al., 2019; Tijan et al., 2021). Operating within a multifaceted global scene of challenges and risks, the complex maritime environment increasingly demands enhanced connectivity and technological advancements. Emphasizing the less focused aspects of the International Ship and Port Facility Security (ISPS) Code's measures, several areas might receive comparatively less attention. Focusing on leveraging emerging technologies presents a pivotal opportunity to mitigate severe security risks within maritime port facilities and onboard vessels, an area receiving comparatively less attention than safety in the industry's agenda (Bueger, 2015; Dalaklis, 2017; Tijan et al., 2021).

Furthermore, ensuring controlled technology integration to educate and train personnel is crucial in addressing the array of threats and vulnerabilities in this complex smart maritime industry (Ben Farah et al., 2022). Throughout history, the sea-to-shore interface has been a source of wealth and risk (Pagán et al., 2016). It remains vital for coastal governments to sustainably manage and protect sea resources (UNCLOS, 1982). The future vision of the Sustainable Development Goals (SDGs) for the international maritime community's efforts to conserve and responsibly utilize marine resources from inland waters to the high seas emphasizes the need for advanced security education and training scenarios within MET programs and assets to equip seafarers and Port Facility Security Personnel (PFSP), decision-makers, support agencies (such as bomb squads and firefighting teams), and stakeholders with skills and updated knowledge necessary from advanced security exercises approaches (Bueger et al., 2020; IMO, 2003; Kim et al., 2021; Ringsberg and Cole, 2020). At present, security exercises adhere to the basic requirements outlined in the ISPS Code, including the utilization of a traditional tabletop simulation approach (IMO, 2003). There is a missed opportunity to utilize advanced computerized simulation techniques (immersive technologies) compatible with technological advances to effectively address the evolving challenges and emerging risks in the maritime industry (Felsenstein et al., 2013; Mallam et al., 2019).

LITERATURE REVIEW

The absence of integrating immersive technological solutions by some maritime security exercise providers may potentially delay the progression of several aspects within the advancing trends of the smart maritime industry (Dewan et al., 2023). Furthermore, this oversight overlooks essential aspects, especially in fostering the mindset of security experts and their skills and knowledge. This encompasses the need for refined strategies, including rehabilitation techniques, to address piracy, armed robbery, cyber threats, vulnerabilities, and other increasingly relevant challenges and risks within today's dynamic and technologically advanced maritime industry (Tam and Jones, 2018). Consequently, maritime security personnel face ineffective preparation in dealing with emergent risks such as cyber threats and other evolving security scenarios (Afenyo and Caesar, 2023). This absence of sophisticated simulations based on immersive technological solutions, delays the comprehensive qualification and preparation of maritime security personnel, influencing their ability to effectively manage real-time security risks in the continually evolving maritime security challenges, whether within port facilities or aboard ships (Bueger et al., 2020; Erstad et al., 2023).

Efforts led by the International Association of Maritime Universities (IAMU) and World Maritime University (WMU) paved the way for innovative research exploring new computerized simulation techniques to adapt immersive technologies into MET. Collaborative projects between maritime industry stakeholders and educational institutions are actively developing novel MET strategies, particularly focusing on instilling crucial leadership skills through initiatives like the Global Maritime Professional - Body of Knowledge (GMP-BoK) (IAMU, 2019;IAMU, 2022). These initiatives aim to enhance the skill sets and knowledge base of maritime personnel in response to the industry's evolving demands. The adoption and integration of advanced computerized simulation techniques based on immersive technologies are crucial for modernizing educational and training methods, especially in renovating maritime security exercises within the maritime sector. Unfortunately, the prevalent reliance on traditional methods for security simulator exercises during epidemics and environmental disasters has exposed a significant technology integration gap at the local, regional, and international levels. This gap specifically concerns the integration of computerized simulation techniques within maritime institutes to meet the requirements outlined in the ISPS Code. This lack of optimal utilization or interest in immersive technology development is concerning.

Governing International Standards

The International Maritime Organization (IMO) is a specialized United Nations body for the maritime industry, its role involves uniting and fostering a safe and secure environment by facilitating coordination among contracting governments to establish codes and conventions. Since 1978, an essential element of the current security training has been outlined within the Standards of Training, Certification, and

Watchkeeping for Seafarers (STCW) Convention (Lun et al., 2023). Furthermore, the obligations and recommendations regarding security needs are available in SOLAS conventions, especially Chapter XI-2 and ISPS Code enforcement in 2004, following the September 11th, 2001 aviation incident, the ISPS code was inspired by best practices from the aviation industry.

Maritime Security "Tabletop Exercise" Approach

The ISPS code mandates that security training "exercise" is required for the capacity-building of seafarers and shore security personnel. The implementation of the ISPS code indicates special methods to carry out security exercises, such as full-scale onsite, tabletop simulation or seminar, or combined exercises with different scenarios that should be performed regularly (Arof and Khadzi, 2018; IMO, 2003). Security exercises must be carried out at least once in consecutive Gregorian years, with a maximum of 18-month interval between each session. The ISPS Code underscores the necessity for security-specialized personnel who undergo training to address security breaches across various security levels (IMO, 2003). This security exercise could be conducted jointly for both the ship and the port facility, either separately or simultaneously. Thus, ensuring familiarity with security plans, security procedures, emergency plans, and the best practices for security mitigation approaches. Moreover, this security exercise scenario could be combined with safety scenarios such as firefighting, and more (Vukelic et al., 2023). Scopus database findings reveal limited sources discussing technology integration within ISPS Code security exercises, particularly focused on tabletop simulation methods for maritime security exercises.

The human factor persists as the game changer in every phase of the maritime industry (Ibrahim, 2022). The specialized security personnel should encompass a wide range of knowledge and training as specified in the ISPS Code; the emphasis on traditional tabletop simulations for MET fails to leverage advanced technological methods for the practical readiness (Kim et al., 2023). Despite the extensive training requirements outlined, covering security administration, legislation, emergency preparedness, and more, the Code's reliance on drills and exercises—typically conducted through tabletop simulations—reveal a limited integration of computerized simulation techniques within some maritime institutes. The Code stresses the importance of security exercises, but the lack of utilization of more advanced, immersive simulation techniques could disable the comprehensive preparedness and practical experience necessary to effectively manage and respond to immediate security threats in the maritime sector. Fig. 1 shows the traditional "Tabletop Simulation" layout parties for MET as the minimum requirement of the ISPS code.

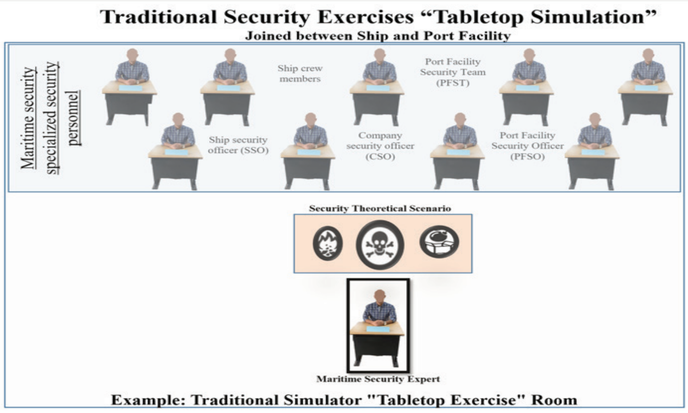

Fig. 1. The traditional security exercise "tabletop simulation".
Source: Author

Unforcefully, when it is utilized as "tabletop simulation", it is still conducted by the majority of MET providers with theoretical demonstration methods without the benefit of computerized simulation techniques. Nevertheless, demonstrations for the roles, responsibilities, and activities during the tabletop simulation scenarios for a security exercise most of the time during pandemics were conducted theoretically with a very rare reliance on the use of technological means to train the joint elements, especially considering that they are in charge of preparing for and fending off security threats. As a result, this would impact the effectiveness and efficacy of MET for the capacity-building of security specialists and would increase the security coordination gaps, for example, while implementing the Declaration Of Security (DOS). Fig. 2 shows the flow of information between the concerned parties when implementing the security levels. The DOS process establishes communication and coordination between a ship and a port facility or a ship and another ship to ensure security measures are aligned and implemented effectively.

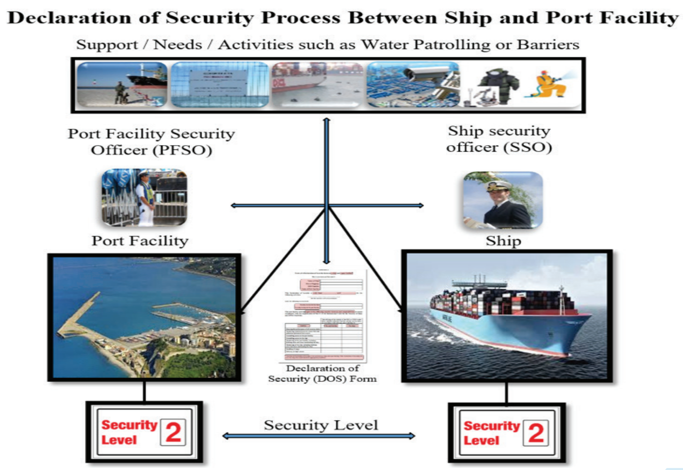

Fig. 2. The completion of the DOS between a ship and a port facility.
Source: Author

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COMPUTERIZED SIMULATION TECHNIQUES

Utilizing simulators or engaging in practical training stands as one of the most effective approaches to acquiring experience, competencies, and essential skills within the maritime industry (Hjellvik and Mallam, 2023). Bridge simulators as examples designed realistically represent safety-simulated scenarios covering watchkeeping, collision avoidance, and other safety concerns. These simulators have found extensive use in practical training for seafarers (Wiig et al., 2023). However, these levels of computerized simulation techniques rarely combine or adapt security scenarios. The integration of computerized simulation techniques within security exercises, especially tabletop simulations, as outlined in the ISPS Code, leads to the potential benefits that could revolutionize the efficiency of MET. By utilizing computerized simulations, participants could experience realistic scenarios of security threats, such as cyber threats or piracy, enabling a more immersive and practical learning environment. This technology would bridge the gap between theoretical knowledge and practical application, offering a dynamic platform to test and adapt responses to various security challenges in the maritime sector (Longo et al., 2023). It would also provide hands-on experience to develop and refine security protocols, potentially leading to more competent and well-prepared responses to real-time security incidents within port facilities or onboard ships. Computerized simulation techniques stand as a pivotal asset in augmenting the capacity-building of security personnel across various industries. By replicating realistic scenarios, they offer an environment for personnel to practice responses to complex security challenges, fostering experiential learning that significantly enhances their capabilities. This allows individuals to learn from mistakes in a risk-free setting, promoting a culture of continual improvement and refining their skills without real-world ramifications (Hjellvik and Mallam, 2023; Longo et al., 2023). The customization capacity of these simulations allows industries to tailor scenarios, directly addressing specific security concerns and ensuring that training is precise and relevant to their field (Baldauf et al., 2016).

Incorporating computerized simulation techniques into security exercises, specifically tabletop simulations following ISPS procedures brings several additional benefits. It allows for the exploration of a wide range of dynamic security scenarios, creating a safe environment for testing response strategies to unforeseen maritime security threats and vulnerabilities (Bueger, 2015; Doolani et al., 2020). This approach also enables the monitoring and assessment of the performance of specialized maritime security personnel in computerized high-risk security scenarios, facilitating targeted improvements and ongoing training refinement while receiving feedback (Bueger et al., 2020; Paro et al., 2022). The interactive nature of these computerized simulations utilizing immersive technologies allows for a comprehensive evaluation of the performance of maritime security specialists participating in the security exercise. These tools collect extensive data during exercises, enabling in-depth assessments of each participant's responses and strategies. This data-driven approach, which offers a detailed understanding of individual strengths and weaknesses, could pave the way for tailored training programs that address identified gaps and enhance competencies effectively (Hilfert and König, 2016; Hjellvik and Mallam, 2023; Vukelic et al., 2023; Yin et al., 2021).

Furthermore, it encourages collaboration between the centers of maritime security responsibility, whether onshore or on board the ship, as various stakeholders within the maritime industry can participate in these simulations, fostering a more comprehensive and cohesive response network within a renovated smart maritime industry (Hjellvik and Mallam, 2023). Therefore, these simulations can significantly enhance the adaptability and readiness of the maritime security specialized personnel, thereby better preparing them to handle the complexities of modern security challenges effectively (Barrionuevo et al., 2021; Felsenstein et al., 2013). An additional advantage lies in the adaptability and currency of these simulations. They can be easily updated to reflect emerging security threats and changes in the smart maritime industry.

DISCUSSION

The conventional security "tabletop exercise" approach, while foundational to some extent in some cases as stated also in the ISPS code, exhibits gaps and limitations in the rehabilitation of the security specialized personnel at various levels within the maritime industry (Arof and Khadzi, 2018; Vukelic et al., 2023). For instance, in preparing for the multifaceted risks faced in the maritime industry in dealing with cyber threats, the tabletop exercise might discuss protocols theoretically, but a computerized simulation can immerse participants in realistic cyber breach scenarios. In the case of piracy or armed robbery, a tabletop exercise might simulate the situation verbally, whereas a computerized simulation could mimic real-time scenarios, offering practical insights into response strategies by utilizing immersive technologies as shown in Table I including Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Extended Reality (XR), Artificial Intelligence (AI), Metaverse, Haptic Feedback Systems, Wearable Technology, 3D Modeling and Visualization, Gesture Recognition, Biometric Recognition and Hologram

Lighting (Doolani et al., 2020; Felsenstein et al., 2013; Hajjami and Park, 2023; Kim et al., 2023; Laera et al., 2023; Paro et al., 2022; Vukelic et al., 2023). The tabletop exercise limitations lie in its theoretical and discussion-based nature, whereas computerized simulations bridge these gaps by providing immersive, practical experiences for a more comprehensive understanding and response preparedness to diverse risks.

Computerized simulation techniques utilizing immersive technologies could replicate various maritime scenarios settings, such as different types of ships, port facilities, and complex infrastructures, offering a diverse range of security exercise environments for renovated "tabletop simulation". This exposure prepares security teams for a wide array of potential security challenges (Felsenstein et al., 2013). These technologies enable trainees to learn and practice security protocols in a risk-free environment (Hjellvik and Mallam, 2023; Longo et al., 2023). They can make mistakes, learn from them, and refine their responses without exposing actual maritime security. This helps in preparing security personnel for rare but critical situations (Felsenstein et al., 2013) and immersive technologies contribute to heightened practical training experiences for maritime security specialized personnel. Additionally, computerized simulation techniques facilitate repetitive training sessions, allowing maritime security specialized personnel to practice scenarios multiple times, improving response times, decision-making skills, and overall preparedness without real-world limitations creating more engaging and interactive training sessions, enhancing the learning experience. Table I shows an integration of computerized simulation techniques of immersive technologies possibilities that could revolutionize the maritime security exercise as per the ISPS code requirements in several ways.

Table I: The Benefits of Immersive Simulation Techniques for Security Exercise

Immersive Technology	Benefits for Security Exercise
Virtual Reality (VR)	Offers realistic, immersive simulations of maritime security exercise scenarios. Provides a practical, interactive experience for the security-specialized personnel.
Augmented Reality (AR)	Overlays virtual elements onto real-world environments, enhancing situational awareness and security exercise within authentic settings.
Mixed Reality (MR)	Merges real and virtual environments, allowing security-specialized personnel to interact with and manipulate virtual objects within their physical surroundings during the security exercise.
Extended Reality (XR)	Encompasses VR and AR, creating a more immersive and interactive security exercise experience by blending real and virtual worlds.
Artificial Intelligence (AI)	Enables dynamic and adaptive security simulations that respond to participants' actions during the exercise, providing personalized challenges and learning experiences.
Metaverse	Revolutionizes training through interconnected, persistent digital environments, allowing collaborative and comprehensive security exercises in a highly interactive, expansive digital space.
Haptic Feedback Systems	Provides tactile sensations for a more realistic simulation experience, enhancing muscle memory and physical skill development.
Wearable Technology	Integrates devices like smart glasses or smartwatches to provide real-time information, enhancing situational awareness and decision-making.
3D Modeling and Visualization	Offers detailed 3D models for in-depth exploration of ship and port facility security layout, aiding in comprehensive understanding and planning during security exercises.
Gesture Recognition	Allows participants to interact with simulations through hand and body signals, providing a more natural and intuitive training experience.
Biometric Recognition	Utilizes biometric data for security access training, enhancing understanding and protocols related to identity verification and security procedures.
Hologram Lighting	Augments the security exercise environment by projecting holographic images, enhancing visualization and understanding of complex maritime structures and security layouts.

Source: Author

Adaptability of Computerized Simulations

Leveraging immersive technologies is exemplified through the integration of AR and gesture recognition systems, incorporating head-mounted devices and sensors worn on the hands of security specialized personnel. These devices, coupled with augmented software, are specifically tailored for constructing security scenarios, such as addressing suspicious objects on ships or within port facilities. The design of these scenarios involves the use of programs that seamlessly integrate them into AR, simulating the actual physical environment for security-specialized personnel. This immersive approach aims to enhance their abilities and skills, enabling them to comprehend and manage potential risks effectively. The milestones of implementing the security exercise simulator, illustrated in Fig. 3 and Table II for the 5C action application, exemplify the practical application of this technology, particularly in scenarios involving the combating of suspicious objects. Moreover, educational institutes with bridge simulators can take the initiative by integrating hologram lighting to display suspicious objects for specialized security personnel. This integration allows for the explanation of scenarios on dealing with such objects, seamlessly merging with safety-specialized simulators and implementing the procedures of the 5C Action application. The transformative influence of computerized simulation techniques on maritime security exercises emphasizes the significant opportunities presented by these immersive technologies.

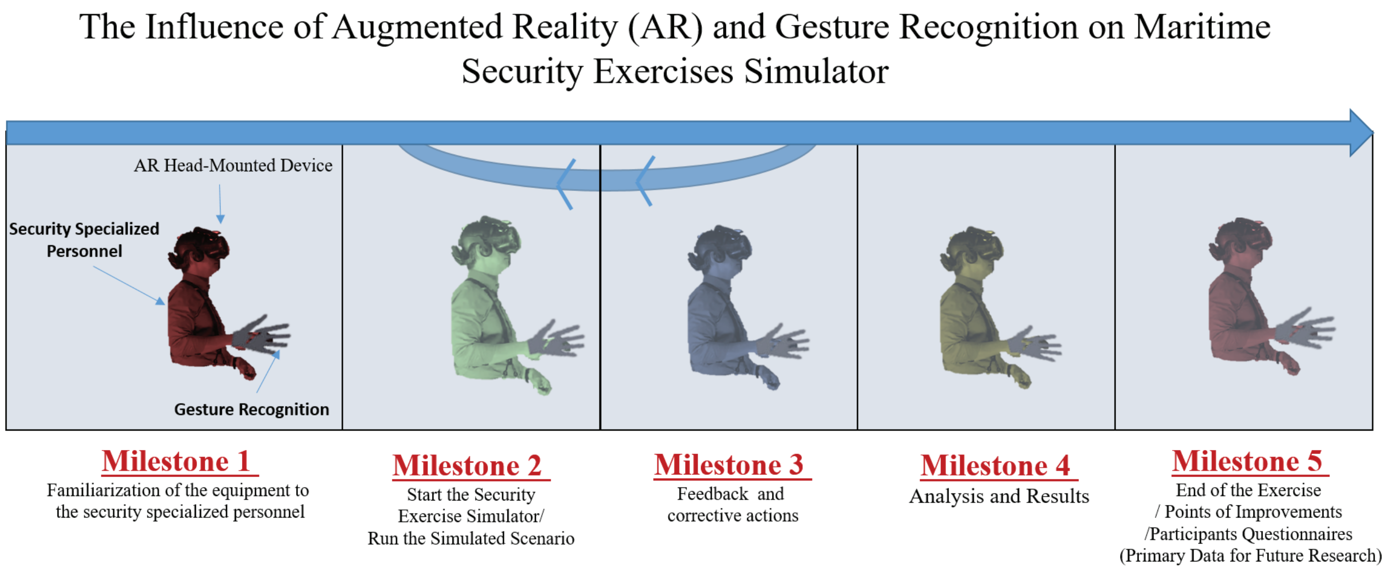

Fig. 3. The milestones of implementing the security exercise simulator
Source: Author

Table II: The 5C Action Application Combating Suspicious Objects

Action	Action Application
Confirm	Confirming the existence and nature of the suspicious object onboard the simulated ship/port facility
Communicate	Effective communication is vital during security incidents. This step involves notifying relevant authorities, such as the ship's security officer, port authorities, or support bodies (e.g. bomb squad).
Clear	Once the suspicious object is confirmed, the area is cleared. Evacuation procedures are implemented based on the simulated scenario for the ship or port facility (master station or shore assembly point).
Cordon	Creating a cordon around a suspicious object typically refers to establishing a secure perimeter or restricted area around the object, especially in scenarios where there is a potential threat or danger. The cordon serves to control access, contain the situation, and prevent unauthorized individuals from entering the area.
Control	This includes collaboration control between designated security personnel, authorities, and any additional resources required for a comprehensive response to deter the risk of the suspicious object.

Source: Author

The advent of computerized simulation techniques by implementing one or a combination of these immersive technologies within computerized simulation tabletop security exercises could significantly enhance the quality, depth, and breadth of security exercises more than the conventional "Tabletop Exercise" approach in the maritime industry, better preparing maritime security specialized personnel to handle a wide range of potential security threats and challenges.

CONCLUSION

Computerized simulation techniques utilizing immersive technologies in maritime security exercises may offer immersive benefits and practical experiences that better prepare maritime security personnel for multifaceted risks, such as cyber threats, piracy, and armed robbery, providing a more comprehensive understanding and response preparedness. These simulations replicate diverse maritime settings, allowing for exposure to various security challenges and the opportunity to practice risk-free, refining responses, decision-making skills, and immediate feedback. Additionally, they offer repetitive training sessions, improving overall preparedness without real-world limitations, resulting in engaging and interactive learning experiences.

The adaptability of computerized simulations ensures that security exercises for the port facility, the ship, or both remain relevant despite external factors like pandemics, while also facilitating remote training and multi-agency participation, fostering knowledge sharing among diverse locations and organizations. These techniques align with joint projects such as the GMP-BoK, fortifying stakeholders and seafarers in cognitive, affective, and psychomotor domains, crucial for their development. Furthermore, the purpose of these simulations, per the ISPS Code, is to ensure security personnel's proficiency in adhering to security incident standards and prompt response, enabling them to recognize and address any security concerns effectively. These technologies standardize training programs, ensuring consistent and comprehensive instruction for security personnel across various maritime facilities. The integration of one of the immersive computerized simulation techniques could significantly improve the preparedness and effectiveness of maritime security-specialized personnel in addressing security challenges within the smart maritime sector.

REFERENCES

Afenyo, M. and Caesar, L.D. (2023) 'Maritime cybersecurity threats: Gaps and directions for future research', *Ocean and Coastal Management*. Available at: https://doi.org/10.1016/j.ocecoaman.2023.106493.

Arof, A.M. and Khadzi, A.F.A. (2018) 'A Delphi study to identify important factors for determining the level of adherence to ISPS Code implementation', *International Journal of Supply Chain Management*, 7(4).

Baldauf, M., Dalaklis, D. and Kataria, A. (2016) 'TEAM TRAINING IN SAFETY AND SECURITY VIA SIMULATION: A PRACTICAL DIMENSION OF MARITIME EDUCATION AND TRAINING', in *INTED2016 Proceedings*. Available at: https://doi.org/10.21125/inted.2016.0983.

Barrionuevo, O., Guarda, T. and Victor, J.A. (2022) 'Impact of the Use of Simulators on Training and Specialization in the Navy', in *Smart Innovation, Systems and Technologies*. Available at: https://doi.org/10.1007/978-981-16-4884-7_14.

Bueger, C. (2015) 'What is maritime security?', *Marine Policy*, 53. Available at: https://doi.org/10.1016/j.marpol.2014.12.005.

Bueger, C., Edmunds, T. and McCabe, R. (2020) 'Into the sea: capacity-building innovations and the maritime security challenge', *Third World Quarterly*, 41(2). Available at: https://doi.org/10.1080/01436597.2019.1660632.

Cicek, K., Akyuz, E. and Celik, M. (2019) 'Future Skills Requirements Analysis in Maritime Industry', in *Procedia Computer Science*. Available at: https://doi.org/10.1016/j.procs.2019.09.051.

Dalaklis, D. (2017) 'Safety and Security in Shipping Operations', in. Available at: https://doi.org/10.1007/978-3-319-62365-8_9.

Dewan, M.H. *et al.* (2023) 'Immersive and Non-Immersive Simulators for the Education and Training in Maritime Domain—A Review', *Journal of Marine Science and Engineering*, 11(1). Available at: https://doi.org/10.3390/jmse11010147.

Doolani, S. *et al.* (2020) 'A Review of Extended Reality

(XR) Technologies for Manufacturing Training', *Technologies*, 8(4). Available at: https://doi.org/10.3390/technologies8040077.

Erstad, E. *et al.* (2023) 'A human-centred design approach for the development and conducting of maritime cyber resilience training', *WMU Journal of Maritime Affairs*, 22(2). Available at: https://doi.org/10.1007/s13437-023-00304-7.

Ben Farah, M.A. *et al.* (2022) 'Cyber Security in the Maritime Industry: A Systematic Survey of Recent Advances and Future Trends', *Information (Switzerland)*. Available at: https://doi.org/10.3390/info13010022.

Felsenstein, C., Benedict, K. and Baldauf, M. (2013) 'Maritime Safety and Security Challenges – 3D Simulation Based Training', *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 7(3). Available at: https://doi.org/10.12716/1001.07.03.02.

Hajjami, O. and Park, S. (2023) 'Using the metaverse in training: lessons from real cases', *European Journal of Training and Development* [Preprint]. Available at: https://doi.org/10.1108/EJTD-12-2022-0144.

Hilfert, T. and König, M. (2016) 'Low-cost virtual reality environment for engineering and construction', *Visualization in Engineering*, 4(1). Available at: https://doi.org/10.1186/s40327-015-0031-5.

Hjellvik, S. and Mallam, S. (2023) 'Integrating motivated goal achievement in maritime simulator training', *WMU Journal of Maritime Affairs*, 22(2). Available at: https://doi.org/10.1007/s13437-023-00309-2.

IAMU (2023) *Development of a VR Training Video Database*.

Ibrahim, A.M. (2022) 'The impact of neurotechnology on maritime port security—hypothetical port', *Journal of Transportation Security*. Available at: https://doi.org/10.1007/s12198-022-00253-x.

IMO (2002) 'International Ship and Port Facility Security Code and SOLAS Amendments ', in *nternational Maritime Organization*.

Kim, J. *et al.* (2023) 'Identifying Optimal Approaches for Sustainable Maritime Education and Training: Addressing Technological, Environmental, and Epidemiological Challenges', *Sustainability (Switzerland)*, 15(10). Available at: https://doi.org/10.3390/su15108092.

Kim, T. eun *et al.* (2021) 'The continuum of simulator-based maritime training and education', *WMU Journal of Maritime Affairs*, 20(2). Available at: https://doi.org/10.1007/s13437-021-00242-2.

Laera, F. *et al.* (2023) 'Evaluating an augmented reality interface for sailing navigation: a comparative study with a immersive virtual reality simulator', *Virtual Reality*, 27(2). Available at: https://doi.org/10.1007/s10055-022-00706-7.

Longo, G. *et al.* (2023) 'MaCySTe: A virtual testbed for maritime cybersecurity', *SoftwareX*, 23. Available at: https://doi.org/10.1016/j.softx.2023.101426.

Lun, Y.V., L.K.-H., C.T.E.& Y.D. (2023) 'Shipping Security and Safety', *Shipping and Logistics Management. Springer* [Preprint].

Mallam, S.C., Nazir, S. and Renganayagalu, S.K. (2019) 'Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies', *Journal of Marine Science and Engineering*. Available at: https://doi.org/10.3390/JMSE7120428.

Pagán, J.I. *et al.* (2016) 'The influence of anthropic actions on the evolution of an urban beach: Case study of Marineta Cassiana beach, Spain', *Science of the Total Environment*, 559. Available at: https://doi.org/10.1016/j.scitotenv.2016.03.134.

Paro, M.R., Hersh, D.S. and Bulsara, K.R. (2022) 'History of Virtual Reality and Augmented Reality in Neurosurgical Training', *World Neurosurgery*. Available at: https://doi.org/10.1016/j.wneu.2022.08.042.

Ringsberg, A.H. and Cole, S. (2020) 'Maritime security guidelines: a study of Swedish ports' perceived barriers to compliance', *Maritime Policy and Management*, 47(3). Available at: https://doi.org/10.1080/03088839.2020.1711977.

Szwed, P. and Benton, G. (2022) 'Helping Accelerate the Global Maritime Professional Body of

Knowledge up the S-Curve of Innovation', in *Proceedings of the International Association of Maritime Universities Conference*.

Tam, K. and Jones, K.D. (2018) 'Maritime cybersecurity policy: the scope and impact of evolving technology on international shipping', *Journal of Cyber Policy*, 3(2). Available at: https://doi.org/10.1080/23738871.2018.1513053.

Tijan, E. *et al.* (2021) 'Digital transformation in the maritime transport sector', *Technological Forecasting and Social Change*, 170. Available at: https://doi.org/10.1016/j.techfore.2021.120879.

Unclos (2023) *United Nations Convention on the Law of the Sea*, *Official UN site*.

Vukelic, G. *et al.* (2023) 'Application of VR Technology for Maritime Firefighting and Evacuation Training—A Review', *Journal of Marine Science and Engineering*. Available at: https://doi.org/10.3390/jmse11091732.

Wiig, A.C., Sellberg, C. and Solberg, M. (2023) 'Reviewing simulator-based training and assessment in maritime education: a topic modelling approach for tracing conceptual developments', *WMU Journal of Maritime Affairs*, 22(2). Available at: https://doi.org/10.1007/s13437-023-00307-4.

Yin, R. *et al.* (2021) 'Wearable Sensors-Enabled Human–Machine Interaction Systems: From Design to Application', *Advanced Functional Materials*. Available at: https://doi.org/10.1002/adfm.202008936.

The Potential Implications of the Designation of the Mediterranean Sea as an Emission Control Area (ECA) on the Competitiveness of the Suez Canal

Mohamed Nabil Bahriz

College of Maritime Transport and Technology
Arab Academy for Science, Technology & Maritime Transport
Alexandria, Egypt.

Email: m_nabawy@aast.edu

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ABSTRACT

Purpose: *The Suez Canal, an essential maritime corridor, is poised for a transformative change with the upcoming designation of the Mediterranean Sea as an Emission Control Area (ECA) in 2025. Even though maritime transport is one of the least polluting modes in terms of greenhouse gas emissions, it is now under increased regulatory scrutiny, especially from the International Maritime Organization (IMO), which is imposing stringent emission reduction standards. These regulations, although environmentally driven, may influence the shipping industry's cost dynamics and its preference for sea born transportation routes. This research addresses three pivotal questions: Will the inception of the ECA impact the income volume through the Suez Canal? What are the chances that shipping lines might opt for alternative maritime routes? And how will these factors together influence the Suez Canal's competitive edge? This paper seeks to delve into the potential ramifications of ECA regulations on the competitive perspective of the Suez Canal versus the Cape of Good Hope route.*

Design/Methodology/Approach: *The methodology amalgamates a comprehensive cost comparison with an extensive literature review.*

Findings:

1. *Competitive Advantage of Suez Canal Route: The Suez Canal route, despite the application of ECA regulations and the associated use of pricier VLSFO fuel in the Mediterranean Sea, remains economically competitive. As stated in Table (5), the total costs for the Suez Canal route amount to approximately $1,195,139.6, which is extensively less than the Cape of Good Hope route's costs of about $1,455,531.32, resulting in savings of approximately $260,391.72.*
2. *Time Efficiency: The Suez Canal route offers a significant time advantage, approximately saving around 14 days of transit compared to the Cape of Good Hope route. This shorter transit duration further underscores its economic attractiveness, especially for shipping operators dealing with time-sensitive cargoes.*
3. *Impact of ECA Regulations: The introduction of ECA regulations in the Mediterranean Sea, necessitating the use of VLSFO, has not deterred the financial advantages of the Suez Canal route. Although the Cape route gains from the cheaper IFO380 fuel, the savings from the Suez Canal's shorter distance and the absence of the longer voyage's additional fuel consumption compensate the higher fuel costs associated with ECA regulations.*
4. *Decision Dynamics in the Maritime Industry: Shipping companies face an ongoing challenge in decision-making, having to constantly weigh fuel costs, time efficiency, and applicable tolls. The current research emphasizes that, despite the looming regulatory changes, the Suez Canal's economic and time benefits position it as an attractive option in global maritime trade.*

Key-words:
Emission, Greenhouse, Suez Canal, Alternative Route, cost, competitiveness.

1. INTRODUCTION

Maritime shipping is indispensable to global trade, yet its contribution to Greenhouse Gas (GHG) emissions is substantial. According to the International Maritime Organization (IMO, 2014), the industry was responsible for about 2.2% of global CO_2 emissions in 2012. Without effective mitigation measures, such emissions from the sector are projected to rise by up to 250% by 2050 (IMO, 2018). Recognizing the gravity of the situation, a significant regulatory adjustment was made in 2021, where sulfur limits for Non-Emission Control Areas (Non-ECAs) were markedly reduced from 3.5% to 0.5%. This move epitomizes the industry's responsiveness and commitment to curbing environmental impact.

The IMO has taken practical measures to address maritime shipping emissions and reduce their environmental impact. The IMO's initial strategy, adopted in 2018, sets ambitious goals for the shipping industry, including a target to reduce total annual GHG emissions by at least 50% by 2050 compared to 2008 levels (IMO, 2018). To achieve these targets, the IMO has implemented various measures as outlined in MARPOL Annex VI. Among these strategies, a key initiative has been the establishment of Emission Control Areas (ECAs); ECAs are specific regions where stricter emission standards are applied to vessels, targeting pollutants such as sulfur oxide (SOx), nitrogen oxide (NOx), and particulate matter (IMO, 2020). The primary objective of ECAs is to mitigate the environmental impact of shipping activities and enhance air quality in coastal areas and sensitive ecosystems.

The designation of the Mediterranean Sea as an ECA for Sulphur Oxides and Particulate Matter presents both challenges and opportunities for the maritime industry, particularly concerning the Suez Canal, a crucial strategic route. Starting from 1 May 2025, vessels transiting the Mediterranean will be mandated to use fuel oil with Sulphur content limit of 0.10% m/m, a significant reduction from the 0.50% m/m enforced outside ECAs. While this move ensures enhanced environmental protection and cleaner air for Mediterranean coastal populations, it could also have profound economic implications for the Suez Canal.

Given the Suez Canal's proximity and its role as a pivotal transit point for vessels navigating the Mediterranean, ship operators might encounter elevated operational costs due to the stricter fuel requirements. This change could make alternative routes, such as the Cape of Good Hope, more appealing, especially if they do not necessitate the same stringent fuel standards. However, the Suez Canal's advantage of reduced sailing time remains, and the canal's competitiveness might hinge on balancing these time efficiencies against the new fuel-associated costs.

With the Mediterranean now joining other ECAs like the Baltic Sea, North Sea, and North USA coastal areas, global maritime stakeholders are witnessing a clear trajectory towards sustainable shipping. For the Suez Canal Authority, this underscores the necessity to strategize and adapt, ensuring that the canal remains an attractive choice amidst evolving environmental regulations and shifting economic dynamics.

The purpose of this study is to evaluate the economic consequences of designating the Mediterranean Sea, encompassing the Suez Canal, as an ECA. The maritime shipping industry is a notable contributor to global GHG emissions. Consequently, ECAs have been proposed as a strategic measure to restrict these emissions and lessen the maritime sector's environmental footprint. However, the introduction of an ECA in the Mediterranean could precipitate elevated operating expenses for vessels navigating the Suez Canal, potentially making alternative routes more economically attractive. Considering this potential scenario, this research endeavors to address three pivotal inquiries.

The first question investigates whether the existence of an ECA would result in a reduction of income and number of ships passing through the Suez Canal. This analysis considers the higher running costs associated with ECAs in comparison to alternative routes, aiming to determine the potential decrease in trade volume passing through the canal.

The second question explores the probability of shipping lines opting for alternative routes instead of passing through Suez Canal the Suez Canal due to the implementation of an ECA. Factors such as the strictness of ECA regulations, fuel price differentials, and environmental concerns will be assessed to understand the decision-making process of shipping lines.

The third question aims to evaluate the overall impact of ECAs requirements on the competitiveness of the Suez Canal. By integrating the findings from the previous analyses, this research seeks to provide insights into the strategic importance of the canal, potential shifts in shipping routes, and the long-term implications of its market share.

2. LITERATURE REVIEW

The role of the shipping industry in global trade is paramount, with approximately 90% of worldwide goods being transported via maritime routes. Nevertheless, the environmental implications of such extensive operations are significant and pose a considerable challenge (Stopford, 2009). Efforts to moderate the industry's GHG emissions have been undertaken extensively.

The IMO has been at the forefront of initiatives aimed at curbing the shipping industry's GHG emissions. The organization released a detailed study on the industry's emissions as part of its Third IMO GHG Study (IMO, 2014). This comprehensive study confirmed that international shipping is a significant contributor to global GHG emissions, despite being an energy-efficient method of transporting goods. The study suggested that without further action, shipping emissions could rise significantly due to the growth of the world economy and associated demand for maritime transport. This was followed by the release of the Initial IMO Strategy on Reduction of GHG Emissions from Ships, which outlined a comprehensive plan for reducing emissions by half by the mid-century (IMO, 2018). This is a strategic document outlining the IMO's commitment and approach to reducing GHG emissions from ships. The strategy set forth a vision, which confirms IMO's commitment to reducing GHG emissions from international shipping and, as a matter of urgency, to phasing them out as soon as possible. This includes reducing total annual GHG emissions by at least 50% by 2050 compared to 2008, while pursuing efforts to phase them out entirely.

The concept of ECAs is one of the strategies being pursued to combat GHG emissions in the shipping industry. ECAs are defined as sea regions where stricter regulations are implemented to minimize airborne emissions from ships, as dictated by the MARPOL Annex VI regulations (IMO, 2020). Numerous studies have examined the potential economic and environmental impacts of ECAs.

Brynolf, S., Magnusson, M., Fridell, E., & Andersson, K. (2014) explored compliance alternatives for forthcoming ECA regulations on shipping emissions. Examining heavy fuel oil (HFO) with SCR and seawater scrubber, marine gas oil (MGO) with SCR, and liquefied natural gas (LNG), it found all methods reduced impacts on particulate matter, ozone formation, acidification, and terrestrial eutrophication but had minimal effect on climate change. The SCR system curbed NOx emissions, necessitating ammonia slip regulation. While LNG has benefits, unchecked methane slip could negate its environmental advantages. The performance of scrubbers in ships warrants further research, and economic considerations are key in compliance strategy selection.

Cullinane, K., & Bergqvist, R. (2014) discussed emission control areas and their impact on maritime transport. The paper also highlights the significant environmental potential of abatement technologies and alternative fuels in maritime transport within emission control areas (ECAs). Despite the vast scale of maritime shipping, its emission levels remain relatively lower than other transport modes. However, operators face complex decisions regarding the adoption of suitable measures and strategies for compliance. Stricter future ECA regulations might prompt shipping companies to prioritize energy efficiency measures. Furthermore, the importance of designating more areas as ECAs is emphasized, given the socio-economic benefits and challenges of pollution in densely populated regions. The paper also points to the need for additional regulations, particularly addressing concerns like ammonia slip from SCRs and methane slip from LNG engines.

The study of Chang, Y.-T., Park, H. (Kevin), Lee, S., & Kim, E. (2018) analyzed the impact of ECAs regulations on European port efficiency using the SBM Data Envelopment Analysis (DEA) and bootstrapped truncated regression (BTR) models. The findings revealed that ECA regulations could lead to a negative effect on port efficiency. Specifically, ports under ECA regulations experienced an average efficiency decline of 0.058 to 0.066 on a 0-1 scale, representing a 15-18% efficiency loss from their average scores. This research is significant as it pioneers the assessment of ECA regulations' influence on European port efficiency using robust analytical methods.

In the study of Zhang, Q., Liu, H., & Wan, Z. (2022), an investigation into the effectiveness of the Emission Control Area (ECA) policy within four main port cities in the Yangtze River Delta (Shanghai, Suzhou, Ningbo, and Nanjing), yielded heterogeneous results. Using the regression discontinuity (RD) method, the research revealed a notable reduction in SO_2 concentrations due to ECA policy implementation in Shanghai and Suzhou at the 1% significance level. However, in Ningbo and Nanjing, the policy did not statistically impact SO_2 concentrations. These findings underscore the varied effectiveness of the ECA policy across different port cities, emphasizing the need for tailored policy improvements based on regional disparities.

Another study by Jiang, R., & Zhao, L. (2022) on the effects of IMO sulfur limits on the international shipping company's operations, delves into the impact of IMO Sulphur limits on international shipping operations using a game theory perspective. Key findings reveal that ECA regulations compel shipping companies to adjust vessel speeds: when specific conditions hold, vessels sail at maximum speed, rendering the regulations inconsequential to optimal speeds. Conversely, in the presence of heightened transit inventory or fixed costs, companies opt for decreased freight volumes and higher speeds. However, higher fuel prices or diminished efficiency prompt a reduction in both speed and freight volume. The competitive landscape also affects freight volume decisions. These insights stem from detailed mathematical proofs and models assessing operational adjustments in response to regulatory measures.

3. METHODOLOGY

To examine the potential impacts of ECAs on the competitive advantage of the Suez Canal route compared to the Cape of Good Hope route, this research employs a dual methodology: comparative cost analysis and a thorough literature review.

Assumption 1 - Via the Suez Canal Route: The first scenario assumes that the ship sails from the port of Ras Tanura, Saudi Arabia, to the port of Rotterdam, passing through the Suez Canal. This route is traditionally shorter, leading to quicker transit times. The Suez Canal is one of the world's most crucial maritime shortcuts, greatly reducing the journey between Europe and Asia, and thereby making trade faster and often more economical.

Assumption 2 - Via the Cape of Good Hope Route: The second scenario assumes that the ship sails from Ras Tanura to Rotterdam via the Cape of Good Hope route. This route, while longer, can sometimes be more economical, especially during times when Suez Canal tolls are high or when there are potential wait times and delays at the Canal. The Cape route was chosen as an alternative due to its historical significance as a primary maritime route before the Suez Canal's construction and is still relevant today in specific circumstances or considerations.

Firstly, the study gathers comprehensive data on the current global market prices for Very Low Sulfur Fuel Oil (VLSFO) – the fuel type mandated within ECAs – and Intermediate Fuel Oil 380 (IFO380) fuels. This data are sourced from reputable international maritime fuel suppliers and cross-verified with industry reports to ensure maximum accuracy and relevance.

Subsequently, using this data, operational costs for ships using each type of fuel are calculated. This process takes into consideration variables such as the vessel's fuel efficiency, distances travelled, and operational speeds.

Alongside these quantitative analyses, a comprehensive literature review is conducted. This review explores the existing knowledge on the economic viability and environmental implications of ECAs in the maritime shipping industry. This provides a context to the numerical findings reached by the researchers, integrates current knowledge, and identifoes gaps where needed.

When evaluating alternate shipping routes, the extended travel distances, and additional sailing times needed to avoid the Suez Canal and instead use the Cape route are considered. These costs are then examined in light of consideration for specific charter agreements.

For vessels operating under **time charter parties**, opting for the longer route may not yield the anticipated savings from using cost-effective IFO380 fuel. Despite the fuel's lower price, the extended sailing duration could lead to additional fuel consumption and prolonged charter periods, effectively increasing the operational costs borne by the charterer, who typically covers fuel and canal transit fees. On the other hand, for vessels operating under **voyage charter parties**, though the Cape route might initially appear cost-efficient due to fuel consumption savings, any potential savings could be offset by the cumulative costs of the extended journey and the canal fees, both of which are typically borne by the owner and significantly impact the operation cost.

After assessing these factors, a comprehensive comparison will be made to gauge if the benefits of IFO380 fuel savings can truly compensate for the added costs linked to the Cape route's longer travel time and distance.

This combined methodological approach ensures a comprehensive understanding of the economic implications of ECAs, fuel type selection, and routing decisions within the shipping industry. However, it is worth noting potential limitations such as fluctuating fuel prices and variations in ship efficiency rates. These are mitigated by considering a range of potential values in the analysis.

By investigating the economic feasibility of implementing ECAs on the Suez Canal, this study aims to illuminate potential benefits and challenges associated with ECA implementation. The findings of this study can guide policy discussions and decision-making processes related to emissions reduction strategies in the shipping industry, contributing to the broader goal of reducing GHG emissions and mitigating climate change.

4. RESULTS AND ANALYSIS

The focus of this study is a comparative cost analysis aimed at investigating the differential in operating costs when using VLSFO mandated within ECAs, versus the cost of IFO380 fuel. The central objective is to establish whether this cost difference is substantial enough to prompt shipping vessels to alter their navigational routes. Specifically, the study assesses whether vessels would choose to circumvent Suez Canal and instead traverse via the Cape route.

The analysis of route competitiveness in maritime shipping between the Suez Canal and the Cape of Good Hope is complex, influenced by various factors, not least of which is the cost-effectiveness of each route. One of the major elements determining this cost-effectiveness is operational expenses, primarily fuel costs and transit fees. However, these costs are not static. They fluctuate due to various market dynamics and regulatory measures. For the purpose of this study, the researchers target a specific price period and recognize this as a constraint in their analysis.

Table 1 compares the fuel prices (IFO380 and VLSFO) per ton in United States Dollar (USD) at different locations and calculates the average price and percentage difference for each type.

Table 1: Average Fuel Price

Fuel Type	Rotterdam Market Price Per Ton ($)	Fujairah Market Price Per Ton ($)	Singapore Market Price Per Ton ($)	Average Price per ton ($)	Average Percentage Difference (%)
IFO380	448.5	423	435	435.83	27.7%
VLSFO	539	559	572	556.67	

Source: Ship & Bunker

For the purposes of this study, the researchers base their analysis on the voyage of a tanker ship with a of 150,000 DWT, setting sail from Ras Tanura to Rotterdam. The comparative analysis encompasses two potential routes: one via the Suez Canal and the other via the Cape of Good Hope.

Parameters for the Study

- **Ship Specifications**: The ship under consideration for this study is a tanker with a deadweight of 150,000 tons.

- **Sailing Speed**: An average sailing speed of 14 knots is assumed for the voyage.

- **Ras Tanura to Rotterdam (via Suez Canal) total Distance and Segments:** Based on measurements from the electronic chart display and information system (ECDIS) simulator, the overall distance between Ras Tanura and Rotterdam spans 6,467 nautical miles. This encompasses various segments as shown in the Table II, including distances between Ras Tanura and Port Said, Port Said and Gibraltar, Gibraltar to the entrance of the English Channel, and the entrance of the English Channel to Rotterdam.

Table II: Suez Route Segments

Route Segment	ECA (miles)	Non-ECA (miles)
Ras Tanura to Port Said		**3180**
Port Said to Gibraltar	**1980**	
Gibraltar to the Entrance of the English Channel		**930**
Entrance of the English Channel to Rotterdam	**377**	
Total distance	**2357**	**4110**

Source: ECDIS Simulator

- **Ras Tanura to Rotterdam (via Cape route) Total Distance and Segments:** The total journey distance measures approximately 11,169 nautical miles, as indicated in Table III. These measurements are based on calculations from the ECDIS simulator. When consulting the ECA map, it becomes evident that via this route, vessels can predominantly circumvent most of the ECAs, except for the regions of the English Channel and the North Sea.

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Map 1: Showing the global existing and new ECAs
Source: research Gate

Table III: Cape Route Segments

Route Segment	Applying ECA (miles)	Not applying ECA (miles)
Ras Tanura to the entrance of English Channel	10,792	
Entrance of English Channel to Rotterdam		377
Total Distance	10,792	377

Source: ECDIS Simulator

- **Daily Fuel Consumption**: The ship's fuel consumption rate is presumed to be 50 tons per day.

- **Fuel Prices (2023)**: Based on data from the Oil Price Information Service (OPIS, 2023), the average fuel prices used for calculations are $556.67/ton for VLSFO and $435.83/ton for IFO380.

- **Suez Canal Toll**: For the Suez Canal route, a transit fee of $325,000 is considered, based on the toll rates specified for a 150,000 DWT tanker (Suez Canal Authority, 2023).

- **Voyage Running Costs (other than fuel)**: Excluding fuel expenses, the voyage incurs a running cost which amounts to 50% of the total operational costs (Haakon and Lindstad 2013). To facilitate the calculation of running costs, excluding fuel, the researchers assume both routes using IFO380 fuel. Given that fuel expenses represent 50% of the voyage's running costs, the total distance of both routes is considered to estimate the equivalent amount for other operational expenses.

Table IV: Voyage Running Cost Other Than Fuels (Both Routes)

Description	Suez rout	Cape route
Total voyage distance (miles)	6,467	11169
Voyage time by days (SP 14 Knts)	19.25	33.24
Average daily consumption (ton)	50	50
Voyage total fuel consumption (tons)	962.5	1662
Fuel Price ($/ton)	435.85	435.85
Fuel consumption cost of by $	419,505.625	724382.7
Voyage running cost $(other than fuel 50%)	419,505.60	724382.7

Source: Data compiled by the author.

5. RESULTANT COSTS:

In the maritime industry, understanding the breakdown of voyage costs, especially regarding fuel consumption, is crucial for decision-making. One of the most significant expenses for ships is fuel. As highlighted by Stratiotis (2018), fuel costs typically represent about 50% of a ship's total running cost. To better illustrate these dynamics, the tables below provide a comparative analysis of two different routes and their associated expense.

This comparison considers both the distance traveled and the type of fuel utilized, further breaking down costs into fuel expenses and other running costs. The detailed breakdown of Voyage running cost (Suez route), along with other traces of the voyage, can be found in Table V below.

Table V: Voyage Running Cost (Suez route)

Description	Fuel type as per the segmented voyage		Total
	IFO380	VLSFLO	
Distance segmented (miles)	2357	4110	6467
Voyage time by days (SP 14 Knts)	7.02	12.23	19.25
Average daily consumption (ton)	50	50	50

Voyage total fuel consumption (tons)	529.5	433	-
Fuel Price ($/ton)	351	611.5	-
Fuel consumption cost of by $	185,854.5	264,779.5	450,634
Suez Canal Toll $ (for 150,000 DWT tanker)	-	-	325,000
Voyage running cost $(other than fuel 50%)	-	-	419,505.60
Total voyage running costs ($)	-	-	1,195,139.6

Source: Data compiled by the author.

The detailed breakdown of Voyage running cost (Cape route), along with other traces of the voyage, can be found in Table VI below.

Table VI: Voyage Running Cost (Cape route).

Description	Fuel type as per the segmented voyage		Total
	IFO380	VLSFLO	
Distance segmented (miles)	10,792	377	11169
Voyage time by days (SP 14 Knts)	32.12	1.12	33.24
Average daily consumption (ton)	50	50	50
Voyage total fuel consumption (tons)	1606	56	-
Fuel Price ($/ton)	435.85	556.67	-
Fuel consumption cost of by $	699,975.1	31,173.52	731,148.62
Voyage running cost $(other than fuel 50%)	-	-	724382.7
Total voyage running costs ($)	-	-	1,455,531.32

Source: Data compiled by the author.

Both primary maritime routes, the Suez Canal and the Cape of Good Hope, have unique dynamics when it comes to cost and efficiency. Table V provides a detailed breakdown of the costs associated with the Suez Canal route, segmented by fuel type and considering the implications of the ECA regulations. Meanwhile, Table 6 delineates the voyage costs for the Cape of Good Hope route.

Suez Canal Route (as detailed in Table V): Holding the variables constant, the aggregate costs for the journey via the Suez Canal amount to approximately $1,195,139.6. This figure incorporates the significant toll for the Suez Canal, which substantially adds to the overall expenditure.

Cape of Good Hope Route (as illustrated in Table IV): By contrast, the Cape route, which side steps canal tolls and primarily uses the less costly IFO380 fuel, accumulates a total cost of around $1,455,531.32. Even with the benefit of bypassing canal tolls and the more extended journey, this route has a higher cost than its Suez Canal counterpart does by roughly $260,391.72.

Intriguingly, even with the introduction of ECA regulations in the Mediterranean Sea, the Suez Canal route, as outlined in Table V, continues to be a competitive choice from a fiscal perspective. While the Cape route's primary financial advantage hinges on the cheaper IFO380 fuel, the Suez Canal route offers savings, even factoring in the pricier VLSFO due to ECA standards. Combined with its shorter transit duration (around a 14-day saving), the Suez Canal emerges as a highly appealing option for maritime operators, especially those handling time-sensitive cargoes.

In the broader maritime industry context, decisions will be a continued balancing act between assessing fuel costs, time efficiency, and relevant tolls. Notwithstanding the ECA regulations in the Mediterranean, the advantages of cost and time as presented in Table V for the Suez Canal route stand strong, underlining its continued allure and importance in global maritime trade given the current economic and regulatory landscapes.

6. CONCLUSION

In conclusion, this paper aimed to analyze the economic viability of implementing an ECA in Suez Canal, a key strategic route in the maritime shipping industry. Maritime shipping, despite being the least emitter of GHG among transportation modes, is under scrutiny to further reduce emissions due to the increasing volume of goods transported seaborne and the consequential rise in the number of operating vessels.

The advent of ECAs, while serving to minimize GHG emissions, also contributes to an increase in shipping costs due to the necessity of using costlier low-sulfur fuels. This could potentially impact the competitiveness of routes like the Suez Canal that may implement such regulations, given that fuel costs constitute a significant portion of a ship's daily running expenses.

The researchers' analysis, based on publicly available data, indicates that implementing an ECA in the Suez Canal might have implications for the canal's income. The increased costs associated with the utilization of low-sulfur fuels might push shipping companies to consider alternative routes, notably the Cape of Good Hope. Such a shift could potentially alter the Suez Canal's standing as a favored maritime route.

However, route selection in maritime transport involves a careful balancing act, considering not only direct costs but also factors such as transit times, and environmental implications. Consequently, despite the apparent cost-saving benefits of alternative routes, shipping lines must also account for the longer journey times, potential weather risks, and greater ship strain associated with these paths.

As the industry continues to balance environmental responsibility and operational costs, strategies such as fuel-efficient ship designs, alternative fuels, and optimal routing data analytics will likely become increasingly important. This study highlights the intricate balance the maritime industry must strike between environmental responsibilities and economic realities. By analyzing the potential economic ramifications of implementing an ECA in the Suez Canal, the research underscores the significance of proactive planning in response to changing environmental regulations. The ultimate goal is twofold: to assist the maritime sector in lowering GHG emissions, thereby combating climate change, and to provide valuable insights for stakeholders when determining optimal shipping routes in the future.

7. RECOMMENDATIONS

The Suez Canal Authority can pursue several strategies to enhance its environmental sustainability without compromising its competitiveness. These could include:

Potentially revising toll fees: considering adjustments to the current pricing structure for vessels using the canal. Given the tight competition in cost-effectiveness between the Suez Canal and Cape of Good Hope routes.

Investment in Green Technologies: By encouraging and supporting the use of green technologies such as scrubbers or LNG propulsion systems, the Suez Canal can contribute to a reduction in emissions without increasing the cost of passage by applying ECA. For instance, the Authority could offer discounted toll rates for ships that employ these technologies.

Operators explore platforms like ABB's OCTOPUS Marine Software. This application, already utilized by many major shipping companies, offers real-time insights into ship performance, weather conditions, and optimal route planning. By leveraging such technology, startups and existing ship operators can better navigate the challenges of environmental regulations and fuel costs, making informed decisions that are both economically and environmentally sound.

REFERENCES

Ajithkumar, A. and PK, S.B. (2022) 'Applicability of hydrogen fuel cells in shipping for a sustainable future', *Sustainability, Agri, Food and Environmental Research*, 10(1).

Brynolf, S. *et al.* (2014) 'Compliance possibilities for the future ECA regulations through the use of abatement technologies or change of fuels', *Transportation Research Part D: Transport and Environment*, 28. Available at: https://doi.org/10.1016/j.trd.2013.12.001.

Chang, Y.T. *et al.* (2018) 'Have Emission Control Areas (ECAs) harmed port efficiency in Europe?', *Transportation Research Part D: Transport and Environment*, 58. Available at: https://doi.org/10.1016/j.trd.2017.10.018.

IMO (2018) 'MEPC.304(72) - Initial IMO strategy on reduction of GHG emissions from ships', *IMO publication*, 304(April).

IMO (2020) 'Energy efficiency and the reduction of GHG emissions from ships', *Media Centre*, 2020(January).

International Maritime Organization (2014) *Third IMO GHG Study 2014: Executive Summary and Report*.

Jiang, R. and Zhao, L. (2022) 'Effects of IMO sulphur limits on the international shipping company's operations: From a game theory perspective', *Computers and Industrial Engineering*, 173. Available at: https://doi.org/10.1016/j.cie.2022.108707.

Lindstad, H., Jullumstrø, E. and Sandaas, I. (2013) 'Reductions in cost and greenhouse gas emissions with new bulk ship designs enabled by the Panama Canal expansion', *Energy Policy*, 59. Available at: https://doi.org/10.1016/j.enpol.2013.03.046.

Ship & Bunker (2023) *World Bunker Price website*.

Stratiotis, E. (2018) *How Fuel Costs Impact Ocean Shipping*.

'Suez Canal Authority.' (1980) *DREDGING & PORT CONSTR.*, 7(9, Sep. 1980, pp.12, 13, 15, 16, 19, 21, 23 and 25.).

Zhang, Q., Liu, H. and Wan, Z. (2022) 'Evaluation on the effectiveness of ship emission control area policy: Heterogeneity detection with the regression discontinuity method', *Environmental Impact Assessment Review*, 94. Available at: https://doi.org/10.1016/j.eiar.2022.106747.

The Transformative Potential of Artificial Intelligence in the Maritime Transport and its Impact on Port Industry

Hossam Eldin Bakr Abdelsalam[1] and Mohamed Nabil Elnabawi[2]

[1,2]College of Maritime Transport and Technology
Arab Academy for Science, Technology & Maritime Transport
Alexandria, Egypt.

Emails: hossambakr@aast.edu, m_nabawy@aast.edu

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ABSTRACT

Purpose: *Artificial intelligence (AI) has been recognized as a critical force in the maritime industry, transforming port operations to meet the needs of the digital age. A paradigm change is taking place in the marine industry, which is a crucial component of global economic systems and international trade. Ports are leading the way in this transformation, using cutting-edge digital and AI capabilities to introduce a new age of operating strategies that provide improved efficiency, accuracy, and security.*

Approach/Design/Methodology: *Providing a historical summary of AI's evolution since the 1950s, the paper emphasizes its vital role in driving technical innovation and changing marine operations. Considerable attention is devoted to the ethical aspects of AI implementation in marine environments, promoting conscientious and ethical use. The article examines how AI improves marine operations, port, and port operation, in efficiency, accuracy, and security. It also addresses data management, financial issues, and ethical issues related to AI applications. The researchers employed a qualitative research technique to examine the transformative capacities of AI in the maritime industry and its impact on port operations with the support of SWOT Analyses. To gather primary data, a survey was conducted with industry professionals, including port officials, maritime specialists, and providers of AI technology.*

Findings: *This study contributes to a better understanding of the role that AI plays in current marine activities through the SWOT analyses outcomes. The article emphasizes the profound ability of AI to bring about significant changes in port operations through the Positive Aspects as Operational Efficiency, Safety and decision making. It discusses the potential advantages and difficulties associated with AI implementation. The article offers useful insights for industry executives and regulators, underlining the need for strategic and ethical AI integration in maritime port operations.*

Key-words:
Artificial Intelligence, Maritime industry, Port, Port operations

INTRODUCTION

The maritime sector is an essential pillar in international trade and global economic frameworks, currently witnessing a paradigm shift (Dwarakish & Salim, 2015). Ports are at the forefront of this evolution, with state-of-the-art digital and Artificial Intelligence (AI) tools ushering in a new era of operational approaches, promising heightened efficiency, precision, and security (De La Peña Zarzuelo et al., 2020).

AI delves into developing computer mechanisms capable of executing intricate tasks, akin to human abilities, without being explicitly directed. It intertwines algorithms, programming prowess, extensive data acquisition, and advanced tech features to produce systems that evolve and engage with their surroundings, facilitating decision-making and problem resolution (Haenlein & Kaplan, 2019). Given its capacity to simulate human-like thought processes, AI's relevance in the maritime realm is soaring (Haenlein & Kaplan, 2019). AI's footprint in ports encompasses facets like digital linkage, traffic orchestration, automation, and self-regulating apparatus. Consequently, AI platforms are adept at reasoning, problem-solving, and decision-making, making waves in processes like cargo management, navigational frameworks, and upkeep procedures.

However, embedding AI into the fabric of any sector is not without its set of complications. Predicaments range from multifaceted data handling and monetary investments to reservations about AI's dependability and precision (Shaheen, 2021). Simultaneously, moral debates concerning AI's part in decisive actions, data discretion, and potential exploitation emerge (Zhuo et al., 2023). The infusion of AI and automated tools in port mechanisms also beckons a revaluation of labor dynamics, with a spotlight on altered industry skill prerequisites, influencing job prospects and educational trajectories.

To fathom AI's essence and influence in the maritime sphere, a holistic exploration of its current manifestations, advantages, obstacles, and moral repercussions is mandated. This document endeavors to present a thorough scrutiny of these facets, building on established studies and insights.

The primary intent of this exploration is to furnish pivotal knowledge for industry frontrunners, regulatory entities, and scholarly investigators, empowering them with the information to craft judicious choices and sculpt efficacious blueprints for capitalizing on AI within port functionalities.

By securing a well-rounded grasp of how AI molds the maritime domain, stakeholders can devise apt strategies for AI assimilation, confront associated hurdles, and stimulate enlightened policy dialogues. Subsequent sections embark on a literature evaluation, methodological approach, detailed analysis, and actionable suggestions to highlight AI's transformative capacity in modern maritime functions.

LITERATURE REVIEW

The researchers focus on how digitalization and AI are reshaping the maritime industry. The review unfolds in a structured manner, covering key themes from the overall impact of digital advances in maritime transport to the specific roles of Smart Ports and AI in port operations. The researchers tackled challenges and opportunities these technologies bring, including financial and cultural implications. Weaving within different research studies, aiming to fill gaps in current knowledge and highlighting the study with unique contribution to understanding the evolving maritime landscape, with comprehensive view of where the industry stands and where it is heading with these technological advancements.

The concept of AI was introduced in the 1950s (McCarthy et al., 2006). AI is the ability of a machine to mimic intelligent human behavior and perform tasks that require human intelligence. Over the years, AI has experienced periods of excitement and large investments, followed by periods of disappointment and low investments, known as the "AI winter"; however, recent advances in computing power, declining costs of data storage, cloud computing, and the availability of big data have contributed to the resurgence of AI; AI has been used in various areas, including computer vision, natural language processing, and machine learning, and has the potential to have a significant impact on society (Toosi et al., 2020; Marquis et al., 2021; Zhang, 2023).

The maritime domain has experienced significant shifts due to digitalization, profoundly altering maritime transport and industry practices. Enhanced information exchange among stakeholders, refined vessel functioning, and more efficient maintenance protocols have been realized thanks to digital advances. Moreover, the advent of digitalization has provided a boost to cargo tracking and traceability and has streamlined decision-making processes (Babica et al., 2020, De La Peña Zarzuelo et al., 2020; Bentyn, 2023). These enhancements have led to heightened operational efficiency, notable cost reductions, and enhanced safety standards.

For sustained growth and ensuring stable port services, it is imperative that Smart Ports seamlessly embed Internet of Things (IoT) functionalities; while automation trends in maritime settings are on the rise, the sector has not progressed at the pace of its counterparts like aerospace or automotive. Emphasis is now placed on AI, machine learning, and both horizontally and vertically harmonized solutions within advanced ports (De La Peña Zarzuelo et al., 2020; Kougias et al., 2021; Hirata et al., 2022; Noto et al., 2023; Ayoub et al., 2023). Additionally, digital evolution has paved the way for innovations in the maritime sphere, including the exploration of unmanned vessels and the adoption of blockchain techniques for heightened security and clarity. Thanks to digital platforms, real-time route optimization, refined ship functions, and better data acquisition and interpretation have become possible (Babica et al., 2020, De La Peña Zarzuelo et al., 2020; Kougias et al., 2021). Moreover, the digital era has unveiled collaborative opportunities and novel monetization prospects for maritime stakeholders (Babica et al., 2020).

Port functions in the maritime realm have been deeply influenced by digital transformation, introducing benefits like enhanced effectiveness, adaptability, and economic viability (Fruth & Teuteberg, 2017; Haenlein & Kaplan, 2019; Ayoub et al., 2023). By digitizing port operations, processes can be more streamlined, allowing for proficient data handling, superior port operation oversight, and smoother stakeholder communication, culminating in more swift and efficient vessel servicing (Fruth & Teuteberg, 2017; Y. Li et al., 2023; Shaykhulova et al., 2023). Additionally, the digital overhaul has potential in curbing both time and financial constraints by minimizing extensive paperwork and physical labor (Fruth & Teuteberg, 2017; Solmaz, 2021, Tardo et al., 2022; Shaykhulova et al., 2023).

According to studies by Munim et al. (2021), Babica et al. (2019), and Fruth and Teuteberg (2017), while digitalization has assumed paramount importance in port operations, it brings forth challenges. These encompass the demand for secure and efficient data protocols, the absence of consistent regulations, and the imperative for system interoperability.

To navigate these obstacles, ports would be wise to adopt diverse, innovative strategies. Firstly, developing new technologies that are tailored to their specific needs (Nguyen et al., 2023); Secondly, create uniform regulations and standards across the industry, for interoperability and efficiency (Rahman et al., 2023); Thirdly, consider investing in open-source technologies, which are more cost-effective (Clemente et al., 2023); Finally, ports should also strive to create partnerships with other organizations and industry stakeholders for collaboration and knowledge sharing. By using these strategies, ports can ensure that digitalization of maritime port operations is successful and helps to improve overall operational efficiency (Munim et al., 2021).

The evolution of maritime port infrastructures has carved an engaging trajectory that deeply influenced AI's progression. Contemporary research endeavors, as underscored by the works of scholars like Chen et al. (2023), Hirata et al. (2022) and Munim et al. (2020), point out that port advancements have catalyzed the inception of AI through avenues like automation, sophisticated robotics, and intelligent infrastructures. To be precise, the infusion of robotics and automated solutions has ameliorated core port tasks such as efficient cargo maneuvering, stockpile administration, and vessel traffic supervision. This pivotal integration of AI within port systems has bolstered their operational prowess, driving them towards heightened efficiency and economical functionality. Moreover, leveraging AI has granted ports the capability to garner precise and trustable intel about their operations, paving the way for strategy optimization. Undoubtedly, the narrative of maritime port evolution resonates deeply with AI's meteoric ascent, fostering an environment where ports thrive on efficiency and cost-effectiveness.

Transitioning to a digital framework within maritime transport is not devoid of hurdles. Priadi (2022) underscores that this digital metamorphosis in maritime logistics necessitates a substantial financial commitment. Initial outlays for requisite hardware, software, allied services, and personnel training could be daunting for certain enterprises. Further complicating this transition is the imperative demand for robust data protection and safeguarding proprietary business intelligence, hindering many from wholeheartedly embracing digitalization. Additionally, the lack of seamless interaction among diverse platforms and systems might stifle digital integration. Coupled with the substantial upkeep costs of these digital systems, especially under constrained fiscal allocations, it is apparent that digitalizing maritime avenues demands both immense commitment and capital infusion, as articulated by Priadi (2022).

In their exploration, Zerbino et al. (2019) delve into the cultural intricacies linked with knowledge handling in ports enhanced by Port Community Systems (PCS). They posit that superimposing PCS onto ports ushers in a distinct array of cultural nuances demanding attention for successful fruition. Introduction of avant-garde tech can inadvertently convolute pre-existing operational dynamics, potentially culminating in coordination lapses and communication disparities amongst the workforces.

Highlighting a case study centered on the Mediterranean port, Zerbino et al. (2019) illustrated how refined analytics can empower professionals to distill pivotal insights, eventually shaping strategies to condense docking durations and uplift port competence. Such implementations bear paramount importance, especially for Mediterranean harbors grappling with escalating vessel counts and their expanding dimensions. This analytical prowess furnishes a paradigm for peers to replicate, affirming the premise that maritime logistics can witness leaps in efficiency through analytical applications.

The maritime arena is witnessing transformative strides due to Big Data and AI, as elaborated by Kougias et al. (2021). Their in-depth examination elucidates the role of these technologies in amplifying maritime efficiency, safety, and profitability metrics. For instance, harnessing Big Data and AI facilitates a deep dive into sensor data from ship hulls, preemptively identifying and neutralizing potential glitches. Furthermore, AI serves as a beacon, enhancing navigation, optimizing operations, and bolstering safety through instantaneous environmental analytics and risk forecasts.

The bibliometric scrutiny of Big Data and AI within maritime domains elucidates their multifaceted applications and the burgeoning academic fascination. This exploration accentuates the exigency to concentrate investigative and developmental zeal on leveraging these groundbreaking tech avenues, propelling the maritime industry to harness their expansive potential optimally. Additionally, as the industry continues to evolve, future research should also focus on the potential impacts of these technologies on safety, efficiency, and compliance related aspects in the maritime industry (Munim et al., 2020).

The literature presents a contrast between the promising benefits of digitalization and AI in maritime operations and the significant challenges they bring. It balances the perspectives of technological advancement and efficiency with the complexities of financial and cultural integration. The review identifies a gap in research related to the long-term cultural and financial impacts of AI and digitalization in maritime operations. It also highlights the need for more focused studies on the implications of AI for safety, efficiency, and compliance in the maritime sector.

This paper contributes to literature by offering a holistic view of the advancements and challenges in the implementation of AI and digital technologies in maritime ports. It extends the understanding of AI's role in this sector, emphasizing the need for strategic and ethical considerations in its deployment. This review not only synthesizes existing research but also identifies areas for future exploration and underscores the importance of a balanced approach to technological integration in maritime operations.

METHODOLOGY

In this research, the researchers employed a qualitative approach, using a structured survey to explore the transformative potential of AI in the maritime industry and its impact on port operations. This survey, conducted over a period of three months, targeted a range of industry professionals, including port authorities, maritime experts, and AI technology providers. The aim was to engage with these experts to gain in-depth insights into the current use of AI, the challenges encountered, and potential future implications, leading to a comprehensive SWOT analysis.

Participants of the survey were carefully selected using a purposive sampling method[1], ensuring a diverse representation of stakeholders within the industry. This included a balanced mix of professionals from various sectors and levels of expertise, aiming for a sample size of approximately 100 respondents to provide a broad perspective.

Secondary data were also gathered from academic journals, industry reports, and relevant publications to supplement the survey responses. This data served as a foundation for understanding existing knowledge and research on AI in the maritime sector. For analyzing the qualitative data from the survey, thematic analysis was employed, systematically organizing and categorizing responses to identify key themes and patterns. Descriptive statistics were used to quantitatively analyze the survey data, presenting an overview of

1 Purposive sampling encompasses a collection of non-probability sampling methods wherein units are deliberately chosen based on their possession of specific characteristics deemed necessary for inclusion in the sample. Purposive sampling involves the deliberate selection of units for specific reasons.

the participants' perspectives.

Throughout this study, researchers maintained strict adherence to ethical standards, ensuring informed consent from participants and confidentiality of their responses. Researchers recognize potential limitations such as participant availability and subjective interpretation of qualitative data. Despite these, researchers are committed to rigorously conducting this study, aiming to significantly contribute to the knowledge base on AI in the maritime industry.

The SWOT framework is a universally accepted and effective instrument in strategic delineation. It offers a blueprint for evaluating both internal and external dynamics that might notably determine the success of a venture, enterprise, or plan. Undertaking a SWOT analysis tailored to AI's role in maritime port functions allows the researchers to accomplish the following:

- Identify Strengths: By exploring the advantages and benefits that AI brings to the maritime industry, which can gain a deeper understanding of why it is crucial for future development (Ceyhun, 2019).

- Recognize Weaknesses: By highlighting the limitations or challenges associated with implementing AI technology in the maritime setting that can take a realistic view of areas that require attention and improvement (Mouzakitis et al., 2022).

- Uncover Opportunities: By discovering potential areas where AI can further contribute to the maritime industry, such as emerging trends or unmet needs, that can capitalize on untapped potential (Ceyhun, 2019; Munim et al., 2020).

- Acknowledge Threats: By examining external challenges or risks that may hinder the successful implementation of AI in maritime operations, which can proactively address and mitigate potential obstacles (Munim et al., 2020).

This extensive SWOT analysis helps make smart decisions and create effective strategies. It helps the researchers enhance strengths, address weaknesses, seize opportunities, and anticipate AI integration into the marine fabric. The SWOT framework is a useful tool for this investigation (Stan & Nedelcu, 2015).

Through these aspects, the SWOT framework provides a clear and comprehensive view of the terrain, encouraging wise decision-making and rigorous blueprinting. It forms a strategic compass to highlight the positives, address the gaps, capitalize on the opportunities, and avoid the risks of integrating AI into maritime and port domains (Stan & Nedelcu, 2015).

ANALYSIS AND RESULTS

According to the methodology followed in this research; SWOT analysis is an appropriate and valuable methodology for this study. Figure 1 presents the main outcomes of the SWOT analyses. Accordingly, researchers delved into a detailed SWOT analysis to explore the strengths, weaknesses, opportunities, and threats associated with AI's role in modern seaport operations.

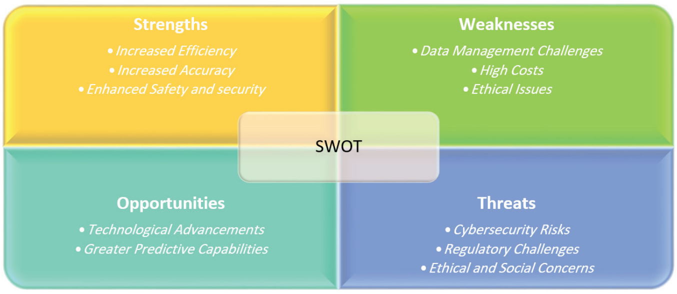

Fig. 1. Main outcomes of the SWOT analysis
Source: Authors

Strengths

1. *Increased Efficiency*: AI provides sophisticated algorithms and machine learning models that can process large amounts of data quickly and accurately, greatly enhancing the efficiency of maritime port operations. Automation, powered by AI, reduces the time needed for tasks such as cargo handling and offers greater precision, minimizing errors.

2. *Increased Accuracy*: AI's predictive capabilities help in forecasting and mitigating potential operational disruptions. Machine learning algorithms learn from data over time, and the more data they process, the more accurate their predictions and decisions become, minimizing the margin for human error.

3. *Enhanced Safety and security:* Real-time analytics offered by AI technologies can detect and predict potential risks in the port and in the maritime environment. By identifying faults or malfunctions early, maritime ports can take necessary precautions to avoid incidence and accidents, thus enhancing safety and security measures.

Weaknesses

1. *Data Management Challenges*: AI systems are dependent on large amounts of data. Managing and ensuring the quality of this data can be challenging. Incorrect or incomplete data can negatively affect the AI system's performance and decision-making capabilities.

2. *High Costs*: Implementing AI technologies requires significant investment in hardware, software, and personnel training. The ongoing maintenance of these systems can also lead to high costs, which may be challenging for smaller ports or those with limited budgets.

3. *Ethical Issues*: As AI systems make more decisions, the ethical implications become more complex. Issues related to privacy, accountability, transparency, and consent can pose serious challenges if not properly addressed.

Opportunities

1. *Technological Progress:* The swift progression in AI tech presents maritime ports with avenues for continuous enhancement in their functionalities and offerings. Breakthroughs in AI, combined with areas like IoT and robotics, stand to redefine the maritime realm.

2. *Enhanced Forecasting Abilities:* The capability of AI to sift through colossal data volumes can unveil essential foresights, facilitating maritime ports to shift from being merely responsive to predictively strategic.

Threats

1. *Digital Security Concerns*: A heightened dependency on digital modalities may heighten vulnerabilities for maritime ports against cyber intrusions. Such jeopardies can imperil the privacy, veracity, and accessibility of systems and information, inducing considerable operational hiccups.

2. *Regulatory Challenges:* The rapid advancement of AI technology can often outpace regulatory frameworks. Compliance with diverse and evolving regulations can pose a significant challenge for maritime ports.

3. *Ethical and Social Concerns:* The wider use of AI in port operations can potentially displace jobs, leading to social implications. Careful management is needed to balance the benefits of automation with the potential social impacts.

In brief, the adoption of AI offers numerous benefits to maritime ports, it is crucial to address the associated weaknesses and threats. A balanced and careful approach, considering all these factors, will be essential to ensure sustainable and ethical application of AI in the maritime industry.

As shown on the chart in Figure 2, the survey data were gathered from 32 stakeholders, each bringing a unique perspective on the implementation and impacts of AI in port operations. The distribution of participants by job role was as follows: Port Managers and Directors, who are pivotal in making strategic decisions regarding AI integration, constituted 19% of the respondents.

AI Technology Providers, essential for insights into the practicalities and technological aspects of AI, represented 16%. Maritime Experts and Consultants, offering a comprehensive view of AI's influence on industry practices, accounted for 22%. Operations Supervisors made up 18%, providing valuable feedback on the day-to-day operational shifts attributed to AI. Logistics and Supply Chain Managers, who shed light on the efficiency and transparency gains in logistics due to AI, formed 10% of the sample. Maintenance or Engineering Managers, critical for discussing the implementation specifics and infrastructure challenges, comprised 9%. The remaining 6% included various professionals such as Environmental Officers, Safety Inspectors, and Financial Analysts, enriching the research with diverse perspectives on the ecological, safety, and economic dimensions of AI in maritime logistics. This calculated assortment of roles ensures a balanced overview of the expectations and real-world implications of AI in the domain of port operations.

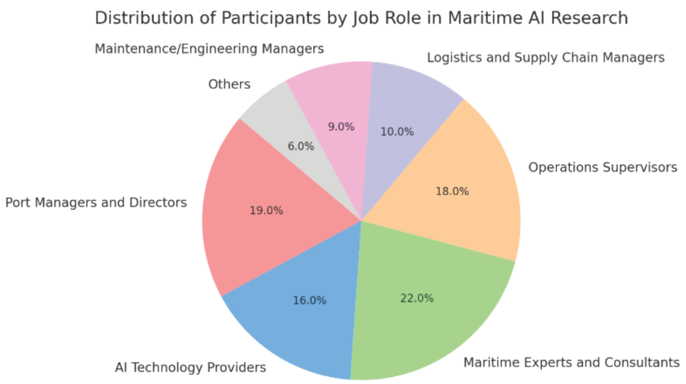

Fig. 2. Distribution of participants by job in maritime AI research
Source: Authors

As shown in Figure 3 and in terms of the benefits of AI in port operations, 25% of the participants recognize increased automation of tasks as a significant advantage. This reveals that 25% of the respondents see the promise of AI in enhancing and refining a variety of processes within the port. Moreover, 37.5% of the respondents identify the enhancement in supply chain clarity as a notable benefit of incorporating AI. This points to the fact that almost 38% of the respondents grasp the significance of employing AI to boost clarity and accountability in the maritime supply chain's product flow.

Also, 18.75% of the respondents view AI's capability to refine ship scheduling and pathing favorably. This suggests that about one in five respondents appreciate AI's potential in streamlining maritime logistics, leading to a spike in overall operational prowess. Approximately 12.5% of the respondents consider the live tracking of port activities as a primary advantage of AI. This points out that around 12% of the respondents understand the importance of AI in offering instantaneous data and facilitating decisions based on this data, ensuring seamless port operations. In conclusion, 6.25% of the respondents see AI's potential in streamlining cargo processing and stock management. This indicates that a minority of the participants, approximately 6%, are aware of AI's ability to optimize these critical aspects of port operations, leading to improved productivity and cost-effectiveness.

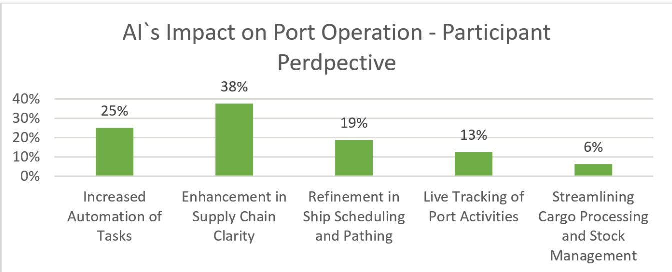

Fig. 3. AI's impact on port operations - participant perspectives
Source: Authors

DISCUSSION AND FINDINGS

Discussion

The continuous digital evolution has driven unprecedented transformations across industries worldwide, and the maritime sector is no exception (Fruth & Teuteberg, 2017). Among the various technologies being introduced, AI holds a particular promise in revolutionizing maritime port operations (Munim et al., 2020).

AI, being a potent technological advancement, has found applications in a broad spectrum of port operations, encompassing areas as vessel arrival schedule and better cargo handling (Lechtenberg et al., 2019), vessel traffic management, and port logistics (Shaheen, 2021). The deployment of AI in these areas has demonstrably enhanced operational efficiency and accuracy (Babica et al., 2020). Additionally, AI's predictive capabilities offer remarkable potential for predictive maintenance, possibly leading to a considerable extension in machinery lifecycle and a subsequent reduction in the operational costs (Zerbino et al., 2019).

However, the incorporation of AI in the maritime industry is not devoid of challenges. For instance, the digitalization of maritime transport operations comes with significant data privacy and security concerns (Kougias et al., 2021). The cost of implementing AI systems is another critical concern, especially for smaller ports with limited resources (Priadi, 2022). Furthermore, there is a significant workforce displacement fear associated with the automation of tasks through AI (Zhuo et al., 2023).

Addressing these challenges requires a balanced approach that factors in the potential benefits while also considering the adverse implications of AI deployment. The industry's need for digital skills calls for substantial investment in training and educational programs to bridge the skill gap. This backdrop sets the stage for a comprehensive understanding of AI's current capabilities, future implications, and how it is shaping the maritime industry.

For validation in the sense of a SWOT analysis, the results of the work were verified and found to be consistent with the literature. Table 1 shows the agreement with the literature.

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Table 1: Compatibility between SWOT Analysis and Sources of Literature

SWOT	Factor	Source	Author
Strengths	Increased Efficiency	Journal of Industrial Information Integration	De La Peña Zarzuelo et al., 2020
		Business Process Management Journal	Wamba-Taguimdje et al., 2020
		Port of Rotterdam Official Website	Port of Rotterdam, 2022
		Port of Los Angeles Official Website	Port Optimizer, 2022
	Increased Accuracy	Journal of Mega Infrastructure & Sustainable Development	Lehmacher et al., 2022
		Science-Open Preprints	Shaheen, 2021
		PTI Blog: Port Machine Learning, AI and IoT. Port Technology International.	Port Technology, 2017
	Enhanced Safety and Security	IntechOpen eBooks	Hirata et al., 2022
		EKOLOJI, 28(107)	Chang, 2019
Weaknesses	Data Management Challenges	Journal of Marine Science and Engineering	Munim et al., 2021
		Maritime Policy & Management	Munim et al., 2020
	High Costs	IOP Conference Series	Priadi, 2022
		Sustainable Cities and Society	Moustafa, 2021
	Ethical Issues	arXiv (Cornell University)	Zhuo et al., 2023
		Science-Open Preprints	Shaheen, 2021
Opportunities	Technological Advancements	Journal of Industrial Information Integration	De La Peña Zarzuelo et al., 2020
		Business Process Management Journal	Wamba-Taguimdje et al., 2020
		Port of Rotterdam Official Website	Port of Rotterdam, 2022
		Port of Los Angeles Official Website	Port Optimizer, 2022
	Greater Predictive Capabilities	International Journal of Mechanical Engineering	Rao & Jayasree, 2022
		Journal of Industrial Information Integration	De La Peña Zarzuelo et al., 2020
		Business Process Management Journal	Wamba-Taguimdje et al., 2020
Threats	Cybersecurity Risks	Transportation Research Part E-logistics and Transportation Review	Li et al., 2023
		Logistics	Song, 2021
	Regulatory Challenges	Science-Open Preprints	Shaheen, 2021
		Journal of Marine Science and Engineering	Munim et al., 2021
		Maritime Policy & Management	Munim et al., 2020

Source: Authors

For leveraging AI effectively in port operations, the outcome percentages indicate that a certain proportion of participants suggest investing in AI training and education for the workforce. This emphasizes the importance of upskilling and preparing employees for the integration of AI technologies in their work processes. Collaboration with AI technology providers to develop tailored solutions is also recognized by a specific percentage of participants, indicating the significance of engaging external expertise in optimizing AI applications within the maritime industry. Furthermore, the establishment of industry-wide standards and regulations for AI implementation is recommended by a certain percentage of participants, reflecting the need for a unified and ethical framework to guide AI adoption. The outcome also suggests that a certain proportion of participants prioritize data privacy and security measures, recognizing the potential risks associated with handling sensitive data in AI-enabled port operations. Finally, fostering a culture of innovation and openness to AI adoption is recommended by a certain percentage of participants, underscoring the importance of embracing a forward-thinking mindset to fully harness the benefits of AI in port operations.

It is important to note that these findings are based on the percentages of the outcomes derived from the responses of the limited sample size of 32 participants. While these insights provide valuable initial indications, a larger and more diverse sample size would be needed to generalize the findings to a broader population.

Findings

As shown in Table 2, the implementation and future direction of AI in the maritime industry is viewed in terms of both positive and negative aspects, based on the results of the SWOT analysis, questionnaire, and previous research.

Table 2: Findings- Positive and Negative Aspects

Positive Aspects	Negative Aspects	Impacts
Operational Efficiency: AI improves efficiency by automating tasks and optimizing workflows (Zerbino et al., 2019).	**Workforce Displacement:** AI automation may reduce the need for certain port jobs (Zhuo et al., 2023).	Enhanced port operations yet potential job losses.
Safety: Reduction in human intervention in hazardous operations increases safety (Kougias et al., 2021).	**Data Privacy and Security:** Concerns over data misuse and security breaches (Kougias et al., 2021).	Safer working conditions yet risks of data breaches.
Predictive Maintenance: AI enables predictive maintenance, preventing costly downtimes (Priadi, 2022).	**High Initial Investment:** Significant initial costs can be a barrier, especially for smaller ports (Priadi, 2022).	Reduced downtime yet high setup costs.
Decision Making: AI assists in making timely and accurate decisions by analyzing large data volumes (Munim et al., 2020).	**Skill Gap:** The digital skill gap in the maritime industry necessitates training (Zerbino et al., 2019).	Improved decision-making yet a need for workforce upskilling.

Source: Authors

The positive aspects of AI are already applied by several port operators round the world under the smart port system. Table 3 provides a present example of five port operator applying smart port concept arranged according to number of terminals.

Table 3: Present Example of Five Port Operator Applying Smart Port Concept which Depends on Several AI Software

No	Port operator	Terminals and countries	Region
1	DP World	83 terminals across 22 nations	Asia, Europe, Africa, the Middle East, and the Americas and Australia
2	Terminal Investment Limited (TIL)	70 terminals in 31 countries	Europe, Africa, Asia, Americas
3	APM Terminals	65 Terminal in 58 countries	Europe, Africa, Middle East, Asia, Americas
4	Singapore's PSA International	60 terminals across 42 countries	Asia, the Middle East, and Europe
5	Hutchison Port Holdings (HPH)	54 terminals in 25 countries	Asia, Europe, Africa, the Middle East, and the Americas and Australia

Source: Authors; Data collected from the official websites of the operators

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CONCLUSION

Even though AI will increase the operation efficiency and safet, help reduce the equipment maintenance cost and better decision-making, and improve cargo handling and logistics, the management of AI applications requires an ethical framework to ensure that technology advancement does not compromise ethical boundaries or lead to unfair practices. The maritime industry should adapt strategies and legislation to overcome the challenges which likely to face, due to the potential transition of AI, such as the workforce that could be displaced due to automation, providing appropriate training and provide opportunities to the existing workforce to prepare them for a more technologically driven work environment.

Moreover, the industry needs to adopt a practical and balanced approach to steer these challenges, focusing on the entire policy that could incorporate risk justification, ethical considerations, and cost management. Stakeholder collaboration, policy development, and regulatory adjustments will play an integral role in this journey, ensuring the responsible and ethical application of AI. In addition to arranging for data privacy and security measures, recognizing the potential risks associated with handling sensitive data in AI-enabled port operations. Finally, a culture of innovation and openness upgrade to AI adoption is recommended, emphasizing the importance of accepting a forward-thinking mindset to fully harness the benefits of AI in port operations.

RECOMMENDATION

1. Digital Infrastructure Allocation: Very essential for the successful integration of AI into port operations and should include the development of data centers, advanced internet solutions, and state-of-the-art data processing tools.

2. Digitally Competent Workforce: Offer training to upskilling the present workforce and onboarding new members who have expertise in AI and data analytics.

3. Data Handling and Protection: Protocols should be in place. Alongside, strong cybersecurity measures should be adopted to ensure the protection of essential and sensitive data.

4. Unified Collaboration: Consistent communication and collaboration across various stakeholders, including port administrators, terminal operators, logistic bodies, and regulatory bodies.

5. Ethical Framework: Due to the rise of AI applications in ports, ethical considerations should be vital. This includes challenges related to job alterations, data integrity, and privacy. By establishing clear guidelines, which can ensure that AI is used sensibly and ethically.

6. Innovation and Advancement: There is a need for more progress and exploration in the field of AI. To enhance the operation efficiency, safety, and cost-effectiveness in port operations.

7. Legislative Evolution: It is seriously necessary to adopt rules and legislations to encourage innovation while ensuring adherence to safety standards and global best practices.

REFERENCES

ABU GHAZALEH, M. (2023) 'Smartening up Ports Digitalization with Artificial Intelligence (AI): A Study of Artificial Intelligence Business Drivers of Smart Port Digitalization', *MANAGEMENT AND ECONOMICS REVIEW*, 8(1), pp. 78–97. Available at: https://doi.org/10.24818/mer/2023.02-06.

Babica, V., Sceulovs, D. and Rustenova, E. (2020) 'Digitalization in Maritime Industry: Prospects and Pitfalls', in, pp. 20–27. Available at: https://doi.org/10.1007/978-3-030-39688-6_4.

Bentyn, Z. (2023) 'The Digitalization of International Logistics Tools', in, pp. 151–163. Available at: https://doi.org/10.1007/978-3-031-23432-3_13.

Chang, W.Y. (2019) 'A data envelopment analysis on the performance of using artificial intelligence-based environmental management systems in the convention and exhibition industry', *Ekoloji*, 28(107).

Chen, X. *et al.* (2023) 'AI-Empowered Speed Extraction via Port-Like Videos for Vehicular Trajectory Analysis', *IEEE Transactions on Intelligent Transportation Systems*, 24(4), pp. 4541–4552. Available at: https://doi.org/10.1109/TITS.2022.3167650.

Clemente, D. *et al.* (2023) 'Blue Seaports: The Smart, Sustainable and Electrified Ports of the Future', *Smart Cities*, 6(3), pp. 1560–1588. Available at: https://doi.org/10.3390/smartcities6030074.

Cullinane, K.P.B. and Wang, T.-F. (2006) 'The efficiency of European container ports: A cross-sectional data envelopment analysis', *International Journal of Logistics Research and Applications*, 9(1), pp. 19–31. Available at: https://doi.org/10.1080/13675560500322417.

Dwarakish, G.S. and Salim, A.M. (2015) 'Review on the Role of Ports in the Development of a Nation', *Aquatic Procedia*, 4, pp. 295–301. Available at: https://doi.org/10.1016/j.aqpro.2015.02.040.

Fruth, M. and Teuteberg, F. (2017) 'Digitization in maritime logistics—What is there and what is missing?', *Cogent Business & Management*, 4(1), p. 1411066. Available at: https://doi.org/10.1080/23311975.2017.1411066.

Haenlein, M. and Kaplan, A. (2019) 'A Brief History of Artificial Intelligence: On the Past, Present, and Future of Artificial Intelligence', *California Management Review*, 61(4), pp. 5–14. Available at: https://doi.org/10.1177/0008125619864925.

Hirata, E., Watanabe, D. and Lambrou, M. (2022) 'Shipping Digitalization and Automation for the Smart Port', in *Supply Chain - Recent Advances and New Perspectives in the Industry 4.0 Era*. IntechOpen. Available at: https://doi.org/10.5772/intechopen.102015.

Idrissi Ayoub, E. *et al.* (2023) 'Mapping the Applications of Vehicular Communications in the Context of Smart Maritime Ports', in *Vehicular Networks - Principles, Enabling Technologies and Perspectives [Working Title]*. IntechOpen. Available at: https://doi.org/10.5772/intechopen.110086.

Kougias, K., K.T., C.K., & E.-E.H. (no date) *The benefits of utilizing blockchain and big data in the maritime industry*, *http://hdl.handle.net/11610/23778 Spatial Coverage*.

de la Peña Zarzuelo, I., Freire Soeane, M.J. and López Bermúdez, B. (2020) 'Industry 4.0 in the port and maritime industry: A literature review', *Journal of Industrial Information Integration*, 20, p. 100173. Available at: https://doi.org/10.1016/j.jii.2020.100173.

Lechtenberg, S., De Siqueira Braga, D. and Hellingrath, B. (2019) 'Automatic Identification System (AIS) data based ship-supply forecasting', in *Digital Transformation in Maritime and City Logistics: Smart Solutions for Logistics. Proceedings of the Hamburg International Conference of Logistics (HICL), Vol. 28*.

Lehmacher, W. *et al.* (2022) 'Reducing port city congestion through data analysis, simulation, and artificial intelligence to improve the well-being of citizens', *Journal of Mega Infrastructure & Sustainable Development*, 2(sup1), pp. 65–82. Available at: https://doi.org/10.1080/24724718.2022.2133524.

Li, K.X. *et al.* (2023) 'Smart port: A bibliometric review and future research directions', *Transportation Research Part E: Logistics and Transportation Review*, 174, p. 103098. Available at: https://doi.org/10.1016/j.tre.2023.103098.

Li, Y. *et al.* (2023) 'Research on Multi-Port Ship Traffic Prediction Method Based on Spatiotemporal Graph Neural Networks', *Journal of Marine Science* *and Engineering*, 11(7), p. 1379. Available at: https://doi.org/10.3390/jmse11071379.

Marquis, P., Papini, O. and Prade, H. (2020) 'Elements for a History of Artificial Intelligence', in *A Guided Tour of Artificial Intelligence Research*. Cham: Springer International Publishing, pp. 1–43. Available at: https://doi.org/10.1007/978-3-030-06164-7_1.

McCarthy, J. *et al.* (2006) 'A proposal for the Dartmouth summer research project on artificial intelligence', *AI Magazine*, 27(4).

Moustafa, N. (2021) 'A new distributed architecture for evaluating AI-based security systems at the edge: Network TON_IoT datasets', *Sustainable Cities and Society*, 72, p. 102994. Available at: https://doi.org/10.1016/j.scs.2021.102994.

Mouzakitis, S. *et al.* (2022) 'Optimising Maritime Processes Via Artificial Intelligence: The VesselAI Concept And Use Cases', in *2022 13th International Conference on Information, Intelligence, Systems & Applications (IISA)*. IEEE, pp. 1–5. Available at: https://doi.org/10.1109/IISA56318.2022.9904345.

Munim, Z.H. *et al.* (2020) 'Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions', *Maritime Policy & Management*, 47(5), pp. 577–597. Available at: https://doi.org/10.1080/03088839.2020.1788731.

Munim, Z.H., Duru, O. and Hirata, E. (2021) 'Rise, Fall, and Recovery of Blockchains in the Maritime Technology Space', *Journal of Marine Science and Engineering*, 9(3), p. 266. Available at: https://doi.org/10.3390/jmse9030266.

Nguyen, H.P. *et al.* (2023) 'Application of IoT Technologies in Seaport Management', *JOIV : International Journal on Informatics Visualization*, 7(1), pp. 228–240. Available at: https://doi.org/10.30630/joiv.7.1.1697.

Noto, S. *et al.* (2023) 'Experimental Evaluation of an IoT-Based Platform for Maritime Transport Services', *Applied System Innovation*, 6(3), p. 58. Available at: https://doi.org/10.3390/asi6030058.

Port of Los Angeles (2023) *Supply Chain, Business, Port of Los Angeles*.

Port of Rotterdam Authority (2022) *launches new company PortXchange to make digital shipping app Pronto available to ports worldwide*.

Priadi, A.A. (2022) 'Optimalization of Smart Technologies in Improving Sustainable Maritime Transportation', *IOP Conference Series: Earth and Environmental Science*, 972(1), p. 012084. Available at: https://doi.org/10.1088/1755-1315/972/1/012084.

Rahman, Md.R. *et al.* (2023) 'Modelling of an Efficient System for Predicting Ships' Estimated Time of Arrival Using Artificial Neural Network', in, pp. 199–206. Available at: https://doi.org/10.1007/978-981-19-7346-8_18.

Shaheen, M.Y. (2021) 'AI in Healthcare: medical and socio-economic benefits and challenges', *SSRN Electronic Journal* [Preprint]. Available at: https://doi.org/10.2139/ssrn.3932277.

Shaykhulova, A., Nikishin, A. and Tristanov, A. (2023) 'Framework Development for Marine Ports Digitalization', in, pp. 76–85. Available at: https://doi.org/10.1007/978-3-031-24820-7_7.

Solmaz, M.S. (2021) 'Digital Transformation in Port Management', in, pp. 165–182. Available at: https://doi.org/10.4018/978-1-7998-2402-2.ch012.

Song, D. (2021) 'A Literature Review, Container Shipping Supply Chain: Planning Problems and Research Opportunities', *Logistics*, 5(2), p. 41. Available at: https://doi.org/10.3390/logistics5020041.

Srinivasa Rao, P. and Jayasree, P. (2022) 'Predictive Maintenance-as-a-Service (PdMaaS) Using Industrial Internet of Things (IIoT) and machine learning for Mechanical Equipment Used into Indian Ship Building Industry', *International Journal of Mechanical Engineering*, 7(5).

Stan, L.C. and Nedelcu, A. (2015) 'SWOT Analysis for Determining the Role of Entrepreneurial Skills in Industrial Successful Business', *Applied Mechanics and Materials*, 809–810, pp. 1414–1419. Available at: https://doi.org/10.4028/www.scientific.net/AMM.809-810.1414.

Tardo, A. *et al.* (2022) 'Addressing digitalization though out a prototyping framework for agile smart services development: the case of Livorno Port', *Journal of Physics: Conference Series*, 2311(1), p. 012007. Available at: https://doi.org/10.1088/1742-6596/2311/1/012007.

Team, P.T. (2017) *Port Machine Learning*, *Port Technology International*.

Toosi, A. *et al.* (2021) 'A Brief History of AI: How to Prevent Another Winter (A Critical Review)', *PET Clinics*, 16(4), pp. 449–469. Available at: https://doi.org/10.1016/j.cpet.2021.07.001.

Wamba-Taguimdje, S.-L. *et al.* (2020) 'Influence of artificial intelligence (AI) on firm performance: the business value of AI-based transformation projects', *Business Process Management Journal*, 26(7), pp. 1893–1924. Available at: https://doi.org/10.1108/BPMJ-10-2019-0411.

Yue Zhuo, T. *et al.* (2023) 'Exploring AI Ethics of ChatGPT: A Diagnostic Analysis', *arXiv preprint arXiv:2301.12867* [Preprint].

Zerbino, P. *et al.* (2019) 'Towards Analytics-Enabled Efficiency Improvements in Maritime Transportation: A Case Study in a Mediterranean Port', *Sustainability*, 11(16), p. 4473. Available at: https://doi.org/10.3390/su11164473.

Zhang, L. (2023) *Artificial intelligence: 70 years down the road*, *Cornell University*. arXiv.org. https://arxiv.org/abs/2303.02819

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The Extant of Familiarity in the Maritime Industry about the Sustainable Development Goals

Adham Sayed Mohamed Torky

College of Maritime Transport and Technology
Arab Academy for Science, Technology & Maritime Transport
Alexandria, Egypt.

Email: adhamtorky@aast.edu

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ABSTRACT

Purpose: *This research study aims to identify the degree of awareness, knowledge, and familiarity with Sustainable Development Goals (SDGs) among marine officers as it is a global issue of utmost importance. The study reveals a lack of knowledge, awareness and familiarity with these goals among some.*

Approach/Design/Methodology: *This study uses one technique to analyze the study data statistically which is Chi-Square independence. A questionnaire was used as the main method of data collecting in this investigation. The available sample was 93 seafarers.*

Findings: *The results of the study indicate that the participants in this survey, who have less experience in the field of the maritime industry, do not have sufficient knowledge of the procedures that are implemented through the International Maritime Organization (IMO) related to these goals. The results confirm the importance of integrating curricula related to sustainable development goals into educational curricula in maritime institutions and universities, with a focus on goals that are related to the field of the maritime industry. Furthermore, enhancing knowledge and understanding of IMO policies and conventions related to these objectives may facilitate the ability of individuals to make meaningful contributions to promoting environmental sustainability. The current study represents a significant advance in understanding these goals among seafarers, and it is expected that this will stimulate further inquiries in this area.*

Key-words:
Sustainable Development Goals, Maritime industry, Seafarers, International Maritime Organization Maritime institutions, Climate change

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INTRODUCTION

The definition of sustainability is the effective and fair transfer of resources between generations to support socioeconomic activities within a limited ecosystem. (Stoddart et al., 2011) The idea behind sustainable development is to advance humankind while simultaneously maintaining the natural systems that supply the resources civilization needs (Turcea and Ion, 2020).

The definition of sustainable development might vary greatly based on the factors taken into account. Scholars and policy makers have given sustainable development a lot of attention for four primary reasons (Ozili, 2022). Firstly, numerous nations have committed themselves to achieving the aim of sustainable development, which is seen as the ultimate objective of the United Nations' global plan (Linnér and Selin, 2013; Bexell and Jönsson, 2017). Secondly, promoting a sustainable earth for future generations is aided by sustainable development (Weiss, 1992; Emina, 2021). Thirdly, since achieving a sustainable level of development is the goal of all other development goals, sustainable development is regarded as an all-encompassing development goal. Finally, it is anticipated that sustainable development will help everyone's socioeconomic status as well as the environment (Szymańska, 2021).

The international marine sector contributes significantly to global sustainability. Maritime industry may make a primary contribution to Sustainable Development Goal 14 (SDG 14), a dedicated goal to conservation and sustainable use of oceans, seas and marine resource, SDG 13 a dedicated goal to climate change, SDG 9 a dedicated goal to industry, innovation and infrastructure and SDG 7 an affordable and clean energy (Benamara et al., 2019; Yuen et al., 2018a) seafarers continue to lack awareness regarding SDGS.

The aim of this study is, therefore, to address one pivotal research question pertaining to the extent of familiarity with sustainable development goals, particularly in relation to the maritime industry.

Approximately 1.9 million seafarers work around the world to improve mankind's quality of life. The BIMCO/ ICS Seafarer Workforce Report 2021 estimated the global supply of seafarers at 1,892,720, up from 1,647,494 in 2015 (Maritime, 2021).

The United Nations (UN) published 169 goals and 17 Sustainable Development Goals (SDGs) in their 2015 publication "Transforming our world: the 2030 agenda for sustainable development" (Wang et al., 2020) environmental and social sustainability. Being one of the key stakeholders, the international maritime industry plays an important role in contributing to global sustainability. By applying the concept of social entrepreneurship (SE. An action plan for people, the environment, and prosperity is included in this agenda. To put this strategy into action, all nations and interested parties should cooperate with one another. The scope and aspirations of this new global agenda are encapsulated in the SDGs and targets. Over the next few years, the goals and targets will spur action in areas that are vital to both the earth and humankind (UN, 2015).

The UN's International Maritime Organization (IMO) has created a number of significant SDG-related laws. For example Annex VI was adopted to Prevention of Air Pollution from Ships of the International Convention for the Prevention of Pollution from Ships (MARPOL) (Lee et al., 2019).

With the use of its regulatory framework, which is influencing global maritime industry trends, the IMO assists Member States in implementing the SDGs. The IMO has begun coordinating its programmers and projects with the SDGs in accordance with its strategic goals and deliverables, emphasizing the connections between the 2030 Agenda for Sustainable Development and the IMO's technical cooperation efforts (IMO, 2019).

This part aims to analyze and review the goals of sustainable development and their relationship to the maritime industry and the response of the IMO to implement these goals. This is done through previous studies.

Within the 17 SDGs of the UN, energy has been acknowledged as a critical element of sustainable development, defining a sustainability agenda for 2030 and beyond (UN, 2015). Within the SDG framework, it is associated with a dedicated SDG 7, which aims to "ensure access to affordable, reliable, sustainable and modern energy for all". In its current form, SDG 7 is specified through five targets defined as (7.1) ensuring universal access to affordable, reliable, and modern energy services, (7.2) increasing renewable energy share, (7.3) doubling global rate of energy efficiency improvement, (7.a) enhancing international cooperation on clean energy research and technology, and (7.b) expanding infrastructure and developing technologies (Gebara and Laurent, 2023).

Around the world, there is increasing evidence of the negative effects of climate change, such as rising sea levels, melting glaciers, an increase in wildfires, and altered biodiversity (Hwang et al., 2021). SDG 13 of the 17 Sustainable Development Goals speaks to action on climate change (Doni, 2020). SDG 13 (climate action) aims to "take urgent action to combat climate change and its impacts". The detailed targets of SDG 13 are: (13.1) strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries; (13.2) integrate climate change measures into national policies, strategies, and planning; and (13.3) improve education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning (Coscieme et al., 2020; Fraisl et al., 2020).

About 60 thousand merchant ships of various types and sizes roam the world to transport all kinds of goods (Heike, 2021). Regarding this massive industry, its effect on the world economy, and its benefits without affecting the climate, the IMO works to combat climate change in several domains, such as energy efficiency, air pollution, and greenhouse gas (GHG) emissions. The maritime sector and the IMO have a major role to play in achieving SDG 7, regarding energy efficiency in particular, and SDG 13 on climate change.

Supporting Goal No. 7 and No. 13 was done by adopting Annex 6 of the International Convention for the Prevention of Marine Pollution that covers mandatory technical and operational energy efficiency measures aimed at reducing greenhouse gas emissions from ships.

On March 1, 2020, a further modification to MARPOL 73/78 came into force. The amendment forbids the use and carrying of non-compliant fuel oil for propulsion or operation on board a ship unless the ship is equipped with an exhaust-gas cleaning equipment called a scrubber (IMO, 2020). In addition to the Initial GHG Strategy whose targets include reducing the carbon intensity of international shipping to reduce CO_2 emissions per transport business, as average across international shipping, by at least 40% by 2030, and to continue efforts towards 70% by 2050, compared to 2008, and that total annual greenhouse gas emissions from international shipping must be reduced by at least 50% by 2050 compared to 2008 (Rutherford and Comer, 2018).

Goal No. 9 is one of the SDGs. It is built around the three interconnected pillars of industry, innovation, and infrastructure (Mead, 2017). The main objective of SDG 9 is to provide a methodical and practical means of attaining environmentally sound and socially inclusive sustainable economic development (Mantlana and Maoela, 2020). The maritime industry and the port sector play an important role in its sustainability. SDG 9 most closely corresponds with the marine industry's core business, which is sustainability (Wang et al. 2020). Because they act as entry points for global trade, enable cargo handling operations, and provide value-added services including storage, packing, and land transportation coordination, ports are essential pieces of infrastructure for economic growth. Ports are an important part of the marine sector and contribute significantly to international trade and commerce (Hossain et al., 2021).

Port operations are crucial to the development of developing nations' economies and employment markets (Azarkamand et al., 2020). Because the activities in this sector are varied and complicated, these operations also have a negative impact on the environment. The aforementioned effects encompass noise pollution, soil contamination, trash generation, and gas emissions that lead to atmospheric pollution, which may have detrimental effects on marine ecosystems and the welfare of nearby residents (Diniz et al., 2023).

The IMO is a UN agency that oversees maritime activities. One aspect of maritime activities is port operations, and ports that use less energy and generate fewer emissions are referred to as green ports, or sustainable ports, which gives environmental sustainability a priority in their development and operations (KSIĄŻKIEWICZ, 2020).

The following are the green ports' primary policies: Green ports employ hybrid or electric machinery to cut pollutants. This covers the use of hybrid cars, electric tractors, and cranes for port transportation. This lessens noise pollution inside the port in addition to reducing emissions. The conservation of water and energy is a key component of green ports. This can be accomplished by using energy-efficient devices and by using renewable energy sources like solar or wind power. Green ports encourage waste reduction and recycling as well. This can involve appropriately disposing of hazardous waste as well as recycling materials like paper, plastic, and metal (Inal, 2023).

One of the SDGs is number 14 or "Life below Water," which emphasizes ocean stewardship and acknowledges the oceans' vital role in supporting life on Earth. Eighty percent of all life forms are found in the oceans, which also generate more than fifty percent of the oxygen on Earth and are essential for climate regulation (European Parliamentary Research Service, 2022).

When cargo holds are light, ships load water for stability and balance. However, when the water is off-loaded, invasive species can spread through the water and contaminate it (Lancaster et al., 2021).

The GloBallast Programmer was developed by the IMO to track and manage the issue of invasive species. In order to restrict the spread of potentially invasive species, international laws were introduced in 2004 with the adoption of the International Convention for the restrict and Management of Ships' Ballast Water and Sediments (BWMC) (IMO, 2017). It is one of the IMO's initiatives to fulfil Goal No. 14.

METHODOLOGY

In order to improve the awareness, knowledge and abilities of marine officers in the shipping business concerning the importance of sustainable development in the field of maritime industry, the current study uses a questionnaire as part of its methodology. This methodology aligns with earlier studies carried out by Omisore et al. (2017), Guan et al. (2019) and Smaniotto et al. (2022).

MATERIAL AND METHODS OF ANALYSIS

The research problem, which focused on the awareness of seafarers operating on board commercial ships of sustainable development goals related to the maritime industry, was chosen to be investigated using the methodology used in this study. The methodological approach that has been adopted can be considered a scientific and systematic way to approach the research problem. This strategy makes it easier to integrate the research findings into the larger theoretical and methodological framework of the subject (Kothari, 2004).

The qualities of the research questions and the topic being studied are the main factors that influence the choice of research methodology. As suggested by Denzin and Lincoln (2005), the current study has used a quantitative analysis technique, which has been judged as suitable for examining relationships between variables and producing numerical data that can be statistically analyzed. It is crucial to recognize that this research aims to investigate a certain facet of the phenomenon rather than providing an exhaustive truth about the subject. The goal is to add to the body of knowledge already available on the topic.

Questionnaires Design

The research design of the study was guided by the primary objective to conduct a descriptive analysis of the correlation between a single independent variable (maritime experience for seafarers) and three dependent variables (knowledge of sustainable development goals, awareness of sustainable development goals related to the maritime industry and familiarity with IMO response in relation to each goal) A questionnaire was used as the main method of data collecting in this investigation.

The questionnaire underwent multiple revisions to ensure it adhered to the guidelines of a pilot study, reviewed data and completed options, and used proper vocabulary and language. To guarantee the security and precision of the language and scientific construction of the survey questions, as well as the degree to which the study's problem and its goals have been addressed in the questionnaire. To enhance the study tool and the application of the five-level Likert scale, more phrases were added and some were reformulated in addition to the review by industry experts.

The questionnaires were sent by the link on Google Drive sent directly to some officers and engineers by social media.

Sampling Procedure

Using stratified sampling, the researchers were able to choose seafarers who belonged to the Arab Academy for Science, Technology, and Maritime Transport (AASTMT) and were of various ranks (marine officers and engineers) who have sailing experience on different types of ships.

By using this specific sampling technique, all the categories that are present in the population were represented proportionately in the sample, which increased the results' overall validity and generalizability.

(Abutabenjeh and Jaradat, 2018). All returned questionnaires were reviewed for stray signs and other damages and valid questionnaires. Correct questionnaires were received, and then the data were entered into an EXCEL sheet.

Data Collection

A standardized questionnaire was employed to gather the data. The previously described tool was specifically designed to collect information about the demographic characteristics of the respondents and their awareness of sustainable development objectives.

Any information obtained from the participants regarding this study will remain confidential and will not be disclosed except with the permission of the participant or as required by law.

Research Limitations

Any scientific research has limitations that can prevent generalization of the results. This research faced a limitation regarding the place as this research targeted the seafarers (officers and engineers) in Egypt. The researcher suggests conducting future studies on different nationalities to see whether the same results will be reached.

Data Analysis

The data that were gathered underwent analysis through the utilization of the Statistical Package for the Social Sciences (SPSS), specifically version 27. To look into the relationship between the independent and dependent variables, the study used a Chi-Square test of independence. Using a set of instructions, the Chi-Square test was carried out. These instructions included calculating the expected and observed frequencies, deducting the expected value from each observed value, squaring the difference, dividing the squares obtained for each cell by the expected value for that cell, adding up all the values, and finally figuring out the degrees of freedom for the contingency table.

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To ascertain whether the computed $\chi 2$ exceeded the critical value given in the table, a comparison with a $\chi 2$ table was performed following the computation of the degrees of freedom and the Chi-Square statistic. The observed result was considered statistically significant at the designated level when the computed $\chi 2$ value was greater than the critical value.

Variables of the Study

Examining the relationship between one predictor variable and three responder variables was the aim of this study. Figure 1 outlines the variables that are being examined:

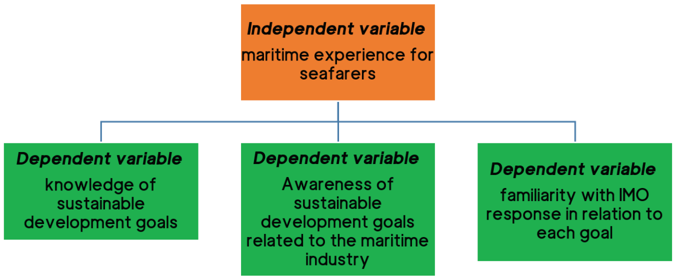

Fig. 1. Research variables

RESULTS

Research Sample

As shown in Figure 2, Along with a wide range of years of experience, a significant portion of participants held the rank of first or second officer. Both managerial and operational viewpoints are included in data analysis, which improves the comprehensiveness and accuracy of the findings.

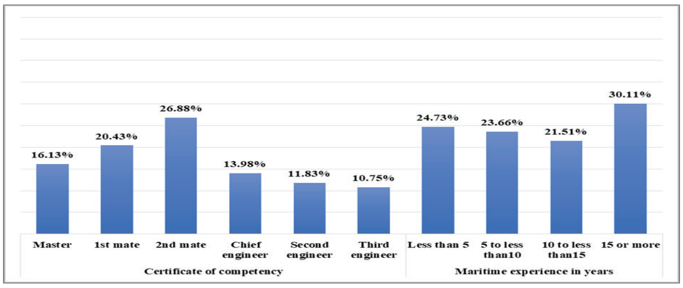

Fig. 2. Research sample

ANALYSIS OF QUESTIONNAIRE RESULTS

In order to determine the correlation between the dependent variables linked to understanding of SDGs and the independent variable of seafarers' maritime experience, an analysis of the questionnaire responses is presented in this section. The Chi-square test of independence is used in the study.

Examining Relationships between Variables

Relationship between maritime experience and understanding the aims of sustainable development goals. Table 1 shows results of study sample responses about understanding the aims of sustainable development goals according to the maritime experience:

Maritime experience in years Not understanding at all		How well do you understand the aims of sustainable development goals?				Total
		Merely understand	Understand	Fully understand		
Less than 5	Count	13	7	3	0	23
	%	56.52%	30.43%	13.04%	0.00%	100.00%
5 to less than10	Count	5	12	5	0	22
	%	22.73%	54.55%	22.73%	0.00%	100.00%
10 to less than15	Count	4	10	5	1	20
	%	20.00%	50.00%	25.00%	5.00%	100.00%
15 or more	Count	3	5	9	11	28
	%	10.71%	17.86%	32.14%	39.29%	100.00%
Total	Count	25	34	22	12	93
	%	26.88%	36.56%	23.66%	12.90%	100.00%
Chi-Square		40.43				
Sig.		0.00				

The results of the chi-square test in Table 1 indicate that there are significant differences at the level of (0.01) in the distribution of the sample responses about understanding the aims of sustainable development goals according to the maritime experience.

Those with the highest years of experience were the ones who understood the aims of sustainable development goals, these results indicate a lack of knowledge of these goals in general among a number of recent graduate participants.

Relationship between maritime experience and the main sources of information on sustainable development goals. Table 2 shows results of study sample responses about the main sources of information on sustainable development goals according to the maritime experience:

Maritime experience in years IMO		What are the main sources of information on sustainable development goals?					Total
		Social media	Newspapers	Lectures	Other		
Less than 5	Count	2	21	1	1	10	23
	%	8.70%	91.30%	4.35%	4.35%	43.48%	100.00%
5 to less than10	Count	2	19	2	1	10	22
	%	9.09%	86.36%	9.09%	4.55%	45.45%	100.00%
10 to less than15	Count	2	18	0	1	14	20
	%	10.00%	90.00%	0.00%	5.00%	70.00%	100.00%
15 or more	Count	16	14	0	1	6	28
	%	57.14%	50.00%	0.00%	3.57%	21.43%	100.00%
Total	Count	22	72	3	4	40	93
	%	23.66%	77.42%	3.23%	4.30%	43.01%	100.00%

The results in Table 2 indicate that the most experienced have the greatest reliance for their knowledge of these goals through the international maritime organization, which can be explained by the lack of knowledge of what the international maritime organization provides among the less experienced. This is consistent with the results reached by a study that showed that there is relationship between years of experience and source of information.

Relationship between maritime experience and understanding the current situation for each goal related to the maritime industry. Table 3 shows results of study sample responses about understanding the current situation for each goal related to the maritime industry according to the maritime experience:

Maritime experience in years Not understanding at all		To what extent do you understand the current situation for each goal related to the maritime industry?				Total
		Merely understand	Understand	Fully understand		
Less than 5	Count	13	7	3	0	23
	%	56.52%	30.43%	13.04%	0.00%	100.00%
5 to less than10	Count	2	14	6	0	22
	%	9.09%	63.64%	27.27%	0.00%	100.00%
10 to less than15	Count	8	6	5	1	20
	%	40.00%	30.00%	25.00%	5.00%	100.00%

Maritime experience in years Not understanding at all		To what extent do you understand the current situation for each goal related to the maritime industry?				Total
		Merely understand	Understand	Fully understand		
15 or more	Count	1	6	8	13	28
	%	3.57%	21.43%	28.57%	46.43%	100.00%
Total	Count	24	33	22	14	93
	%	25.81%	35.48%	23.66%	15.05%	100.00%
Chi-Square		52.47				
Sig.		0.00				

The results of the Chi-square test in Table 3 indicate that there are significant differences at the level of (0.01) in the distribution of the sample responses about understanding the current situation for each goal related to the maritime industry according to the maritime experience.

Those with the highest years of experience were the ones who understood the current situation for each goal related to the maritime industry, these results indicate weak awareness of the goals related to the field of the maritime transport industry among a group of less experienced participants.

The relationship between maritime experience and familiarity with the IMO's support for sustainable development goals. Table 4 shows results of study sample responses about the IMO supporting the goals of sustainable development according to the maritime experience:

Maritime experience in years Strongly disagree		The International Maritime Organization supports the goals of sustainable development.					Total
		Somewhat disagree	Neutral	Somewhat agree	Strongly agree		
Less than 5	Count	8	7	4	3	1	23
	%	34.78%	30.43%	17.39%	13.04%	4.35%	100.00%
5 to less than10	Count	2	5	9	6	0	22
	%	9.09%	22.73%	40.91%	27.27%	0.00%	100.00%
10 to less than15	Count	1	8	7	3	1	20
	%	5.00%	40.00%	35.00%	15.00%	5.00%	100.00%
15 or more	Count	0	4	6	6	12	28
	%	0.00%	14.29%	21.43%	21.43%	42.86%	100.00%
Total	Count	11	24	26	18	14	93
	%	11.83%	25.81%	27.96%	19.35%	15.05%	100.00%
Chi-Square		43.01					
Sig.		0.00					

The results of the Chi-square test in Table 4 indicate that there are significant differences at the level of (0.01) in the distribution of the sample responses about the IMO supporting the goals of sustainable development according to maritime experience.

Those with the highest years of experience were the most likely to agree on this question, these results indicate a lack of familiarity with the efforts undertaken through the IMO among a number of participants in this questionnaire with less experience.

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The relationship between maritime experience and familiarity with IMO support for Goal No. 9. Table 5 shows the results of the study sample responses about response from the IMO regarding goal No. 9 on industry, innovation and infrastructure according to the maritime experience.

Maritime experience in years Strongly disagree		There is a response from the International Maritime Organization regarding Goal No. 9 on industry, innovation and infrastructure					Total
		Somewhat disagree	Neutral	Somewhat agree	Strongly agree		
Less than 5	Count	7	8	4	4	0	23
	%	30.43%	34.78%	17.39%	17.39%	0.00%	100.00%
5 to less than10	Count	5	7	7	3	0	22
	%	22.73%	31.82%	31.82%	13.64%	0.00%	100.00%
10 to less than15	Count	2	6	8	3	1	20
	%	10.00%	30.00%	40.00%	15.00%	5.00%	100.00%
15 or more	Count	0	4	7	6	11	28
	%	0.00%	14.29%	25.00%	21.43%	39.29%	100.00%
Total	Count	14	25	26	16	12	93
	%	15.05%	26.88%	27.96%	17.20%	12.90%	100.00%
Chi-Square		36.04					
Sig.		0.00					

The results of the Chi-square test in Table 5 indicate that there are significant differences at the level of (0.01) in the distribution of the sample responses about response from the IMO regarding goal No. 9 on industry, innovation and infrastructure according to the maritime experience.

Those with the highest years of experience were the most likely to agree on this question, these results indicate a lack of familiarity with the concrete efforts undertaken by the IMO among a number of recent graduate participants.

The relationship between maritime experience and familiarity with IMO support for Goal No. 13. Table 6 shows the results of study sample responses about response from the IMO regarding goal No. 13 on climate action according to maritime experience.

Maritime experience in years Strongly disagree		There is a response from the International Maritime Organization regarding Goal No. 13 on climate action					Total
		Somewhat disagree	Neutral	Somewhat agree	Strongly agree		
Less than 5	Count	7	7	5	3	1	23
	%	30.43%	30.43%	21.74%	13.04%	4.35%	100.00%
5 to less than10	Count	3	3	10	6	0	22
	%	13.64%	13.64%	45.45%	27.27%	0.00%	100.00%
10 to less than15	Count	1	6	6	4	3	20
	%	5.00%	30.00%	30.00%	20.00%	15.00%	100.00%
15 or more	Count	0	1	6	7	14	28
	%	0.00%	3.57%	21.43%	25.00%	50.00%	100.00%

Maritime experience in years Strongly disagree		There is a response from the International Maritime Organization regarding Goal No. 13 on climate action					Total
		Somewhat disagree	Neutral	Somewhat agree	Strongly agree		
Total	Count	11	17	27	20	18	93
	%	11.83%	18.28%	29.03%	21.51%	19.35%	100.00%
Chi-Square		42.86					
Sig.		0.00					

The results of the Chi-square test in Table 6 indicate that there are significant differences at the level of (0.01) in the distribution of the sample responses about response from the IMO regarding goal No. 13 on climate action according to the maritime experience.

Those with the highest years of experience were the most likely to agree with this question, and these results indicate that although climate change is one of the environmental challenges most frequently discussed at both national and international levels, there is still a group of people who are less experienced and are not familiar with this topic or IMO procedures.

The relationship between maritime experience and familiarity with IMO support for Goal No. 14. Table 7 shows results of study sample responses about response from the IMO regarding goal No. 14 on life below water according to the maritime experience.

Maritime experience in years Strongly disagree		There is a response from the International Maritime Organization regarding Goal No. 14 on life below water					Total
		Somewhat dis-agree	Neutral	Somewhat agree	Strongly agree		
Less than 5	Count	8	7	5	3	0	23
	%	34.78%	30.43%	21.74%	13.04%	0.00%	100.00%
5 to less than10	Count	4	6	10	2	0	22
	%	18.18%	27.27%	45.45%	9.09%	0.00%	100.00%
10 to less than15	Count	3	6	6	4	1	20
	%	15.00%	30.00%	30.00%	20.00%	5.00%	100.00%
15 or more	Count	0	4	5	7	12	28
	%	0.00%	14.29%	17.86%	25.00%	42.86%	100.00%
Total	Count	15	23	26	16	13	93
	%	16.13%	24.73%	27.96%	17.20%	13.98%	100.00%
Chi-Square		41.45					
Sig.		0.00					

The results of the Chi-square test in Table 7 indicate that there are significant differences at the level of (0.01) in the distribution of the sample responses about response from the IMO regarding goal No. 14 on life below water according to the maritime experience.

Those with the highest years of experience were the most likely to agree on this question, and these results indicate that the participants in this questionnaire, who have less experience in the field of the maritime transport industry, do not have sufficient knowledge of the procedures implemented through the IMO related to this goal.

DISCUSSION

The main research question we posed is whether seafarers are aware of and have sufficient knowledge about the SDGs after analyzing the results, it can be concluded that, as in other similar studies but in other areas such as Omisore et al., (2017), Guan et al., (2019) and Smaniotto et al., (2022), raising awareness about the SDGs is still a major task.

The shipping sector is widely seen as a major contributor to the achievement of the SDGs, and as such, it plays a crucial role in achieving the goals. This study looked at the relationship between a set of independent variables (marine experience) and dependent variables (those working in the maritime industry's understanding, attitudes, and behavior regarding the SDGs).

One point that has to be emphasized is the significant correlation that exists between sailors' years of experience and their awareness of these goals, with the knowledge of these goals increasing with experience.

The significance of the increasing attention to educating marine officers in the shipping sector on the SDGs and the IMO's plans pertaining to these goals should be considered by decision makers in shipping businesses.

In order to familiarize maritime students with the objectives of sustainable development, the study also suggests that colleges and institutions of marine education create new curricula. In addition to other policies, agreements and strategies adopted by governmental and non-governmental organizations.

The aforementioned suggestions aim to bridge acknowledged gaps in knowledge and cultivate an atmosphere that supports proactive conduct and policy-making that acknowledges the pressing need to accomplish the SDGs.

One of the main limitations of the study is that the research faced a limitation regarding the place as this research targeted the seafarers (officers and engineers) in Egypt. As a result, it would be ideal to increase the sample size to include individuals of other nationalities.

CONCLUSION AND RECOMMENDATIONS

The findings of this study can serve as a foundation for evaluating the level of awareness that exists today about the SDGs. Furthermore, the understandings gathered from the study at hand may help develop a better information-dissemination plan that will raise seafarers' awareness of and attitudes towards those objectives. The study also intends to stimulate more scientific research into the perceptions and comprehension of the SDGs among mariners in the future.

The maritime education sector must now actively contribute to sustainable development goals and use them as a springboard for their own growth and long-term objectives.

In order to give sailors a thorough understanding of all facets of sustainable development and equip them to spearhead sustainability initiatives in their future careers, this is accomplished by incorporating the goals of sustainable development into the curricula of colleges and maritime institutes, whether through the undergraduate or postgraduate stages.

Since this study was conducted on Egyptians, the researcher suggests conducting future studies on other nationalities from different maritime colleges and institutes to see whether the same results will be reached.

REFERENCES

Abelando, M., Bobinac, M. and Fiore, J.C. (2020) 'Assessment of the efficiency of controls to prevent biologic invasions at the San Lorenzo Port, Argentina', *Environmental Monitoring and Assessment*, 192(7). Available at: https://doi.org/10.1007/s10661-020-08359-2.

Abutabenjeh, S. and Jaradat, R. (2018) 'Clarification of research design, research methods, and research methodology: A guide for public administration researchers and practitioners', *Teaching Public Administration*, 36(3). Available at: https://doi.org/10.1177/0144739418775787.

Azarkamand, S., Wooldridge, C. and Darbra, R.M. (2020) 'Review of Initiatives and Methodologies to Reduce CO2 Emissions and Climate Change Effects in Ports', *International Journal of Environmental Research and Public Health*, 17(11), p. 3858. Available at: https://doi.org/10.3390/ijerph17113858.

Benamara, H., Hoffmann, J. and Youssef, F. (2019) 'Maritime transport: The sustainability imperative', in *Sustainable Shipping: A Cross-Disciplinary View*. Available at: https://doi.org/10.1007/978-3-030-04330-8_1.

Bexell, M., and K.J. (2017) 'Responsibility and the United Nations 'Sustainable Development Goals', *Forum for Development Studies* , 44(1), pp. 13–29.

Coscieme, L. *et al.* (2020) 'Going beyond Gross Domestic Product as an indicator to bring coherence to the Sustainable Development Goals', *Journal of Cleaner Production*. Available at: https://doi.org/10.1016/j.jclepro.2019.119232.

Denzin, N.K. and Lincoln, Y.S. (2000) 'Introduction: The discipline and practice of qualitative research', in *Handbook of qualitative research (2nd edition)*.

Diniz, N.V. *et al.* (2023) 'Disclosure of the sustainable development goals in the maritime industry and port sector', *Revista de Gestão e Secretariado (Management and Administrative Professional Review)*, 14(5). Available at: https://doi.org/10.7769/gesec.v14i5.2185.

Doni, F., Gasperini, A. and Soares, J.T. (2020) *SDG13 – Climate Action: Combating Climate Change and its Impacts*, *SDG13 – Climate Action: Combating Climate Change and its Impacts*. Available at: https://doi.org/10.1108/9781787569157.

Emina, K.A. (2021) 'SUSTAINABLE DEVELOPMENT AND THE FUTURE GENERATIONS', *Social Sciences, Humanities and Education Journal (SHE Journal)*, 2(1). Available at: https://doi.org/10.25273/she.v2i1.8611.

European Parliamentary Research Service (2022) *EU action on ocean governance and achieving SDG 14*.

Fraisl, D. *et al.* (2020) 'Mapping citizen science contributions to the UN sustainable development goals', *Sustainability Science*, 15(6), pp. 1735–1751. Available at: https://doi.org/10.1007/s11625-020-00833-7.

Gebara, C.H. and Laurent, A. (2023) 'National SDG-7 performance assessment to support achieving sustainable energy for all within planetary limits', *Renewable and Sustainable Energy Reviews*, 173. Available at: https://doi.org/10.1016/j.rser.2022.112934.

Guan, T. *et al.* (2019) 'Public attitudes toward sustainable development goals: Evidence from five Chinese cities', *Sustainability (Switzerland)*, 11(20). Available at: https://doi.org/10.3390/su11205793.

Heike Deggim (2021) *Providing weather information to support safe navigation*.

Hossain, T., Adams, M. and Walker, T.R. (2021) 'Role of sustainability in global seaports', *Ocean & Coastal Management*, 202, p. 105435. Available at: https://doi.org/10.1016/j.ocecoaman.2020.105435.

'How Important are the Sustainable Development Goals? A Bibliometric and Modern Data Analysis' (2020) in *Proceedings of the International Conference on Economics and Social Sciences*. Sciendo, pp. 624–635. Available at: https://doi.org/10.2478/9788395815072-063.

Hwang, H. *et al.* (2021) 'Cross-societal analysis of climate change awareness and its relation to sdg 13: A knowledge synthesis from text mining', *Sustainability (Switzerland)*, 13(10). Available at: https://doi.org/10.3390/su13105596.

IMO (2020) 'MARPOL Annex VI-Prevention of Air

Pollution from Ships National Workshop (virtual) on Ratification and Effective Implementation of MARPOL Annex VI for Algeria'.

IMO, I.M.O. (no date) *A Strategy for the IMO Secretariat to identify, analyse and address emerging issues and opportunities to further support Member States in their implementation of the 2030 Agenda for Sustainable Development*, *https://wwwcdn.imo.org/localresources/en/MediaCentre/Documents/SDG_Strategy and planning.pdf*.

Imo.org (2017) *Index of IMO Resolutions*, *http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine--Environment-Protection- Committee-%28MEPC%29/Documents/MEPC.288%2871%29.pdf Accessed 20 August 2020.*

Inal, O.B. (2023) 'An Academic Research An Overview of Green Ports and Sustainable Development Goals', pp. 409–413.

Kothari, C.R. (2004) *Research Methodology: Methods & Techniques*, *New Age International (P) Ltd*. Available at: https://doi.org/10.1017/CBO9781107415324.004.

KSIĄŻKIEWICZ, D. (2020) 'Clean air policy in european marine ports', *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 2020(149), pp. 371–381. Available at: https://doi.org/10.29119/1641-3466.2020.149.32.

Lancaster, M.L., Winsor, P. and Dumbrille, A. (2021) *Strategies for Sustainability Sustainability in theeMaritime Domain Towards Ocean Governance and Beyond*, *Strategies for Sustainability Sustainability in the Maritime Domain Towards Ocean Governance and Beyond*.

Lee, P., Kwon, O. and Ruan, X. (2019) 'Sustainability Challenges in Maritime Transport and Logistics Industry and Its Way Ahead', *Sustainability*, 11(5), p. 1331. Available at: https://doi.org/10.3390/su11051331.

Linnér, B.-O., and H.S. (2013) 'The United Nations Conference on Sustainable Development: Forty Years in the Making.' Environment and Planning C: Politics and Space', *Linnér, B.-O., and H. Selin*, 31(6), pp. 971–989.

Mantlana, K.B. and Maoela, M.A. (2020) 'Mapping the interlinkages between sustainable development goal 9 and other sustainable development goals: A preliminary exploration', *Business Strategy & Development*, 3(3), pp. 344–355. Available at: https://doi.org/10.1002/bsd2.100.

Maritime, O.F. (2021) 'maritime transport '.

Mead (2017) *How can progress on infrastructure, industry and innovation contribute to achieving the SDGs?*, *http://sdg.iisd.org/ commentary/policy-briefs/how-can-progress-on-infrastructureindustry- and-innovation-contribute-to-achieving-the-sdgs/*.

Omisore, A.G. *et al.* (2017) 'Awareness and knowledge of the sustainable development goals in a University Community in Southwestern Nigeria', *Ethiopian Journal of Health Sciences*, 27(6), p. 669. Available at: https://doi.org/10.4314/ejhs.v27i6.12.

Ozili, P.K. (2022) 'Sustainability and Sustainable Development Research around the World', *Managing Global Transitions*, 20(3). Available at: https://doi.org/10.26493/1854-6935.20.259-293.

Rossi, S. (2023) *SDG 14: Life Below Water*. Cham: Springer International Publishing. Available at: https://doi.org/10.1007/978-3-031-19467-2.

Rutherford, D. and Comer, B. (2018) 'International Maritime Organization's Initial Greenhouse Gas Strategy', *International Council on Clean Transportation (ICCT)* [Preprint], (April 2018).

Smaniotto, C. *et al.* (2022) 'Sustainable Development Goals and 2030 Agenda—Survey on Awareness, Knowledge and Attitudes of Italian Teachers of Public Mandatory Schools, 2021', *Sustainability*, 14(12), p. 7469. Available at: https://doi.org/10.3390/su14127469.

Stoddart, H., S.K., D.F., S.A., B.M., C.J., & W.R. (2011) 'A pocket guide to sustainable development governance'.

Szymańska, A. (2021) 'Reducing Socioeconomic Inequalities in the European Union in the Context of the 2030 Agenda for Sustainable Development', *Sustainability*, 13(13), p. 7409. Available at: https://doi.org/10.3390/su13137409.

United Nations. Transforming our world (2015) *the 2030 agenda for sustainable development. Resolution adopted by the general assembly on 25 september 2015*. New York.

Wang, C.M. and Wang, B.T. (2020) 'Floating Solutions for Challenges Facing Humanity', in, pp. 3–29. Available at: https://doi.org/10.1007/978-981-15-5144-4_1.

Wang, X. *et al.* (2020) 'How can the maritime industry meet Sustainable Development Goals? An analysis of sustainability reports from the social entrepreneurship perspective', *Transportation Research Part D: Transport and Environment*, 78, p. 102173. Available at: https://doi.org/10.1016/j.trd.2019.11.002.

Weiss, E.B. (1992) 'In Fairness to Future Generations and Sustainable Development', *American University International Law Review*, 8(1).

Yuen, K.F. *et al.* (2018) 'Interaction impacts of corporate social responsibility and service quality on shipping firms' performance', *Transportation Research Part A: Policy and Practice*, 113. Available at: https://doi.org/10.1016/j.tra.2018.04.008.

Enhancing Security Risk Assessment Towards Smart Maritime Industry: A Comprehensive Analysis of Candidate Approaches

Ahmed Mohy Ibrahim[1], Mohamed Abdelfattah[2], Mohamed Mohasseb[3] and Said Abdelkader[4]

[1&2] Regional Maritime Security Institute, Arab Academy for Science, Technology and Maritime Transport (RMSI - AASTMT).

[3] Head of Egyptian Navy Research Department, Egypt.

[4] College of Maritime Transport and Technology, Arab Academy for Science, Technology and Maritime Transport, Alexandria, Egypt.

Emails: ahmedmohyyy@aast.edu, mlmf_001@yahoo.com, mohamedmohasseb@live.com, abdelkader500@hotmail.com
[1]ORCID https://orcid.org/0000-0001-5582-382X, ahmedmohyy@gmail.com

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ABSTRACT

Purpose: *Maritime security risk assessment forms the cornerstone of effective security measures for ships, ports, and port facilities. However, the current security risk assessment approaches lack adequate preparedness to align with the rapid technological advancements and transformations in the smart maritime industry. The main factor groups and parameters for those approaches have to be adapted, in order for the approaches to keep pace with the dynamic developments of potential technological threats.*

Approach/Design/Methodology: *This paper aims to examine points of strength and weakness in security risk approaches in the maritime industry, with a focus on the transition to a smart maritime industry. It scrutinizes recommended security risk assessment approaches outlined in security guidelines and published research, emphasizing challenges in their selection, by using a descriptive-analytical approach. It also explores their effect on the smart maritime industry when applied to ships such as maritime teleoperated vessels (MTVs), elucidating key concepts. A comparative analysis of selected approaches underscores structural characteristics and values. Finally, the study critically assesses transforming the maritime industry for improved security risk assessment practices for MTVs and their maritime teleoperation centers (MTCs).*

Findings: *Findings highlight the necessity for a more comprehensive maritime security risk assessment approach.*

Key-words:
Maritime Security, Risk Assessment, STPA/STPA-Sec, TRAM, RAMT.

List of abbreviations

Abbreviation	Term
MTV	Maritime Teleoperated Vessel
MTC	Maritime Teleoperation Center
STPA-Sec	System Theoretic Process Analysis - Security
TRAM	Threat and Risk Analysis Matrix
RAMT	Risk Assessment and Management Tool
ILO	International Labor Organization
IMO	International Maritime Organization
SOLAS	International Convention for the Safety of Life at Sea
ISPS Code	International Ship and Port Facility Security Code
RSE	Regulatory Scoping Exercise
AI	Artificial Intelligence
MSC	Maritime Safety Committee
STAMP	System-Theoretic Accident Model and Process
MIT	Massachusetts Institute of Technology
IEC	International Electrotechnical Commission's
NIST	National Institute of Standards and Technology's
FAA	Federal Aviation Administration
UAS	Unmanned Aircraft Systems
IACS	International Association of Classification Societies

INTRODUCTION

The maritime industry, a constantly evolving connection of global trade and commerce, has experienced profound transformations in recent years, marked by enormous progress and innovation across ships, ports, and port facilities, with a notable advancement being the development of MTVs and their MTCs (Rødseth et al., 2023). Amid the technological shift towards intelligent shipping, some overlook the critical need to align with maritime security requirements. Despite progress in developing intelligent technologies for vessels and port infrastructure, security procedures lag behind the rapid pace of innovation (Bueger et al., 2020; Thieme et al., 2018). The contemporary maritime landscape is threaded together by automation, digitalization, and connectivity. Vessels, once reliant on traditional navigation and communication systems, now boast state-of-the-art technologies are transforming them into MTVs at the forefront of the smart shipping revolution and, on some stages, operating from their MTCs (Amro and Gkioulos, 2023; Veitch and Alsos, 2022). However, as ships encompass autonomy and evolve into MTCs, a tangible shift in the characteristics and quantity of security threat parameters becomes obvious (Amro and Gkioulos, 2023).

This research acknowledges that maritime security goes beyond physical threats to include sophisticated ones, such as cyber threats. The growing dependence on digital technologies makes smart shipping vulnerable to cyber-attacks, posing significant risks to the safety, security, integrity, continuity, and sustainability of maritime operations (Sahay et al., 2023). Security risk assessments serve as the cornerstone for formulating effective security measures that could provide the integrity, reliability, and resilience of MTVs and their MTCs. The maritime security landscape is characterized by a multitude of security risk assessment approaches and their associated factor groups including their parameters inside each group, introducing the complexities to the decision-makers (stakeholders) and also guidance process for tailored security plans.

As the smart maritime industry is deployed, a critical examination of the characteristic security risks in these advanced systems becomes critical. The study was outlined depending on the established security approaches in the guidelines, such as the maritime security editions (2008, 2012, and 2021), the International Labor Organization (ILO)/ International Maritime Organization (IMO) Security in Ports Code of Practice, and recommendations from published journals (IMO, 2008; IMO, 2011; IMO, 2021a). Thus, the study adopts a descriptive-analytical approach to conduct a comparative analysis between System Theoretic Process Analysis - Security (STPA/STPA-Sec), Threat and Risk Analysis Matrix (TRAM), and Risk Assessment and Management Tool (RAMT) as they were specifically tailored for security perspectives for the maritime industry. This analysis would play a pivotal role in the security risk assessment procedures, aiming to address potential security risk assessment gaps and limitations that might be encountered in the future of the smart maritime industry when applied to ships such as MTVs and their MTCs (IMO, 2018b; IMO, 2021b; Lim et al., 2018). It serves as a proactive measure, to emphasize challenges and answer critical questions: How effective are the commonly recommended maritime security risk assessment approaches (STPA/STPA-Sec, TRAM, and RAMT) outlined in security guidelines and published journals? The examination investigates the structural characteristics and values of these approaches, shedding light on their advantages and shortcomings, by conducting a thorough gap analysis before the implementation of the MTV code by the IMO.

LITERATURE REVIEW

Maritime transport encountered many challenges that can pose a security risk due to different types of threats. Piracy, stowaways, and cyberattacks partly for stealing information algorithms or to take control of the ship are some of the identified threats to the safety and security of vessels, passengers, seafarers, cargo, and economy (Lun et al., 2023). Despite the significant improvement in the decision-making process for safety and security measures achieved by the international maritime regulations adopted by the maritime industry at that time, better-targeted decision-making can be attained when the exposure to risks is accurately identified early on. This involves providing adequate risk mitigation measures that align with the same degree of technological development within the industry at that particular time (IMO, 2022; Lim et al., 2018).

Following the World Trade Center explosion, the 9/11 attack served as a crucial wake-up call for the maritime industry to enhance security standards (Bueger, 2015). The incident uncovered the vulnerabilities of the shipping sector to hijacking and terrorism. In response to the September 11, 2001 attack, the IMO's Maritime Safety Committee (MSC) and its security working group immediately took action. Their goal was to expedite the creation and implementation of necessary security measures. During the diplomatic conference on maritime security in December 2002, new regulations for SOLAS 74 and the ISPS Code were instituted (Dekker and Stevens, 2007). Considering the ongoing and rapid development of the maritime industry and the diverse dangers it faces, the ISPS Code took effect just 18 months after its adoption alongside the SOLAS '74 amendments. The previously mentioned incidents prompted the rapid release of the security code.

Since this rapid shift, the development was marked by the necessity to create an imperfect product rather than having nothing at all, aiming to standardize security procedures onboard ships and at port facilities (Mukherjee, 2007; Smelikova and Penza, 2022). This was also reflected in the outline for the security risk assessment approaches, which sequentially their main factor groups and their associated parameters for assessing the potential security risks for the maritime industry. At that time, the capabilities and components were significantly constrained to address dynamic shifts in ship operations, ports, and port facilities (Afenyo and Caesar, 2023). Furthermore, the establishment of a common and recommended security measurers framework and various security risk assessment approaches among member states of the IMO becomes crucial, e.g., the ISPS code, or maritime security risk assessment approaches outlined in security guidelines. Notably, tangible gaps exist in various editions (IMO, 2008; IMO, 2011; IMO, 2021a), as well as the published security risk assessment approaches in scientific journals within the current operations of the maritime industry. These approaches primarily concentrate on existing practices, overlooking future considerations associated with addressing and estimating security risks relevant to the ongoing smart maritime transformation (Torkildson et al., 2018).

Moreover, governmental and non-governmental recommendations often adhere to a standard framework for security risk assessment, specially tailored for traditional ships, ports, and facilities. Unfortunately, this framework exhibits limitations in its scope for assessing security risks tied to technological transformations (IAPH, 2021). Consequently, this gap extends to the applicability of security risk assessment approaches tailored for the maritime industry when applied to ships such as MTVs and their MTCs (Thieme et al., 2018). Given the integrated sophisticated and intelligent systems that this stage of transformation is witnessing, relying on one of the existing security risk assessment approaches may lead to inadequacies and gaps in the evaluation process. Hence, these gaps persist in the potential application of widely recommended and utilized approaches like STPA/STPA-Sec, TRAM, and RAMT. There is a need for auditing, designing, and addressing security gaps to tailor them explicitly for this transformative stage in the maritime industry such as introducing the MTVs and their MTCs. The objective is to ensure adaptability to evolving threats and dynamic vulnerabilities within the smart maritime transformation.

In 2017, the IMO identified reshaping the regulatory framework as a strategic priority, focusing on a regulatory scoping exercise for MTVs to assess environmental sustainability, security, and safety challenges (IMO, 2017b). However, the pace of technological advancement raised concerns, as technology often outpaces thorough studies and discussions needed to address resulting and potential risks. Recognizing security risks as a significant weakness to automated ships and full digital transformation development that could hinder the progress of the maritime industry. Hence, the IMO released publications in conjunction with the MTV regulatory scoping exercise (RSE), underscoring the significance of risk assessments and addressing a range of threats, including cyber vulnerabilities (IMO, 2017a; IMO, 2017b; IMO, 2018a). The IMO defined four levels of autonomous vessels (IMO, 2018a) and encouraged innovation in frameworks by interested governmental and non-governmental organizations for MTVs and their MTCs. This initiated numerous challenges related to safety and security measures in the smart maritime industry. Despite technological assessment gaps, the standards and recommendations for security risk assessment approaches are applied for assessing digitalized ports and port facilities undergoing technological transformation, and not only that but they are also applied for assessing operating ships that can be classified as MTV level 1 according to the IMO taxonomy Table 1 (IMO, 2018a).

Table 1: Outlines the Four Levels of Taxonomies for MTV (source: Author, inspired by Zhang et al. (2024))

MTV Level of Autonomy	MTV Operations	MTV Watchkeeping	MTV Decision Making
Level 1	Seafarers on board	Seafarers on board	Seafarers on board
Level 2	MTV Systems support MTC crew members	MTV Systems support MTC crew members	MTV Systems support MTC crew members
Level 3	MTC crew members support systems onboard MTV	MTC crew members support systems onboard MTV	MTC crew members support systems onboard MTV
Level 4	MTV systems (i.e. AI)	MTV systems (i.e. AI)	MTV systems (i.e. AI)

Unfruitfully, security requirements have not received due attention compared to the current security risks faced by the maritime industry (Zhang et al., 2024). A reverse that could pose even greater security risks for MTVs and their MTCs in the future. Moreover, reliable approaches for assessing the security risks of these MTVs are lacking, despite their approval and classification by the IMO (Chaal et al., 2020). Furthermore, international interest in the security of these MTVs has not been comprehensive, particularly considering the interdependence of the ship and its MTCs, both of which could be integral to each other's security. Publications on the scientific database highlight that, thus far, security and safety concerns have not garnered the same level of international attention awarded to autonomous ships (Thieme et al., 2018).

The MSC 105th session, starting in April 2022, initiated efforts to create a goal-based instrument overseeing such ships as MTV operations. The MSC endorsed a roadmap outlining a work plan for developing IMO instruments related to MTV, initially as a non-mandatory Code, with the aim of adoption in the latter half of 2024 as the initial phase. Following the experience gained from implementing the non-mandatory MTV Code, a mandatory MTV Code is anticipated to be formulated, and set to come into effect on January 1, 2028 (IMO, 2022). As far as practicable, the MTV code should address the gaps and limitations for the safety and security of the relation between MTV and MTC on board, based on new technologies and possible consequences.

As highlighted earlier, it becomes evident that existing maritime security risk assessment approaches may exhibit gaps and shortcomings. In the evolving maritime security landscape, technological advancements are driving transformations, as notably demonstrated by such ships as MTVs and their MTCs. However, these innovations pose significant challenges, particularly in the capability and applicability of the security risk assessment approaches for these autonomous entities. These challenges encompass the main factor groups and their associated parameters, such as their reliability, cyber-attacks, or evolving regulations that current approaches may not be adequately capable of when assessing security risks for MTVs and their MTCs. Recognizing the need for further exploration in this context, this study attempts to undertake a comprehensive examination between selected security risk assessment approaches (STPA/STPA-Sec, TRAM, and RAMT) in the subsequent sections. The aim is to identify and address potential limitations, contributing to the ongoing discourse on refining and enhancing maritime security risk assessment approaches tailored for such ships as MTVs.

THE MARITIME SECURITY RISK ASSESSMENT APPROACHES

Choosing an effective risk assessment approach is crucial for obtaining essential information without unnecessary complexity. However, current maritime security risk assessments for novel technologies are essential for evaluating security risks for MTVs and their MTCs in an attempt to form a foundation for the MTV code objectives and avoid security risk approach limitations. Unfortunately, there is a global lack of optimal and cohesive application of security requirement criteria in many countries, needing intensive efforts from all stakeholders (Herbert-Burns et al., 2008; Khafendi, 2016). This deficiency leads to a lack of directives for choosing the optimal security risk assessment, causing potential risks and threats to MTVs and their MTC locations. This study compares and analyses three approaches (STPA/STPA-Sec, TRAM, and RAMT) focusing on their structural characteristics, values, gaps, and strengths. It precisely focuses on the transition to a smart maritime industry and explores its impact on MTVs and their MTCs.

THE STPA-SEC APPROACH

The STPA-Sec analysis approach is utilized to identify critical control structures and analyze potential risks in complex systems from a security perspective, aiming to identify security vulnerabilities (Leveson and Thomas, 2018; Sun et al., 2022). STPA/STPA-Sec is a risk assessment approach rooted in the System-Theoretic Accident Model and Process (STAMP), it has been used in some innovative domains, including the maritime sector (Chaal et al., 2020; Glomsrud, 2019; Wróbel et al., 2018). The main steps of STPA-Sec provide the security perspectives, and the STPA provides the safety perspectives, but they are the same (Sahay et al., 2023).

STPA/STPA-Sec was developed by Nancy Leveson, a professor of aeronautics and astronautics engineering at the Massachusetts Institute of Technology (MIT) (Harkleroad et al., 2013; Leveson, 2016; Leveson and Thomas, 2018). Since its development, STPA/STPA-Sec has been accepted by a variety of organizations and industries as a tool for identifying and mitigating risks associated with complex systems. It has also been included in various safety and security standards, comprising the International Electrotechnical Commission's (IEC) and the National Institute of Standards and Technology's (NIST) Cybersecurity Framework (Sahay et al., 2023; Torkildson et al., 2018; Zhou et al., 2021). Furthermore, the Federal Aviation Administration (FAA) has used STPA to assess the safety risks associated with the integration of unmanned aircraft systems (UAS) into the National Airspace System (NAS) (Harkleroad et al., 2013).

STPA/STPA-Sec has been utilized to evaluate the dynamic positioning systems of vessels, creating verification goals and recognizing hazards (Utne et al., 2020). Valdez Banda and Kannos (2018) analyzed the hazards related to an autonomous ferry project in Finland utilizing STPA, integrating input from several stakeholders and experts. They recognized 15 hazards that, if uncontrolled, could result in accidents, including collisions, grounding, or passenger involvement in accidents. One of the focus topics is the software reliability of the system, which can lead to critical operational disruptions, potential safety hazards, and the necessity for a robust reliable approach to ensure reliable operations (Banda and Goerlandt, 2018). One of the International Association of Classification Societies (IACS) members has also developed guidelines for applying STPA to the safety and security of MTVs and MTCs. These guidelines provide a framework for conducting STPA-based risk assessments of MTVs and MTCs and identifying potential safety and security hazards and threats but could be more subjective for their point of view for their adopted MTVs and MTCs experiments projects and also more safety subjectivity (Guzman et al., 2021; Wróbel et al., 2018). However, the main associated parameters, e.g. intention, general probability, and unmanned systems security parameter, have been omitted from security perspectives that relied on them to be examined for potential security risks and propose approaches for MTVs and their MTCs as one entity.

STPA/STPA-Sec does not eliminate all the problems related to standard risk matrices created by expertise, but it just does propose a more logical foundation for classifications (Leveson, 2019). Furthermore, the lack of a threat model in STPA-Sec limits the reflection of novel fundamental factors (Sahay et al., 2023). Additionally, STPA-Sec is time-consuming, resource-intensive, and complex to apply for countermeasures (Sun et al., 2022). Nevertheless, STPA-Sec is not a quantitative method and should be combined with quantitative analysis techniques (mixed method), so it might not be preferable to be singly utilized to calculate the exact probability or severity of risks for MTV and MTC. To overcome this constraint, additional assessment metrics can be integrated with STPA/STPA-Sec approaches. This enhancement enables a more thorough analysis and vulnerability scoring, aiding in the evaluation of identified insecure behaviors and scenarios (Ruddle et al., 2009) Fig.1, shows the structure of the STPA/STPA-Sec common steps.

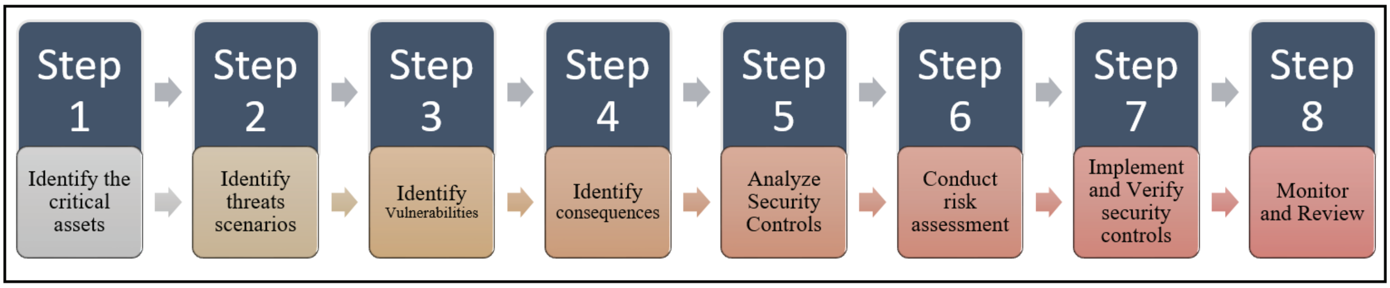

Figure 1: Structure of the STPA/STPA-Sec common steps (Guzman et al., 2021; Harkleroad et al., 2013; Sahay et al., 2023).

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THE TRAM APPROACH

TRAM is an approach utilized for risk assessment in ports and maritime environments and was originally developed jointly by the ILO and IMO. The objective of TRAM is to categorize risks so that countermeasures can be achieved and suggested to avoid, distinguish, and reduce the effects of any potential crisis, would it occur. An effective tool for resource allocation, emergency planning, and budgeting may be such an analysis (McCartan et al., 2018). The TRAM approach is commonly utilized by port authorities and maritime organizations around the globe as a standard approach for security risk assessment and management. TRAM offers a structured and systematic way to identify and evaluate security risks and supports prioritizing mitigation measures to reduce the likelihood and impact of potential security risk incidents (González-Gutiérrez et al., 2022; ILO/IMO, 2004).

The TRAM is established on a risk-based approach to maritime security, focusing on evaluating the likelihood and impact of threats (Faz and Orive, 2016). This initiative aimed to address the gaps in maritime security identified within the ISPS Code (Stavrou et al., 2018). While the ISPS Code only applies to specific ships and port facilities, leaving several areas of the port insecure. The TRAM approach pairs this by assessing and mitigating risks in those uncovered areas. Although the ISPS Code provides minimum security standards and guidelines, it does not mandate precise measures, making TRAM a useful dynamic tool, enhancing security position, and reducing the likelihood of a successful attack (Bichou, 2008). The TRAM has gained extensive adoption by governments, organizations, and maritime security experts, for its effectiveness in recognizing and assessing maritime security threats, by incorporating it into national and international security frameworks to tackle a variety of threats like armed robbery, terrorism, and smuggling associated with maritime operations in a structured and systematic way (Romero-Faz and Camarero-Orive, 2015; 2017). By employing practical controls, renovating policies, conducting training, and constantly monitoring risks. TRAM ensures that resources are directed to address the most critical threats first. Also, the approach facilitates clear communication of risks and mitigation plans to stakeholders, fostering awareness and understanding between all involved parties. As a dynamic process, TRAM allows for ongoing adaptation to altering situations and evolving threats, permitting continuous improvement in risk management processes for maritime governments and organizations. TRAM is a quantitative simplified analysis, which involves using statistical models to assess the likelihood and impact of potential risks.

The accuracy of the TRAM depends on the quality and completeness of the information available. If there are gaps in knowledge or information is outdated, the TRAM may not provide an accurate assessment of risks (Abdelfattah et al., 2022; Faz and Orive, 2016). The TRAM can be a time-consuming process, mainly if it encompasses a huge number of stakeholders or requires a detailed analysis of complex threats. This can make it challenging to implement in maritime organizations with limited resources or tight timelines. The TRAM mainly focuses on assessing and mitigating specific risks, potentially influencing adaptability to evolving smart technological security risks for MTVs and their MTCs. This adaptation may present limitations in addressing the evolving landscape of security challenges associated with the combination of advanced technologies in the smart maritime industry. It may not take into account broader systemic security risks or external factor groups and their associated parameters that could impact the potential maritime target. The TRAM can be a complex tool, particularly for individuals who are not familiar with security risk assessment, management concepts, and risk terminologies. This can make it difficult to use effectively without specialized training or expertise. These drawback factors can make it challenging to individually apply the TRAM to new technologies in the smart maritime industry, especially for MTV and their MTC as a recommended approach from a security perspective. Fig.2, shows the structure of the TRAM common steps.

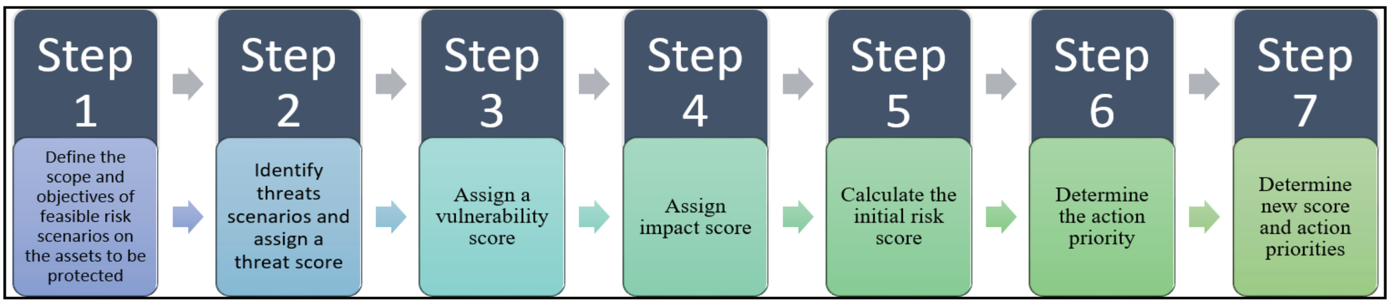

Figure 2: Structure of the TRAM common steps (ILO/IMO, 2004).

THE RAMT APPROACH

The IMO issued and designed guidance including the RAMT to assist national authorities in undertaking security risk assessments related to potential maritime targets or for maritime assets that need to be security protected (IMO, 2008; IMO, 2021a). The guidance's editions 2008, 2012, and its late updates in 2021 provide an outlined framework for conducting a comprehensive security risk assessment of maritime security threats and vulnerabilities, regardless of the type or size of the ship or the port facility assessing security risks and identifying appropriate security measures to mitigate those risks. However, it does not specifically recommend or endorse particular risk assessment and management tools. Instead, the IMO concentrates on providing a framework and general principles for conducting risk assessments and implementing effective security measures. The guidelines emphasize the significance of conducting a risk assessment to ascertain the applicability and extent of their guidelines. Based on the results of the risk assessment by grouping related data and information, appropriate security measures can be applied to reduce the risk of an attack and reduce the potential consequences.

The RAMT is a valuable tool for maritime security experts. By utilizing this tool, organizations can improve their understanding of the threats they face and progress more effective strategies to mitigate those threats. The RAMT creates a risk management plan that contains references for appropriate risk mitigation measures, based on the outcomes of the risk assessment. This supports ensuring that security risks are appropriately recognized and managed to reduce the risk of security incidents. The RAMT was updated in the 2012 edition to encompass new features. The 2012 edition involved a new section on the assessment of risks associated with human factors, which is a critical aspect of safety and security in the maritime industry (IMO, 2011). In 2021, the IMO once again issued updates to the maritime industry, which includes the updated RAMT. This updated version combines the latest developments in risk assessment approaches and reveals the evolving regulatory requirements and industry practices for risk assessment for the majority of port facilities, small to medium-sized ports, mobile drilling units, and the majority of ships (IMO, 2021a).

Effective risk management is crucial when using the information and the risk scoring collected on RAMT for threats, impacts, and vulnerabilities. This stage expects effective and sustainable long-term risk mitigation strategies. Cooperative efforts among all stakeholders are vital to frame commonly accepted tactical action plans. The adequacy of the security risk level develops a crucial consideration in this perspective, given the potential alternatives in criteria among designated authorities in different countries. However, the RAMT approaches exhibit a weakness in providing clear guidance on how to address this matter.

The utilization of the RAMT for assessing maritime assets (potential maritime targets) comes with several limitations. Firstly, the availability and quality of data can pose challenges, as precise and up-to-date information is crucial but not constantly readily accessible. Secondly, RAMT employs simplified models and assumptions, potentially oversimplifying complex risk factors and inadequate to seize the exclusive features of specific maritime security assets or security environments (Abdelfattah et al., 2022; IMO, 2021a). Therefore, it could directly negatively influence the security risk assessment for MTV and its MTC if it is utilized as it is. Nonetheless, the assessment of the impacts lacks security risk parameters and inaccuracy in determining the distinctive criteria. Additionally, subjective judgment plays a role in security risk assessments conducted utilizing RAMT, leading to variations and inconsistencies between several maritime security experts' or organizations' techniques.

This tool also has a partial scope, focusing mainly on technical and operational aspects while ignoring other vital security risk factor groups and their associated parameters such as criticality, reliability, cost-benefit assessment, and environmental issues that were not obviously specified. Within this framework, the vulnerability assessment utilized in RAMT lacks specific parameters, tackling them in a broad and unclear approach. This presents a notable drawback compared to security risk assessment parameters that are explicitly defined with clear characteristics (Abdelfattah et al., 2022). Moreover, the dynamic nature of security risks in the maritime industry can overtake the effectiveness of the tool if it is not frequently renovated. Finally, utilizing RAMT effectively necessitates maritime security expertise and training, as inadequate information may misinterpret the outputs and lead to incorrect security risk assessments. Therefore, it is crucial to admit these limitations and increment RAMT with surplus tools, information, and maritime security expert judgment to ensure a comprehensive and accurate security risk assessment of maritime assets. RAMT persists as a valuable reference for evaluating maritime security risks (IMO, 2021a). Thus, it should be complemented with tailored security risk assessment approaches to ensure a detailed assessment, particularly concerning MTV and its MTC. Figure 3 shows the structure of the RAMT common steps.

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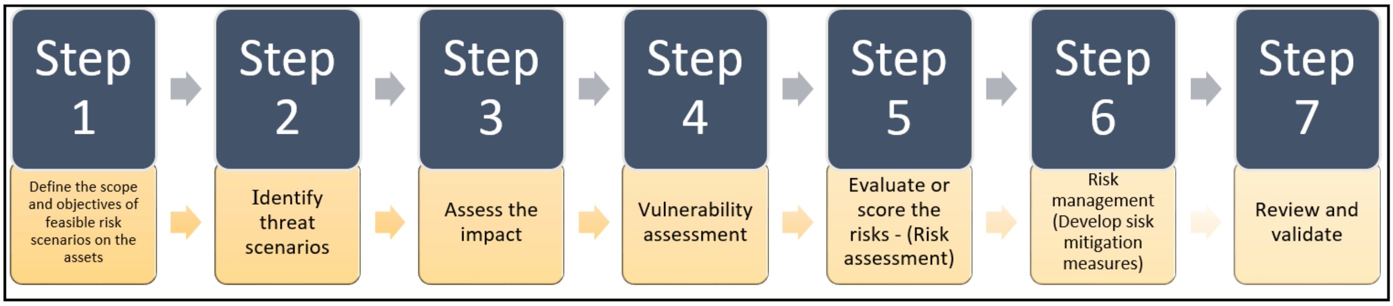

Fig. 3. Structure of the RAMT common steps (IMO, 2008;IMO, 2021a).

COMPARISON OF SECURITY RISK ASSESSMENT APPROACHES

In this essential period for the transformation to the smart maritime industry, strategic solutions are imperative to ensure an effective and sustainable future in this vital sector. This perspective forces one into an inclusive exploration of security risk assessment approaches tailored for MTVs and their MTCs. What becomes obvious at this instant is a lack of introspection in security transactions and security risk assessment approaches. There is a lack of variety and specificity tailored for MTVs and their MTCs to effectively implement their security plan. Table 2 provides a comprehensive comparative analysis of the three selected security risk assessment approaches (STPA/STPA-Sec, TRAM, and RAMT).

Table 2: Comparison of Three Candidate Security Risk Assessment Approaches for Evolving MTVs and their MTCs

Approach	STPA/STPA-Sec	TRAM	RAMT
Technique	Primarily qualitative and could be combined with quantitative analysis techniques (Mixed method)	Quantitative simplified	Quantitative
Purpose /Key Concepts of the Analytical Approach and Procedure Steps	• Aims to identify and analyze the causal relationships between various elements of the potential complex system-level for security risk structure, behavior, and environment, including threats, vulnerabilities, and consequences, through a common eight steps to develop a comprehensive understanding of the system risk assessment and inform risk management strategies.	• Identify and assess the likelihood and the impact of threats and risks specific to the maritime security for the relationship between the port facility and the ships within a port or maritime environment through a common seven steps.	• Utilizes a systematic comprehensive approach to assess and analyze security risks for threats and vulnerabilities in the maritime sector through common seven steps for assessing the security risk for the critical maritime structures.
Application Scope	• Utilized inside the maritime industry and primarily used for security analysis in critical complex systems.	• Recommended for the maritime industry, including shipping, ports, and related operations.	• Recommended for the maritime industry, includes most port facilities, small to medium-sized ports, mobile drilling units, and most ships.
Reference Source	• Issued in the Handbook by Nancy Leveson, and utilized by the U.S. Navy analysis for assessing the cybersecurity risks to MTVs.	• Issued in ILO/IMO Security in ports Code of practice, to protect assets, infrastructure, and personnel.	• Issued in the IMO guidances to maritime security and the ISPS Code 2008/2012/2021 editions, to assist national authorities in undertaking risk assessments.
Risk Equation	Tailored Matrix by experts based on a risk equation (Risk = Threat x Vulnerability x Consequence)	Risk = Threat x Vulnerability x Impact	Risk = Threat x Impact x Vulnerability

Pros	• Developed specifically for security assessment, to determine how to find the inadequate control that caused an accident and how to find the inadequate control in a design. • Identifies the goal and considers complex interactions within maritime system boundaries and potential failures from a security perspective. • Considers the role of human operators in the system, which is particularly relevant for MTV and MTC since the level of autonomy may vary between different systems and situations. • Identifies risks in a top-down approach and proposes a structured framework for risk assessment. • Lists system states or conditions that with the environmental worst-case scenario, lead to an unacceptable loss. • Lists the controls by presence (passive) and the controls by action (active) through detection, measurement, diagnosis, or response. • Lists conditions when each control action or their lack creates a risk. • Lists risk through degradation over time.	• Focuses primarily on maritime-specific threats and risks, and provides a structured approach tailored for maritime security risk assessment. • Identifies risks in a top-down approach and proposes a structured framework for risk assessment • Simple to use and easy to apply. • Considers specifically the risk of terrorist attack, sabotage, intrusion, etc. • Uses a matrix to assess the likelihood of occurrence and potential impact of each identified risk and then assigns a risk rating based on these factors, which could be utilized for the MTVs and their MTCs as a guidance matrix. • Provides a structured and systematic way to identify and evaluate risks and helps to prioritize mitigation measures to reduce the likelihood and impact of potential security risk incidents. • A helpful tool for resource allocation, planning, emergency planning, and budgeting may be such an analysis that could be utilized as guidance for MTVs and their MTCs.	• Focuses primarily on maritime-specific threats and risks, and provides a structured approach tailored for maritime security risk assessment. • Assists in conducting comprehensive risk assessments for maritime security threats and vulnerabilities, which could benefit the MTVs and their MTCs assessment. • Identifies risks in a top-down approach and proposes a structured framework for risk assessment.
Cons	• Lists causal scenarios and additional constraints for risk evaluation from the unsafe control action analysis. • Can identify error types, such as crosslinking factors causing errors, which are not readily determinable through other approaches, which could benefit the MTVs and their MTCs assessment. • Uncovered practical and relatively probable scenarios that led to specific failures previously considered unlikely in the official risk assessment is not a quantitative method, so it cannot be used to calculate the exact probability or severity of risks alone. It requires a high level of expertise and knowledge of the system being analyzed. • Can be subjective, depending on the experience and judgment of the analysts. • Does not consider non-safety but security-critical issues (e.g., data confidentiality) and lacks efficient guidance for identifying information security concepts. • Can be time-consuming and resource-intensive. • Does not concentrate on the appropriate countermeasures, this reflects that it should be modified before utilization specifically before utilization for MTV and their MTC. • The primary emphasis of STPA/STPA-Sec lies in the reactive detection of scenarios that may lead to losses, rather than adopting a proactive approach. • The acceptable risk score is not mentioned. • Does not incorporate a threat model to consider new causal factors such as criticality, reliability, cost-benefit evaluation, human elements, and environmental considerations that were not indicated or primarily required. • May require adaptation to suit specific national or local contexts. • The dynamic nature of risks in the maritime industry can outpace the tool's effectiveness if it is not regularly updated. • Utilizing STPA/STPA-sec effectively requires expertise and training, as insufficient knowledge may lead to inaccurate assessments or misinterpretation of outputs. • The degree of acceptable risk does not effectively reflect the degree of acceptable risk that can be relied upon. • STPA/STPA-Sec does not eliminate all the problems associated with standard risk matrices generated by expertise, but it just does offer a more logical foundation for categorizations. • STPA analysis examined non-failure scenarios and did not assume perfect behavior on the part of the crews. • STPA/STPA-Sec faces challenges in identifying complex autonomous systems' dynamic status changes.	• The concrete aspects that could affect security are not being valued. • The evaluation of the vulnerabilities is unspecific and very general. • The consequences are valued in a very global way, specific damage to human life or environmental damage, etc., are not valued although it seems that in an implicit form. • To preserve its efficacy should be updated as frequently as changing circumstances may need from the maritime security perspective. • The acceptable risk score is not mentioned • May require adaptation to suit specific national or local contexts. • Availability and quality of data can pose challenges, as accurate and up-to-date. information is crucial but not always readily accessible. • Subjective judgment plays a role in risk assessments. • The tool also has a limited scope, focusing primarily on operational and technical aspects while neglecting other important factors such as criticality, reliability, cost-benefit evaluation, human elements, and environmental considerations that were not indicated or required. • The dynamic nature of risks in the maritime industry can outpace the tool's effectiveness if it is not regularly updated. • Utilizing TRAM effectively requires expertise and training, as insufficient knowledge may lead to inaccurate assessments or misinterpretation of outputs.	• May require adaptation to suit specific national or local contexts. • Availability and quality of data can pose challenges, as accurate and up-to-date information is crucial but not always readily accessible. • RAMT employs simplified models and assumptions, potentially oversimplifying complex risk factors and failing to capture the unique characteristics of specific assets or environments. • The evaluation of the impacts lacks parameters and inaccuracy in determining the distinctive criteria. • Subjective judgment plays a role in risk assessments. • The tool also has a limited scope, focusing primarily on operational and technical aspects while neglecting other important factors such as criticality, reliability, cost-benefit evaluation, human elements, and environmental considerations that were not indicated or required • The vulnerability assessment used in RAMT does not refer to specific assessment parameters but rather mentions them broadly. • The dynamic nature of risks in the maritime industry can outpace the tool's effectiveness if it is not regularly updated. • Utilizing RAMT effectively requires expertise and training, as insufficient knowledge may lead to inaccurate assessments or misinterpretation of outputs. • The degree of acceptable risk does not effectively reflect the degree of acceptable risk that can be relied upon.

Threat Assessment	• Threat scoring for potential targets into three levels and may vary based on the implementation and customization of the approach for a particular maritime system or context. • A structured approach to security threats analysis that can help identify potential security threat factor group and their associated parameters. • Break down the maritime system into its constituent components, such as vessels, ports, communication systems, surveillance systems, and personnel. Analyze how these components interact and depend on each other. • Consider various threat categories relevant to maritime security, including but not limited to terrorism, piracy, smuggling, sabotage, cyber-attacks, insider threats, and natural disasters. This broadens the scope of potential threats to be analyzed. • Identify the sources or actors that could pose threats to the maritime system. This may include individuals, criminal organizations, state-sponsored entities, extremist groups, or even environmental factors. • Identify potential security threats associated especially with MTV and its MTC. This involves considering possible security threats.	• Threat focuses on specific potential targets and scores into three levels. • Consider threat scenarios from both internal and external sources to which the identified maritime potential target may be vulnerable. • The maritime potential target needs to determine the level of threats. • The allocation of a particular threat score may be based on specific information received or the known characteristics of the maritime potential target.	• Identifying Threats by focusing on specific maritime potential targets and scoring into four levels of each threat scenario. • Determining the likelihood of each threat occurring based on intent and capability. • Assign the score should reflect the likelihood of each threat scenario occurring if there were no security measures or mitigating controls in place to prevent them.
Vulnerability Assessment	• Vulnerability scoring of potential targets into three levels and may vary based on the implementation and customization of the approach for a particular maritime system or context • Evaluate the components, processes, and security controls of the maritime system to identify vulnerabilities. These vulnerabilities could arise from technological weaknesses, design flaws, procedural gaps, human error, inadequate security measures, or insufficient training. • Determine the likelihood and ease with which each vulnerability can be exploited by potential threats. • Analyze the potential impact that the exploitation of each vulnerability could have on the security objectives of the maritime system's. • Identify vulnerabilities that could be exploited by the identified threats for MTV and MTC. This includes weaknesses in the autonomy system of the ship, the MTC, and the communication links between them.	• The vulnerability assessment scores of four levels and each has its specific descriptor. • The criteria for the vulnerability scoring focus on levels of protection or security measures for the maritime potential target and the effectiveness of existing security measures as general without specifying any specific elements.	• The vulnerability assessment scores of four levels translate the vulnerability assessment into the vulnerability score. • It considers and evaluates the characteristics of potential maritime targets but also the efficacy of early warning indicators, the functionality of embedded monitors, and the effectiveness of existing mitigating controls. By analyzing these aspects, a more robust understanding of the vulnerabilities within the maritime sector can be attained, leading to more effective generic risk management strategies.
Consequences Assessment	• Consequence scoring of the potential maritime target into three levels and may vary based on the implementation and customization of the approach for a particular maritime system or context. • Identify and describe the potential impacts that could result from each threat scenario. Consider both immediate and cascading effects on various aspects of the maritime system, including personnel, infrastructure, operations, environment, reputation, and economic factors. • The consequence component of the risk equation involves assessing the potential consequences of a threat exploiting a vulnerability in the maritime system. Taking into account the interactions between system components and the potential impacts on safety, security, and operations. • The potential consequences of each risk scenario are estimated, based on factors such as the severity of each threat, and their severity is evaluated during or after a successful attack for MTV, and MTC. This includes damage to the MTV or MTC, loss of control, potential harm to human life, environmental impact, economic impact, reputational/social impact, communication failures impact, operational impact, and more.	• The consequences/impact of an incident scores five levels and the criteria for the scoring are focused on the nature of loss. • Provide flexibility to alter consequences score as well.	• The impact assessment scores four levels and each score has its specific descriptor. • Considering what the impact of each threat scenario materializing would be and how much effect this would have.

Assessment Outcome	• Conduct a risk assessment to determine the risk level for each risk scenario based on the likelihood and potential consequences of security incidents. This allows prioritization of the potential risks for MTV and MTC for mitigation efforts. • Determine the level of risk associated with each potential threat scenario. This can be done using an expert's expert-designed risk matrix, which could map the likelihood and consequences on a scale to determine the risk level (Primarily qualitative). • Supports decision-making processes, resource allocation, and the implementation of effective security measures in the maritime industry. • It helps organizations proactively address risks, enhance security posture, and safeguard critical maritime assets, operations, and personnel.	• The assessment outcome is reflected as a risk score. • The scoring is derived from the multiplication of the scoring of threat, vulnerability, and impact. • The acceptable risk score is not mentioned, thus it is left to the port facility/port/maritime entity (maritime critical assets e.g. MTVs and their MTCs) to determine. • Tabulating and listing the scores for each threat against each potential target will assist in assessing the priority in which to deal with each potential incident. • Identify risks so that countermeasures can be performed and suggested to avoid, recognize, and minimize the effects of any possible crisis, should it occur.	• Risk scoring assesses the security risk given all the factors noted and their associated parameters e.g. MTVs and their MTCs. • Risk can be ranked into three broad categories (high, medium, and low), with a residual risk score
Mitigating Action	• Implement the security controls that have been identified and analyzed, ensuring that they are properly configured and maintained for mitigation actions. • By employing STPA, The maritime industry can strengthen its security measures, reduce vulnerabilities, and enhance the overall resilience of the maritime system. • Verify that the security requirements are effective and feasible by testing and evaluating the maritime system. This can involve conducting security drills and exercises, as well as ongoing monitoring and evaluation of the security performance of the maritime system. • Generate recommendations to mitigate the identified security risks for the maritime systems that should be applied. These could be modifying the maritime system design, improving access controls, and enhancing security procedures.	• Mitigation options involve lowering the risk score by decreasing vulnerability, impact score, or both through targeted mitigation activities or initiatives. • The compilation of all potential maritime targets into a master matrix, grouping them based on similar threat scenarios, and identifying common security measures aims to maximize the benefits of risk mitigation actions.	• The risk management phase evaluates how to effectively and practically address weaknesses identified during vulnerability and risk scoring, implementing sustainable, long-term mitigation strategies. • Collaborative efforts among stakeholders are essential to reaching a consensus on joint tactical action plans for effective risk mitigation.

DISCUSSION

The deliberate selection of these approaches is based on industry recommendations and practices. They were chosen based on their adoption within the maritime sector-related security guidances and publications out of their belief in their effectiveness in identifying security risks through their main factor groups and their associated parameters of the risk equation. This analytical discussion aims to determine the differences, strengths, and limitations of each approach, contributing to a deeper understanding of their applicability in the context of security risk assessment for the practices of transformation in the maritime industry, particularly concerning ships such as the MTV.

Each approach identifies separate sets of security risks and presents the differences between them, gaps, limitations, and strengths. These approaches provide a structured framework for comprehensive security risk assessment for maritime targets. STPA/STPA-Sec emerges as a remarkable approach, considering the crucial role of human operators, detailing system conditions in worst-case scenarios, and incorporating a list of risks through degradation over time from the perspective of risks that could be relevant to the varying autonomy levels onboard ships such as the MTVs and their MTCs. Its ability to identify complex security risk types, like cross-linking factors, provides an accuracy in understanding not easily attainable through alternative security risk assessment approaches.

Additionally, the important linkage of STPA/STPA-Sec to innovative technological security risk assessment, particularly in assessing cyber-attack parameters within its threat factor group, enhances its applicability to the evolving landscape of MTVs and their MTCs. However, STPA/STPA-Sec's demanding requirement for high expertise and system knowledge, coupled with its subjective and time-consuming nature, presents challenges. Rather than adopting a proactive perspective, the approach's reactive detection of scenarios further adds complexity. It encounters difficulties in identifying dynamic status changes in complex autonomous systems. Nevertheless, the STPA-Sec requires tailored evaluation matrices for a more comprehensive analysis and vulnerability scoring. This continual need for customization may be seen as a limitation, requiring extra efforts from maritime security professionals to manage explicit maritime security risk concerns more accurately. This may be reflected in the lack of effective guidance to define information security concepts for security risk assessments of ships and also includes high exposure to the subjectivity factor.

In contrast, TRAM and RAMT offer simplicity and ease of application. The matrix-based security risk assessment of TRAM provides a valuable guidance matrix for MTVs and their MTCs, aiding in resource allocation and budgeting, a feature not shared by other approaches, whereas the acceptable risk score is not mentioned for further mitigation opportunities. Moreover, the quantitative value is represented as numerical values for the calculated security risk scenario. When applied to ships such as MTVs and their MTCs, the approach offers prioritization for security risk scenarios, yet lacks the integration of stakeholders' priorities within the goal objectives to be reflected in the ranking score. Thus, it does not indicate a clear reflection of whether the level of risk is high, medium, or low. Additionally, the evaluation of the vulnerabilities and consequences factor groups are unspecific and valued in a very global way. Sequentially, the associated vulnerability and consequence security risk parameters may not be explicitly defined, constantly remaining implicitly addressed. This implicit-based nature could pose a significant limitation and gaps when utilizing this approach for assessing MTVs and their MTCs. Furthermore, this would require expertise training, as insufficient knowledge may lead to inaccurate maritime security risk assessments or misinterpretations of outputs for the MTVs and their MTC's assessment.

Meanwhile, RAMT contributes to comprehensive security risk assessments, aligning with maritime industry recommendations. At the same time, RAMT's simplified models and assumptions may oversimplify risk factors, potentially overlooking the unique characteristics of specific maritime assets. This may have a negative impact on the scope of the MTVs and their MTCs as a whole and their main components partially. This is also reflected in the criticality scores and reliability criteria of the maritime assets undergoing the assessment process in subsequent security risk assessments if this approach is used to evaluate MTVs, MTCs, or related critical and reliable components. This approach has shortcomings in integrating these parameters, whether explicitly or implicitly within the main factor groups of the security risk assessment equation that assesses security risks if they are applied to MTVs and their MTCs.

The study recommendation based on these potential integration of the effectiveness of the chosen approaches lies in the absence of regular updates. However, the common absence of explicit security risk assessment parameters, such as cost-benefit assessment or security environmental considerations, can also pose limitations in the evaluation of the dynamic smart maritime industry. Also, the availability and quality of data can pose challenges. Considering these observations, a recommended security risk assessment approach for ships such as MTVs and their MTCs involves proposing a regularly updated matrix. The main finding of this study emphasizes that the chosen security risk assessment approaches bring significant gaps and limitations, both in their individualities and shared structural characteristics and values. The differences in the associated parameters integrated into their main factor groups for the risk equation of these approaches significantly influence their potential efficacy, highlighting the need for a critical reassessment of these parameters to enhance security risk assessment for the practices of transformation of the maritime industry to the MTVs and their MTCs.

Still, there are shortages in security analysis related to detecting potential security threats that can confront these different levels of automation related to those types of ships such as MTVs and their MTCs. Proposed security risk assessment approaches for ships such as MTVs and their MTCs, should incorporate a threat model, accounting for new causal factors or parameters such as reliability, criticality, resilience, geopolitical dynamics, and confidence in autonomous system considerations. Selection and regular training of maritime security experts are crucial, as inadequate knowledge may lead to inaccurate assessments. Assigning degrees of acceptable risks for each security risk scenario and associated parameters (threat, vulnerability, consequences) is essential. Efforts should be made to minimize subjective judgment in conducting security risk assessments for ships such as MTVs and their MTCs.

CONCLUSION

Recent amendments and increased emphasis on maritime security guidelines by the IMO and stakeholders signify progress; however, a gap remains in effectively integrating technological advancements and security risk assessment approaches. This shortfall impedes exploring innovative opportunities and formulating guiding security risk assessment approaches for ships such as MTVs and their MTCs toward the development of the smart maritime industry.

The tangible gaps in security risk assessment arise from both the rapid evolution of ships, ports, and facilities and the security risks. Simultaneously, the search for comprehensive risk assessment approaches supported by maritime authorities becomes challenging due to complex developments within the smart maritime industry. Researchers in this specialized domain, particularly concerning MTVs and their MTC, recognize the need for collaborative efforts that would contribute to the development of future-proof and diverse security risk assessment approaches, specifically tailored for automated ships, smart ports, and port facilities. These efforts should aim to serve as a foundational framework for comprehensive security risk assessment approaches in the evolving landscape of smart industries within the maritime sector. Future research in this field is expected to call for the adoption of a robust standard for integrated security risk assessment in the context of MTVs and their MTCs. This adoption would involve incorporating specific security risk factor groups and their associated parameters to customize the assessment procedures accordingly.

REFERENCES

Abdelfattah, M., Elsayeh, M.E. and Abdelkader, S. (2022) 'A proposed port security risk assessment approach, with application to a hypothetical port', *Australian Journal of Maritime and Ocean Affairs*, 14(1). Available at: https://doi.org/10.1080/18366503.2021.1909206.

Afenyo, M. and Caesar, L.D. (2023) 'Maritime cybersecurity threats: Gaps and directions for future research', *Ocean and Coastal Management*. Available at: https://doi.org/10.1016/j.ocecoaman.2023.106493.

Amro, A. and Gkioulos, V. (2023) 'Cyber risk management for autonomous passenger ships using threat-informed defense-in-depth', *International Journal of Information Security*, 22(1). Available at: https://doi.org/10.1007/s10207-022-00638-y.

Bichou, K. (2009) 'Security and Risk-based Models in Shipping and Ports: Review and Critical Analysis', in. Available at: https://doi.org/10.1787/9789282102329-6-en.

Bueger, C. (2015) 'What is maritime security?', *Marine Policy*, 53. Available at: https://doi.org/10.1016/j.marpol.2014.12.005.

Bueger, C., Edmunds, T. and McCabe, R. (2020) 'Into the sea: capacity-building innovations and the maritime security challenge', *Third World Quarterly*, 41(2). Available at: https://doi.org/10.1080/01436597.2019.1660632.

Carreras Guzman, N.H. *et al.* (2021) 'A Comparative Study of STPA-Extension and the UFoI-E Method for Safety and Security Co-analysis', *Reliability Engineering and System Safety*, 211. Available at: https://doi.org/10.1016/j.ress.2021.107633.

Chaal, M. *et al.* (2020) 'A framework to model the STPA hierarchical control structure of an autonomous ship', *Safety Science*, 132. Available at: https://doi.org/10.1016/j.ssci.2020.104939.

Dekker, S. and Stevens, H. (2007) 'Maritime security in the European Union - Empirical findings on financial implications for port facilities', *Maritime Policy and Management*, 34(5). Available at: https://doi.org/10.1080/03088830701585274.

'Engineering a safer world: systems thinking applied to safety' (2012) *Choice Reviews Online*, 49(11). Available at: https://doi.org/10.5860/choice.49-6305.

Glomsrud, J.A. and Xie, J. (2020) 'A structured STPA safety and security co-analysis Framework for autonomous ships', in *Proceedings of the 29th European Safety and Reliability Conference, ESREL 2019*. Available at: https://doi.org/10.3850/978-981-11-2724-3_0105-cd.

González-Gutiérrez, A. *et al.* (2022) 'The identification and analysis of risks for civilian ports adapted to military uses', *Ocean and Coastal Management*, 227. Available at: https://doi.org/10.1016/j.ocecoaman.2022.106276.

Harkleroad, E., V.A.& K.J. (2013) *Review of Systems-Theoretic Process Analysis (STPA) method and results to support NextGen concept assessment and validation*. Washington.

Herbert-Burns, R., Bateman, S. and Lehr, P. (2008) *Lloyd's MIU Handbook of Maritime Security*, *Lloyd's MIU Handbook of Maritime Security*. Available at: https://doi.org/10.1201/9781420054811.

'IAPH Cybersecurity Guidelines for Ports and Port Facilities' (no date). Available at: https://sustainableworldports.org/wp-content/uploads/IAPH-Cybersecurity-Guidelines-version-1_0.pdf.

ILO/IMO (2004) *Security in ports. Code of practice*. Available at: https://www.ilo.org/global/publications/ilo-bookstore/order-online/books/WCMS_PUBL_9221152863_EN/lang-en/index.htm.

IMO. (2008). Non-Mandatory Guidelines on Security Aspects of The Operation of Vessels Which do Not Fall Within The Scope of Solas Chapter XI-2 and The ISPS Code [Online]. Available: https://wwwcdn.imo.org/localresources/en/OurWork/Security/Documents/MSC.1%20Circ.1283.pdf [Accessed 10 May 2023].

IMO. (2011). MEASURES TO ENHANCE MARITIME SECURITY - Maritime Security Manual - Guidance for port facilities, ports and ships MSC 89/INF.13 [Online]. Available: https://portalcip.org/wp-content/uploads/2019/07/Guide-to-Maritime-Security-and-the-ISPS-Code-2012.pdf [Accessed 2 MAY 2023].

IMO (2017a). Guidelines on Maritime Cyber Risk Management. International Maritime Organization London, UK.

IMO (2017b). Report of the Maritime Safety Committee on Its Ninety-Eighth Session. MSC 98/23.

IMO (2018a). " Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS). MSC 99th session, MSC, 99.

IMO. (2021a). Guide to Maritime Security and the ISPS Code 2021 Edition [Online]. Available: https://www.imo.org/en/OurWork/Security/Pages/SOLAS-XI-2%20ISPS%20Code.aspx [Accessed 1 April 2023].

IMO. (2022). Maritime Safety Committee (MSC 106) for MASS code , 2-11 November 2022. MSC 106 adopted a new amendments to mandatory instruments for MASS Code [Online]. Available: https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MSC-106.aspx [Accessed 1 February 2023].

IMO, M. (2018b). " Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS). MSC 99th session, MSC, 99.

IMO, M. C. (2021b). Outcome of the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS) (No. MSC.1/Circ.1638). IMO London, UK.

Khafendi, K. (2020) 'Evaluasi Penerapan ISPS Code di Pelabuhan Bitung', *Jurnal Penelitian Transportasi Laut*, 18(1). Available at: https://doi.org/10.25104/transla.v18i1.1397.

Leveson, N. (2019) 'Improving the Standard Risk Matrix using STPA', *Journal of System Safety*, 55(2). Available at: https://doi.org/10.56094/jss.v55i2.44.

Lim, G.J.*et al.* (2018) 'Models and computational algorithms for maritime risk analysis: a review', *Annals of Operations Research*, 271(2). Available at: https://doi.org/10.1007/s10479-018-2768-4.

'Maritime Safety Committee (MSC 106), 2-11 November 2022' (2022). Available at: https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MSC-106.aspx.

McCartan, S. *et al.* (2018) 'A modular search and surveillance ses platform to support port and harbour security in the future megacities of 2050', in *RINA, Royal Institution of Naval Architects - SURV 9 - Surveillance, Search and Rescue Craft, Papers*.

Mukherjee, P.K. (2007) 'The ISM Code and the ISPS Code: A critical legal analysis of two SOLAS regimes', *WMU Journal of Maritime Affairs*, 6(2). Available at: https://doi.org/10.1007/BF03195110.

N. Leveson, J.T. (2018) 'STPA_Handbook', *MIT, Cambridge* [Preprint].

Rødseth, Ø.J. *et al.* (2023) 'The Societal Impacts of Autonomous Ships: The Norwegian Perspective', in. Available at: https://doi.org/10.1007/978-3-031-24740-8_18.

Romero Faz, D. and Camarero Orive, A. (2016) 'Security assessment in harbours: parameters to be considered', in. Available at: https://doi.org/10.4995/cit2016.2016.3181.

Romero-Faz, D. and Camarero-Orive, A. (2017) 'Risk assessment of critical infrastructures – New parameters for commercial ports', *International Journal of Critical Infrastructure Protection*, 18. Available at: https://doi.org/10.1016/j.ijcip.2017.07.001.

Romero-Faz, D.& C.-O.A. (2015) 'New Indices of Risk Assessment for Security in Port Infrastructures', *International Journal of Engineering and Advanced Research Technology (IJEART) ISSN: 2454-9290*, 1(5).

Ruddle, A., W.D., W.B., I.S., R.Y., F.M., L.T., F.A., G.S.& H.O. (no date) 'Security requirements for automotive on-board networks based on dark-side scenarios', *EVITA project*.

Sahay, R. *et al.* (2023) 'A comparative risk analysis on CyberShip system with STPA-Sec, STRIDE and CORAS', *Computers and Security*, 128. Available at: https://doi.org/10.1016/j.cose.2023.103179.

Smelikova, V. and Penza, I. (2023) 'Implementation of the ISPS Code provisions in maritime English course for future navigators', *Australian Journal of Maritime and Ocean Affairs*, 15(3). Available at: https://doi.org/10.1080/18366503.2022.2069073.

Stavrou, D.I., Ventikos, N.P. and Yang, Z.L. (2018) 'Benchmarking container port security risks by applying a FIS methodology', in *International Journal of Shipping and Transport Logistics*. Available at: https://doi.org/10.1504/ijstl.2018.10014638.

Sun, L., Li, Y.F. and Zio, E. (2022) 'Comparison of the HAZOP, FMEA, FRAM, and STPA Methods for the Hazard Analysis of Automatic Emergency Brake Systems', *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part B: Mechanical Engineering*, 8(3). Available at: https://doi.org/10.1115/1.4051940.

Thieme, C.A., Utne, I.B. and Haugen, S. (2018) 'Assessing ship risk model applicability to Marine Autonomous Surface Ships', *Ocean Engineering*. Available at: https://doi.org/10.1016/j.oceaneng.2018.07.040.

Torkildson, E.N. *et al.* (2018) 'Empirical studies of methods for safety and security co-analysis of autonomous boat', in *Safety and Reliability - Safe Societies in a Changing World - Proceedings of the 28th International European Safety and Reliability Conference, ESREL 2018*. Available at: https://doi.org/10.1201/9781351174664-369.

Utne, I.B. *et al.* (2020) 'Towards supervisory risk control of autonomous ships', *Reliability Engineering and System Safety*, 196. Available at: https://doi.org/10.1016/j.ress.2019.106757.

Valdez Banda, O.A. and Goerlandt, F. (2018) 'A

STAMP-based approach for designing maritime safety management systems', *Safety Science*, 109. Available at: https://doi.org/10.1016/j.ssci.2018.05.003.

Veitch, E. and Andreas Alsos, O. (2022) 'A systematic review of human-AI interaction in autonomous ship systems', *Safety Science*, 152. Available at: https://doi.org/10.1016/j.ssci.2022.105778.

Venus Lun, Y.H. *et al.* (2023) *Shipping and Logistics Management*, *Shipping and Logistics Management*. Available at: https://doi.org/10.1007/978-3-031-26090-2.

Wróbel, K., Montewka, J. and Kujala, P. (2018) 'System-theoretic approach to safety of remotely-controlled merchant vessel', *Ocean Engineering*, 152. Available at: https://doi.org/10.1016/j.oceaneng.2018.01.020.

Zhang, W., Zhang, Y. and Zhang, C. (2024) 'Research on risk assessment of maritime autonomous surface ships based on catastrophe theory', *Reliability Engineering and System Safety*, 244. Available at: https://doi.org/10.1016/j.ress.2024.109946.

Zhou, X.Y. *et al.* (2021) 'A system-theoretic approach to safety and security co-analysis of autonomous ships', *Ocean Engineering*, 222. Available at: https://doi.org/10.1016/j.oceaneng.2021.108569.

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Measuring the Impact of Covid-19 Pandemic and the Russian Ukrainian War on Dry Bulk Freight Market

Zaid Shaker Abuhamour[1] and Ahmed Ismail Ahmed Hafez[2],

[1] Broker at Eurasian Maritime Ltd. PhD Researcher at Arab Academy for Science, Technology and Maritime Transport (AASTMT)

[2] Institutional Research Department, Arab Academy for Science, Technology and Maritime Transport.

Emails: yaseenahmedismail@gmail.com, Zaed@hotmail.com

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ABSTRACT

Purpose: *Covid-19 pandemic stands as a monumental disaster in human history, reshaping the global landscape and profoundly impacting various sectors of human life, most notably the world economy. The repercussions of the pandemic were felt acutely, resulting in significant disruptions marked by the variation of demand and supply and the effect on the supply chain. Furthermore, the conflict arising from Russia's invasion of Ukraine instigated a new global economic crisis, particularly in Europe. This war exerted a substantial toll on global economic growth, further compounded by the lingering consequences of Covid-19 pandemic.*

Approach/Design/Methodology: *This research aims to investigate and analyze the impacts of the Russian Ukrainian war and Covid-19 pandemic; on the dry bulk freight market within the shipping industry during the period from 2019 to 2022. An electronic questionnaire was conducted, 472 samples were analyzed using SPSS. The study encompasses ship owners, ship operators, charterers, shipbrokers, investors engaged in the shipping business specially the dry cargos, international traders, importers, exporters, and governmental entities.*

Findings: *The results show that Covid-19 pandemic had a negative impact on the bulk freight market as the freight decreased all over the world; and the Russian Ukrainian war had a negative impact on the dry bulk freight market as the freight increases suddenly all over the world.*

Key-words:
Covid-19, Russian Ukrainian War, Dry Bulk Freight Market.

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INTRODUCTION

Maritime transport is responsible for ninety percent of total worldwide trade volume, which is considered the lifeline of the worldwide economy. Moreover, there could be no trade between the continents of the world without maritime transportation in terms of raw materials, food or manufactured items will be feasible (UNCTAD, 2018). The shipping industry consists of four interlinked shipping markets, which can be categorized as follows: The freight market, second-hand vessels market, new building market, and vessel demolition market. The freight market has sectors like tankers, passenger, containers, heavy lift, and dry Bulk. As it can be affected by supply and demand, world economy status, international maritime trading, and fuel prices also it can be affected by the other shipping industry elements.

The shipping sector is divided into various separate market niches, each with its own traits, levels of competition, and levels of competitiveness. Commodities are traded internationally, and there are many distinct types of commodities that are traded. It is impossible to overestimate the importance of both wet and dry bulk commodities. Dry bulk commodities make up over 66% of all seaborne trade globally when the volume of cargo transported by sea is totaled, and as of 2015, dry bulk cargo still accounts for around two-thirds of all seaborne trade internationally. The estimated four billion tons of bulk dry cargo that are shipped by sea serve as a reminder of the sector's importance and the fact that without it, there would be no viable global trade or industry. Dry bulk transportation is one of the global industries with the highest levels of competitiveness (Abrahamsson, 2019).

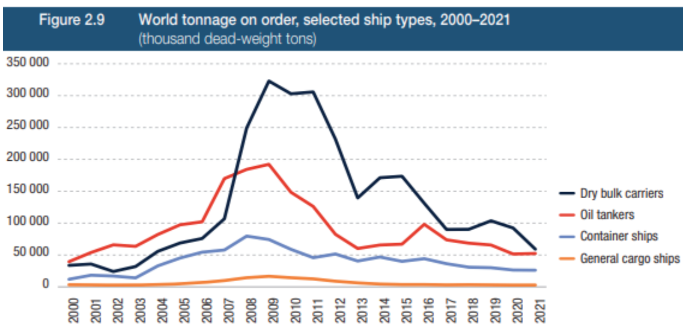

Fig. 1. World tonnage on order selected by ship types from 2000 to 2021.
Source: UNCTAD, 2021.

About 71% of the world's shipping is made up of dry bulk, with the second largest segment oil taking only 17%. Additionally, the Baltic Dry Index (BDI), which measures the performance of the dry bulk shipping market, is frequently employed. The BDI also functions as a global economic indicator. A high BDI value is an indicator of a strong economic climate in both the dry bulk shipping sector and the global market since dry bulk shipping accounts for 60% of all worldwide traffic in goods (Xu et al., 2021). Furthermore, because worldwide demand drives the shipping industry, it is susceptible to a variety of unforeseen events or shocks, which results in significant volatility and dangers. Volatility also increases when global problems arise. It is obvious that there are greater dangers associated with global difficulties in the dry bulk shipping business. Consequently, it is crucial to anticipate market risk during a global incident (Cho et al., 2020).

LITERATURE REVIEW

In the early 2020, seaborne trade suffered from Covid-19 pandemic; freight rates in shipping were severely impacted and continued to be influenced by how supply capacity was managed. Dry bulk freight costs were impacted by the shock of low demand, mainely from China, due to the outbreak of the coronavirus. During the first six months of 2020, the market for dry bulk freight rates were influenced by supply and demand mismatches, which were exacerbated by the impact of the pandemic and resulted in considerable swings, particularly among larger vessels. Overcapacity was already affecting the dry bulk market, since supply growth had been outpacing demand for several years, as previously discussed.

This worsened by the negative demand shock of the pandemic, which put downward pressure on shipping freight rates (UNCTAD, 2021), and the noticeable rise in global oil prices, which reached 130 per barrel in March 2022, as well as the 40% increase in basic food commodities, particularly wheat, to reach 396 dollars per ton, and the 21% increase in corn prices as a result of the disruption in agricultural export movement in Ukraine, due to an increase in the insurance premiums required for shipping goods, shipment delays, and port congestion, the Black Sea has been classified as a risky area because marine fuel prices are tied to oil prices, ship charter fees have increased by almost 20%. Dong (2021) mentioned the impact of Covid-19 on Chinese shipping firms and government-promoted countermeasures, as well as an examination of how this pandemic affects shipping company operations and recommendations for them. Furthermore, the impact of this outbreak on China and other nations is an effect on a quickly shifting global supply chain, which is why so many countries are implicated and in such a tricky situation. Besides, when Covid-19 occurred, shipping businesses encountered greater difficulties. Then, inspired by and related to the similarities of the 2008 economic crisis, the attention shifted to whether and how financial flexibility could affect shipping businesses and their performance following a pandemic.

Ho et al. (2021) used monthly panel data from 13 Chinese provinces (cities) from December 2019 to August 2020 to investigate the impact of Covid-19 on Chinese freight transport evidence, and analyzed the overall impact of the epidemic on China's freight transport from a macro-level perspective, contributing to the pandemic literature, the empirical findings filled gaps in the Covid-19 transport literature by supporting new consumption behavior during the Covid-19 outbreak, and the researchers used the multi-region demand model to examine the impact of Covid-19 on China's freight transport. However, the findings revealed that Covid-19 has a positive impact on road freight transport turnover; this effect is stronger when there are more verified Covid-19 instances and less gasoline production, and vice versa; moreover, these findings were robust when various dependents and independents were used.

Worldwide, Covid-19's economic effects have had an impact on a wide range of sectors and services. The slowdown in the global GDP, the drop in oil prices, and the disruptions to the supply chain are all indicators of how serious this epidemic is. Examining the trade activities of the top fifteen nations also demonstrates how Covid-19 has affected global commerce. When compared to the first quarter of 2018, the trading density dropped from 0.833 to 0.429. Every element of the global economy can clearly see how Covid-19 has reduced commercial activity (Xu et al., 2021).

International trade naturally decreased by a cliff's worth of percentage points because of the enormous hit to the world economy. The maritime sector took the heaviest hit from this health epidemic as it was the principal carrier of global trade. Liner firms canceled trips to save money when there was no demand for transportation (Marobhe, 2021). Dry bulk is shipped by land and rail to ports. Covid-19 outbreak-related initiatives had a substantial impact on every dry bulk trade mechanism throughout the pandemic. This condition had a significant impact on international sea transportation trade since governments banned transport connections with other nations based on physical distance restrictions (Wang et al., 2022). Based on the previous studies that were illustrated, the study can assume the hypothesis of the study, which is that there is a statistically negative relationship between Covid-19 on dry bulk freight market.

As Russia invaded Ukraine in 2022, geopolitical tensions between the West and Russia rose, lowering global growth expectations because it was uncertain how the battle would affect the global supply chain. The global economy is affected by the sanctions that the Western nations have placed on Russia. Conflict has triggered shocks in the trade, energy, and commodity markets as well as an increase in the price of commodities, energy, food which has resulted in worldwide inflation in many nations (Balbaa et al., 2022).

Food supplies such as wheat, corn, and edible oils have been affected, as has the global consumer products industry (sunflower oil). A quarter of all exports from the area come from the export of wheat, which is one of the top exports from both Ukraine and Russia. While Ukraine is the only country that supplies most of China's corn needs, these two economies provide over 70% of the grain needed by nations like Turkey and Egypt. Approximately 50% of the total global export of sunflower oil is said to come from Ukraine, making it the largest exporter worldwide (Prakasa et al., 2022). These costs of the products, as well as those of other agricultural products that rely on those crops as raw materials, have increased dramatically due to a lack of them on the world market. According to short-term perspective research released by the European Commission, most EU countries are ready for increased pressure on the agri-food business. For instance, it is anticipated that regional milk output will diminish by about 1.5% soon, which will result in a decrease in products like cheese, butter, and other everyday items. Because some raw materials to produce feeds are imported from both Ukraine and Russia, the poultry farming industry is also anticipated to be negatively impacted (Orhan, 2022).

Rožić et al. (2022) investigated the fluctuating freight rates in the maritime container business because of Russia's invasion of Ukraine. Data from scholarly and scientific journals, as well as investigations by the IMO, the European Union, and the United Nations, served as the foundation for the analysis. These enormous rises in freight costs in the maritime container sector, which also have a considerable negative impact on supply chains, put the recovery of the global economy in jeopardy. The expenses of production and the prices of the goods that are dependent on the services provided by this company will be impacted by a rise in freight rates in this market. As was previously said, it is estimated that in 2023 the increase in consumer product prices because of the change in freight rates will be 1.5%. For the least developed nations and islands, this is particularly important. There, the anticipated price rises for consumer items brought on by higher freight costs might reach approximately 9% in 2023. The distance between these nations and the industrialized nations serves as an additional obstacle for these nations, and efforts should be made to lessen this barrier. The European Union has already experienced an ongoing rise in consumer goods prices, which began when the pandemic initial spread and was further exacerbated by Russia's invasion of Ukraine.

Because of the huge disruptions that this invasion—which, tragically, is still causing—has caused, it is anticipated that the process of returning to the pre-crisis scenario would be exceedingly challenging. Increased economies are having to contend with inflationary pressures, financial market imbalances, and problems importing goods from the Russian and Ukrainian markets. The pandemic's disruptions have had an impact on both supply and demand, which emphasizes the need for having a lot of flexibility to lower the dangers from the epidemic and balance demand. Freight prices have gone up since the pandemic initially began but their largest development dynamics were visible in the period right after the beginning of the Russian invasion of Ukraine. Based on prior experiences with crisis situations, it is projected that the disruptions may hinder the dynamics of the recovery of some national economies and will have a higher impact on smaller economies (Rožić et al., 2022).

Allam et al. (2022) clarified that uncertainty has grown because of the ongoing conflict between Russia and Ukraine at a time when the global economy is recovering from the Covid-19 outbreak. The conflict had a significant effect on the tanker market because Russia is a major player in the oil and gas industry, but the impact on the dry bulk industry was less significant because of the small contributions made by both Russia and Ukraine to the global dry bulk trade. Based on the previous studies that were illustrated, the study can assume its hypothesis, which is that there is a statistically negative relationship between the Russian-Ukrainian war on dry bulk freight market.

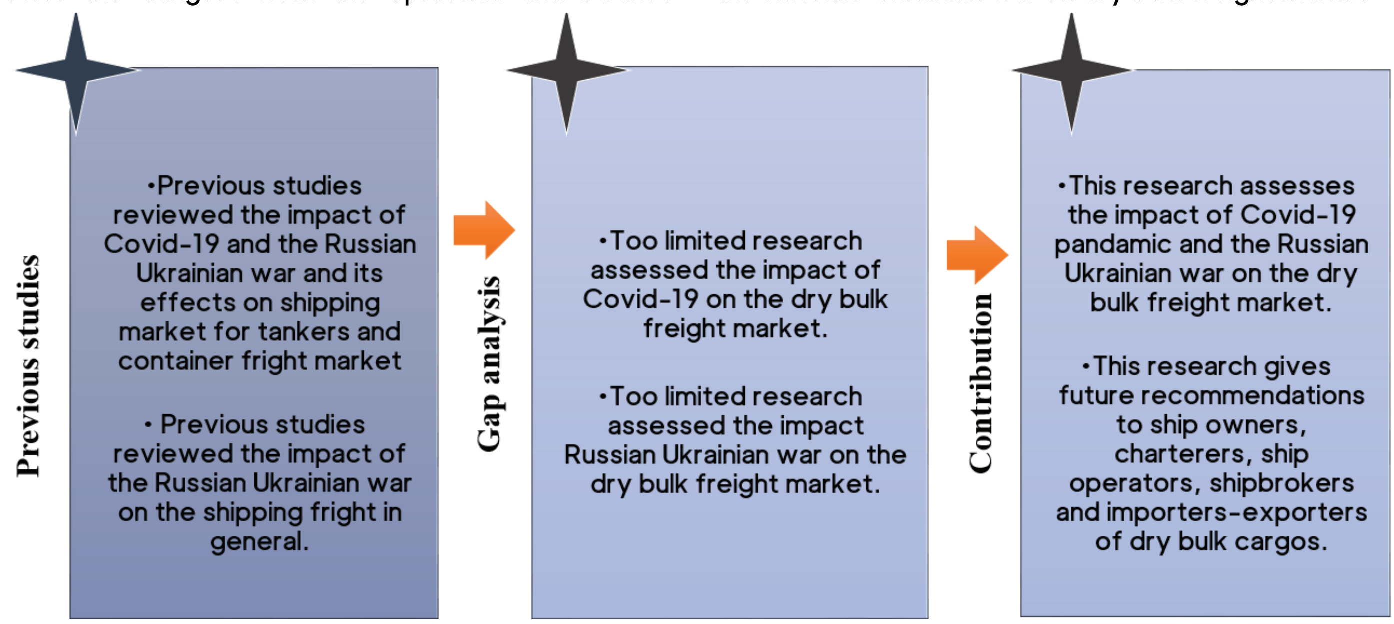

Fig. 2. Research gap and contribution

Statement of the Problem

Covid-19 outbreak is a disaster in human history, which changed the world system and affected many life sectors such as the world economic sector, which was seriously damaged due to fluctuation and imbalance of demand and supply. Ocean freight is an important means of transporting goods and commodities globally, the year of Covid-19 and its aftermath revealed a wide range of challenges for this type of transportation, such as the prohibitive cost of sea freight, which led to an increase in the prices of goods for consumers. The index of Panamax and capsize dry bulk carriers decreased by 16.92%, 24.56%, and 38.94%, respectively, when the freight rate performance in 2019 and 2020 before and after the Covid-19 pandemic was ???. In addition, the invasion of Ukraine by Russia set off a fresh global fiscal crisis in Europe and that the consequences of the Covid-19 pandemic, which slowed down economies around the world by imposing port closures, had a substantial influence on global growth, and that Russia's military actions in Ukraine added to the disruption of the world supply chain. Figure (3) depicts the oscillations in the bulk freight industry.

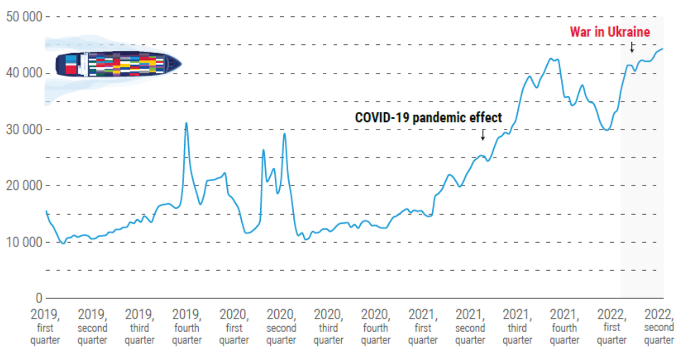

Fig. 3. Bulk freight market fluctuations from 2019 to 2022.
Reference: Clarksons Research Studies, 2022.

Research Aims and Objectives

This research aims to find out the effect of Covid-19 pandemic and the Russian Ukrainian war on the dry bulk freight market, ship owners, ship operators, charterers, shipbrokers, investors in shipping business, international traders, importers and exporters of the dry bulk cargos and the governments. In addition, it aims to find solutions so as to mitigate effects of such things as pandemic in the future. Research objectives are to investigate the effect of Covid-19 pandemic and the Russian Ukrainian war on the dry bulk freight market.

Research Hypothesis

- Covid-19 pandemic has a negative impact on the dry bulk freight market.
- Russian Ukrainian war has a negative impact on the dry bulk freight market.

RESEARCH METHODOLOGY

This research follows a deductive approach through using an electronic questionnaire that was conducted by using interview and analyzed by using SPSS Software. The questionnaire helps to find out the impact of Covid-19 pandemic and the war between Russia and Ukraine on the dry bulk freight market. Research variables can be illustrated as in Figure 4.

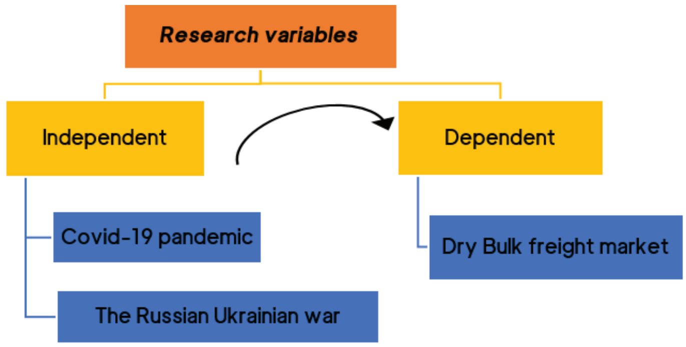

Fig. 4. Research variables
Source: Author

The entire set of cases from which the sample is drawn is referred to as the population. The researcher selects the appropriate sample that best addresses his research aims in accordance with the objectives of the study. Dry bulk ship owners, operators, brokers, charterers, importers, and exporters make up the sample frame of the research. The exact number of stakeholders could not be identified. Thus, the researcher used other theories to determine the sample size. Helal (2020) identified that using ratio of variables to 15 participants, as this research has only three variables, 45 participants could be enough to calculate this research. However, the researchers found that they can distribute more than this number for the validity of the results of the research.

STATISTICAL DATA ANALYSIS

The statistical package for social sciences (SPSS V28) was utilized for both descriptive and inferential statistics, and Smart PLS 3.2.9 was used for (SEM-PLS) modeling.

Data Preliminary Examination

In quantitative research, this analysis is crucial. According to Sue and Ritter (2012), mistakes and incomplete responses should be removed from the gathered data by screening and cleaning. The inspection is crucial to guarantee that the results of the statistical analysis are accurate, even when remedial measures are not usually required. According to Hair et al. (2017), it is important to examine the problems with the data that were gathered, such as odd answer patterns, disengaged respondents, missing data, outliers, data distribution, and common technique bias. Therefore, SPSS is used to evaluate those major data difficulties in the following steps.

Outliers

Outliers, which happen when one or more responses were noticeably different from other responses, are a common illustration of illogical answers (Sekaran and Bougie, 2016). Outliers are cases that have anomalous values (either too low or too high) that set them apart from other examples. Outliers have the potential to skew statistical tests (Field, 2013), change the distribution of the data and undermine the validity of the data. In conclusion, outliers have an impact on the normalcy of data distribution, hence it was critical to check the dataset for outliers before submitting it to a parametric analysis. In the results the researchers achieved there is no outliers. As such, it is essential to identify and manage outliers. Finding the cases with variable values that are either extremely high or low is known as univariate identification of outliers. Minimum and maximum values can be used to identify this kind of anomaly (Sarstedt and Mooi, 2014).

Missing Data

Missing data are a widespread problem in behavioral, marketing, and social science studies (Hair et al., 2017). When researchers do not have missing data issues, it is sporadic. Also, missing data occur when participants leave one or more questionnaire questions unanswered (Sekaran and Bougie, 2016). Moreover, missing data are an issue since they reduce the quantity of data accessible for analysis and may lead to incorrect conclusions, which adds to bias in the results (Hair et al., 2014). Because the SEM-PLS approach is not designed to examine partial data, the impact of missing data is overly critical when using it for data analysis. Furthermore, when the sample contains missing data, the Bootstrapping function, which is used in SmartPLS to evaluate the connections between constructs, cannot be computed. The data gathered for this inquiry contain no missing values.

Normality

Field (2013) defines normality as the statistical distribution of a single variable. In the best-case scenario, Data follow a bell-shaped curve to show a normal distribution (Hair et al., 2016). The normality test is one of the first steps in ensuring that the data gathered are suitable for statistical data analysis. In other words, non-normally distributed data may have an impact on the reliability and validity of statistical data analysis. Researchers such as Kline (2016) proposed two values to quantify the form of data distribution: skewness and kurtosis. Skewness is a measure of the symmetry of data distribution, whereas kurtosis is a measure of the height of the distribution.

Positive skewness values indicate a left-skewed distribution, whereas negative Skewness values indicate a right-skewed distribution. Positive kurtosis implies a too-peaked distribution, while negative kurtosis indicates a too-flat distribution (Kline, 2016). Skewness values of -2 to +2 and kurtosis values of -7 to +7 are regarded acceptable for demonstrating normal distribution (Byrne 2016). Results show the normality test results, which show that the Skewness and kurtosis values for the model elements were within the required range.

Structural Equation Modeling

In this research, the model was examined using structural equation modeling (SEM) by the researchers. The SEM is a generic approach for determining the connection between exogenous and endogenous variables. The partial least squares SEM analysis (PLS-SEM) is employed in this investigation. PLS is a model for structural equations (SEM) method like covariance-based SEM. This kind of model analysis investigates both the measurement model and the path at the same time, which assists in the construction of more realistic assumptions (Hair et al., 2017). As a result, the focus of this study is on investigating the prediction of the variable, with an emphasis on explaining the endogenous characteristics. The PLS-SEM analysis findings are shown in the subsections that follow. The preceding sections described SEM assumptions and how they were satisfied. The fourth stage includes estimating the PLS path model, and the 5th stage involves assessing the outputs of the measurement model. The sixth step entails assessing the consequences of the structural model. The final stage is to make final interpretations of the results and conclusions.

Stage One: Specifying the structural model

The structural model, often known as the inner model, is built at this stage. The structural model displays the connections of the variables. The structural model is designed using comprehensive literature research, and the arrangement of the components must be based on theory, logic, or observations (Hair et al., 2017). The causal relationship is the relationship in the structural model of this study. Causal links or relationships are those that exist between two elements and predict the other.

Stage Two: Specifying the measurement models

The outer model, also known as the measuring model, specifies the relationships between the constructs and their variables. Measuring models can be reflective

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or formative. Reflective measurement approaches are frequently used in social science research. The variables in these models reflect the impact of the underlying concept, meaning that the causal effect is launched from the construct to its variables. Because all variables measuring the same construct are caused by the same construct, the correlation between them must be strong. Furthermore, all the variables used to measure a certain construct must be interchangeable, such that removing one of the variables does not affect the meaning of the construct if the reliability is enough (Hair et al., 2017). This research is focused with a model of reflecting measurement.

Stage Three: Data Collection and Examination

After the measurement models have been established, data collection and analysis are necessary. This stage comprises defining the target population and collecting the required data using an appropriate sampling strategy. The information gathered was utilized to validate the structural and measurement models.

Stage Four: Path Model Estimation

Data are utilized to estimate the path model after it has been collected and examined. This stage necessitates the selection of parameter values based on a knowledge of the PLS-SEM method and its statistical properties. The three structural model weighing schemes are the centroid weighting scheme, the factor weighting system and the route weighing scheme are two schemes. Although the results of using both approaches are not statistically different, the route weighing strategy is suggested since it produces the best R2 value for the endogenous construct. In addition, the path weighing method applies to all path model descriptions and estimations (Hair et al., 2017).

Stage Five: Assessing the Measurement Model

Assessing the internal consistency reliability is necessary for evaluating the reflective measurement models in PLS-SEM, there are two types of validity: convergent validity and discriminant validity. After establishing the reliability and validity of the measurement model, the structural model is reviewed. The subsections that follow explore the reliability and validity of the measurement methodology.

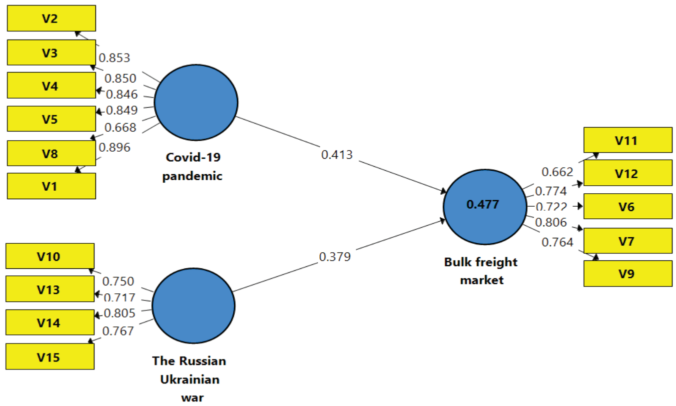

Fig. 5. Measurement model assessment

Stage Six: Assessing the structural model

After determining the validity and reliability of the measurement model, it is time to evaluate the structural model. This entails investigating the predictive capability of the model as well as the relationships between the components. The structural model, also known as the inner model, describes the interactions between the structures and its evaluation comprises assessing the links between the constructs of the model (Henseler and Sarstedt, 2013; Henseler et al., 2009).

Internal Consistency Reliability

Internal consistency dependability investigates whether all the indicators linked with a concept truly measure it (Pallant, 2010). Internal consistency may be measured in a variety of ways. Cronbach's alpha is the most often used statistical metric for this purpose. Cronbach's alpha calculates the average correlation between all indicators that belong to the same construct.

Table 1: Analysis of Measurement Model Reliability

Construct	Cronbach's Alpha	rho_A	Composite Reliability	Remark
Bulk freight market	0.8	0.803	0.863	Reliability attained
Covid-19 pandemic	0.908	0.915	0.93	
The Russian Ukrainian war	0.758	0.761	0.846	

Despite its popularity, Cronbach's alpha is criticized for presuming that all indicators have equal outer loadings and that the number of indicators influences Cronbach's alpha calculation in that fewer items result in a lower value, particularly on scales with items less than ten. Due to the limits of Cronbach's alpha, researchers are advised to use other metrics of internal

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consistency, such as rho A and composite reliability (CR), which evaluate internal consistency while taking into consideration the fact that each indication has a different outer loading. The accepted value of reliability is 0.7; however, values more than 0.6 are also accepted (Fornell and Larcker, 1981; Taber, 2018). The results in Table 2 show that all constructs had reliability scores greater than 0.6.

Convergent Validity

Convergent validity evaluates the link between variables measuring the same construct. The item outer loadings and the extracted average variance (AVE) are frequently used to test the convergent validity of reflective measurement models.

Table 2: Convergent Validity Analysis (AVE)

Construct	Average Variance Extracted (AVE)	Remark
Bulk freight market	0.558	Convergent validity attained through AVE values
Covid-19 pandemic	0.689	
The Russian Ukrainian war	0.578	

Common statistics used to prove convergent validity is the AVE, which reflects the grand meaning of the squared loadings of the indicators measuring a concept. AVE values greater than 0.5 are acknowledged. The convergent validity in Table 2 was obtained using the prior principles. Another indicator of dependability is item loading, the outer loadings needed are 0.70 (Hair et al., 2014). The requirement for an outside loading of at least 0.70, since the square of the outside loadings of a standardized item - also known as communality - reveals the degree of variation shared by the build and the item. The square of 0.70 will equal 0.50. This implies that if an item has an outside loading of 0.70, the construct may explain half of the variance in the item. However, the authors indicated that if the outer loading is between 0.4 and 0.7, the influence of indication deletion on internal consistency reliability should be investigated in this study. If deletion does not raise the measure(s) above the threshold, the reflecting indication must remain in place.

Validity of Discrimination

After establishing convergent validity, discriminant validity is investigated, which examines how much a construct differs from other constructs. Typically, discriminant validity is determined by evaluating the Fornell-Larcker criterion, which ensures that the indicator only loads heavily on the concept to which it is linked. An indication is often loaded to many constructs; nevertheless, the indicator's loading on its associated construct must be larger than its correlation with other constructs.

Table 3: Validity of Discrimination (Fornell-Larcker criterion)

	Bulk freight market	Covid-19 pandemic	The Russian Ukrainian war
Bulk freight market	**0.747**		
Covid-19 pandemic	0.61	**0.83**	
The Russian Ukrainian war	0.594	0.52	**0.761**
Remark: *Discriminant validity through Fornell-Larcker criterion attained*			

The square root of AVE is compared to the correlations of the concept when employing the Fornell-Larcker criterion. The AVE square root of the construct ought to be greater than any of its connections with other constructs. In accordance with these guidelines, the discriminant validity was built because, as shown in Table 3, The AVE square root of the construct values were bigger than any of its correlations with other constructs. The Hetrotrait-Monotrait ratio (HTMT) is another method for determining discriminant validity. Hair et al. (2017) define HTMT as "the ratio of between-trait correlations to within-trait correlations" (page number). Its value must be less than one. The discriminant validity was built using these guidelines because all the constructs have HTMT values less than the stated threshold. Table 4 presents the HTMT values of the Constructs.

Table 4: Discriminant Validity (HTMT Ratio)

	Bulk freight market	Covid-19 pandemic	The Russian Ukrainian war
Bulk freight market			
Covid-19 pandemic	0.7		
The Russian Ukrainian war	0.759	0.624	
Remark: *Discriminant validity through HTMT criterion attained*			

Descriptive Statistics

Following the determination of the reliability and validity of the variables, it is necessary to offer some descriptive statistics for the selected constructs, as shown in Table 5. In the same table, the mean (M) and standard deviation (SD) were computed and reported. The independent variable of the descriptive statistics

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"Covid-19 pandemic" was $(M=4.425,SD=0.709)$, for the other independent variable *"The Russian Ukrainian war"* were $(M=4.545,SD=0.508)$, and for the dependent variable *"Bulk freight market"* were $(M=4.534,SD=0.511)$.

Table 5: Selected Variables Descriptive Statistics

Construct	N	Mean	Std. Deviation
Covid-19 pandemic	472	4.4251	0.70905
The Russian Ukrainian war	472	4.5445	0.50751
Bulk freight market	472	4.5339	0.51148

Pearson Multiple Correlations

To examine correlations between constructs, Pearson's correlation (r) was utilized. Pearson's correlation is a popular method for validating the strength of an existing linear relationship between variables, and it evaluates the linear relationship between quantitative variables. This coefficient represents the degree of linear dependency between two quantitative variables and spans from -1 to 1.

If it is negative, one variable reduces while the other increases; if it is positive, one variable grows while the other decreases. The following r values are distributed: r = 0-0.3, low correlation; r = 0.3-0.7, moderate correlation; and r = 0.7-1, high or strong correlation. Correlation coefficients denoted with three stars (***) were statistically significant at 0.001, i.e. 99.9% confidence level, correlation coefficients marked with two stars (**) were significant at 0.01, indicating 99% confidence level, coefficients marked with one star (*) were significant at 0.05, indicating 95% confidence level, and coefficients NOT marked were not significant at 0.05, indicating P-values greater than 0.05.

Table 6: Correlation between the Main Variables

		Covid-19 pandemic	The Russian Ukrainian war	Bulk freight market
Covid-19 pandemic	Pearson Correlation	--		
	N	472		
The Russian Ukrainian war	Pearson Correlation	.524***	--	
	Sig. (2-tailed)	0.000		
	N	472	472	
Bulk freight market	Pearson Correlation	.598***	.595***	--
	Sig. (2-tailed)	0.000	0.000	
	N	472	472	472

Table 6 displays the Pearson correlation coefficient matrix for the major variables. The findings demonstrate a significant moderate association between Covid-19 epidemic and the Russian-Ukrainian conflict since (r(472)=.524, P0.001). Furthermore, since (r(472) =.598,P0.001), there is a significant moderate association between Covid-19 epidemic and the Bulk freight market. Moreover, there is a significant moderate relationship between the Russian Ukrainian war and Bulk freight market since $(r(472)=.595,P<0.001)$.

Table 7: Criteria of Structural Model Assessment

Criteria	Guidelines	References
Collinearity	VIF < 5	Hair et al., 2017
Path coefficients	Significance: $p \leq 0.05$	Hair et al., 2017
Coefficient of determination (R^2)	$R^2 < 0.1$, Negligible $R^2 >= 0.1$, Adequate	Falk and Miller, 1992
Effect Size (f^2)	f^2 between 0.02-0.14, small; f^2 between 0.15-0.34, moderate; $f^2 \geq 0.35$, High.	Cohen, (1988
Cross-validated redundancy (Q^2)	Predictive Relevance Using blindfolding $Q^2 > 0$	Chin, 1998
Goodness of Fit (GoF)	GoF less than 0.1, no fit; GoF between 0.1 to 0.25, small; GoF between 0.25 to 0.36, medium; GoF greater than 0.36, large.	Wetzels, et al., 2009

Researchers recommended collinearity, path coefficients, coefficient of determination (R2), Effect Size (f2), and Predictive Relevance (Q2) for evaluating and presenting the structural model (Hair et al., 2017). Review studies on PLS-SEM (Ringle and Straub, 2012) and many others observed that when studying the structural model, researchers often report those criteria. The results of such evaluations are reported in the following subsections based on those criteria and standards.

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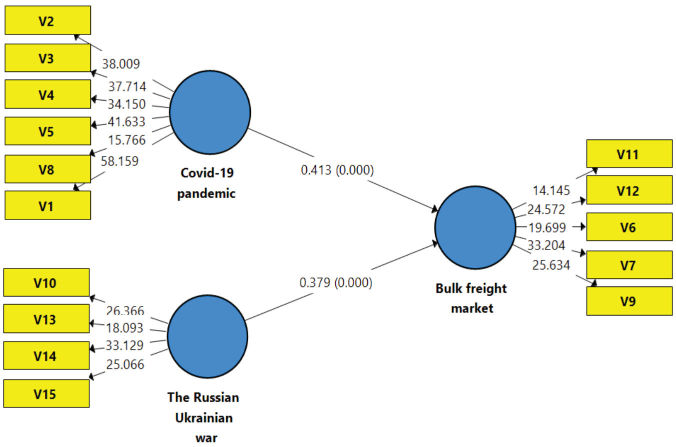

Fig. 6. Structural model for the research hypotheses

Collinearity

High correlation between two constructs is known as collinearity, and it can lead to problems with interpretation. Collinearity occurs when more than two conceptions are involved.

Table 8: Variance Inflation Factor

Path	VIF	Remark
Covid-19 pandemic -> Bulk freight market	1.37	NO collinearity problem exists
The Russian Ukrainian war -> Bulk freight market	1.37	

Collinearity may be investigated using the variance inflation factor (VIF). It is computed by dividing one by tolerance and relates to the variance described by one independent construct that the other independent constructs do not explain. A VIF value of Five or higher indicates a high collinearity. All VIF values in Table 8 were below the cut-off point; providing evidence that the collinearity between independent constructs has no existence (Hair et al., 2017).

Path Coefficients

Path coefficients are estimates of the relationships between the components of the model. These coefficients vary from +1 to -1, with +1 representing a strong positive association, zero representing a weak or non-existent link, and -1 representing a large negative relationship (Garson, 2016). When evaluating PLS paths, research should provide path coefficients in addition to the significance level, t-value, and p-value. To establish the signs, magnitude, and statistical significance of the estimated route coefficients between the constructs, hypothesis testing was performed. Path coefficients with higher values suggest a greater association between the predictor and the predicted variables. The significance of the alleged correlations was established by calculating the significance of the p-values for each path with a p-value threshold of 0.05, p 0.01 being used to measure the importance of the path coefficient estimations (Henseler et al., 2009). Later, conclusions for all hypotheses were made based on the significance of p-values at the previously specified conventional levels. Table 9 shows the p-values, hypothesis inferred, and confidence level for each estimate.

Table 9: Hypothesis Testing Results

Path	*B*	*t-value*	*P-value*	*Ninety-five percent Bias-Corrected CI*		Remark
				LB	*UB*	
H1: Covid-19 pandemic -> Bulk dry freight market	0.413	7.1	0	0.293	0.519	Supported
H2: The Russian Ukrainian war -> Bulk dry freight market	0.379	5.484	0	0.252	0.518	Supported

The results of hypothesis testing in Table 9 showed that:

- Covid-19 pandemic had a significant impact on Bulk dry freight market as (β=0.413, t=7.1, P<0.001,95% CI for β=[0.293,0.519]), consequently, the first hypothesis is confirmed.
- The Russian Ukrainian war had a significant effect on Bulk dry freight market as (β=0.379, t=5.484, P<0.001,95% CI for β=[0.252,0.518]), consequently, the second hypothesis is confirmed.

Coefficient of Determination

The influence of independent factors on dependent latent variables expressed by the coefficient of determination (R2) (Hair et al., 2012), which is one of the quality measurements of the structural model. R2 estimates range from 0 to 1, with zero representing little explained variation and 1 representing large, explained variance.

Table 10: R Square Values

	R Square	R Square Adjusted
Bulk freight market	0.477	0.475
Remark: Moderate accepted values		

The researchers used a different cut-off number for R2. Hair et al. (2011), for example, stated in marketing research that R2 values of 0.25, 0.50, or 0.75 are low, moderate, or high, respectively. Chin (1998) proposed in business research that R2 values of 0.19, 0.33, or 0.67 are low, moderate, or high, respectively. According to the results of Table 10, the fluctuation in both Covid-19 epidemic and the Russian Ukrainian war accounts for about 48% of the volatility in the Bulk freight market.

Effect Size (f^2)

The f2 effect size quantifies the amount of impact that an inherent structure would have if an exogenous construct is eliminated from the model. A construct is deemed to have a modest influence if its f2 value is between 0.02 and 0.14, a medium effect if it is between 0.15 and 0.34, and a big effect if its f2 value exceeds 0.35. An f2 value of 0.02 indicates that the construct has no influence on the endogenous construct (Hair et al., 2017).

Table 11: f^2 Effect Size

Path	f-Square	*Remark*
Covid-19 pandemic -> Bulk freight market	0.237	Moderate
The Russian Ukrainian war -> Bulk freight market 0.201 Moderate		

Table 11 shows the f^2 the structures' effect size, all values were moderate and accepted. The results of effect size indicate that *Covid-19 pandemic* Moderately Affects *Bulk freight affected. market* since ***(f^2=0.237)***, also, *The Russian Ukrainian War* Moderately affects *Bulk freight market* since ***(f^2=0.201)***.

Predictive Relevance (Q^2)

The model's out-of-sample prediction ability is shown by the Q^2 value. A model can accurately anticipate data that were not employed in the model estimate process if it is said to have a predictive power or a predictive relevance. One method of calculating the Q^2 value is to blindfold someone. An omission distance (D) needs to be supplied before this process may be executed. The researchers advise choosing a D between 5 and 10, but they must be cautious to ensure that the sample size divided by the chosen D does not result in an integer.

Table 12: Predictive Relevance

	SSO	SSE	Q^2 (=1-SSE/SSO)
Bulk freight market	2360	1744.888	0.261
Covid-19 pandemic	2832	2832	
The Russian Ukrainian war	1888	1888	
Remark: Predictive Relevance established			

During the blindfolding process, the x data point of each item are excluded and then predicted, with x being the specified D value. This is shown by the exclusion distance. A D of five for each blindfolding cycle indicates that around 20% of the data points were eliminated. A D of ten, on the other hand, indicates that around 10% of the data points were eliminated during each blindfolding session. A Q^2 value greater than zero for an endogenous construct signifies the predictive significance of the model for that construct (Hair et al., 2017). Seven was chosen as the omission distance to evaluate the prediction ability of the model. The study yielded Q^2 values, which are shown in Table 12. It is reasonable to say that the study model has substantial predictive significance because Q^2 is greater than zero.

Goodness of Fit of the Model

The Goodness of Fit (GoF) is the geometric mean of the average R^2 and the average variance derived from the endogenous variables. The goal of GoFs is to evaluate the research model at every level, including the structural and measurement models, with a focus on the overall performance of the model (Henseler and Sarstedt, 2013). One way to compute the GoF index is as follows:

$$GOF = \sqrt{\overline{R^2} \times \overline{AVE}} = \sqrt{0.477 \times 0.608} = 0.539.$$

Table 12 lists the GoF criterion for determining if a given set of GoF values is too little, too large, or too acceptable to be considered a globally adequate PLS model. Based on these standards and the value of GoF (0.539), it is reasonable to say that the GoF model fits the data better enough to be regarded as a genuine global PLS model.

Questionnaire Results

The statistical analysis showed that the data are valid, analyzable, and achieved normality. since all the responds came between 1-5 as per Likert scale, they must be minimum one maximum five so no outliers found in the data. Also, there is no missing data at all and normality has been achieved as all skewness results came in between (2 to -2) and kurtosis results came in between (7 to -7), therefore the data are valid and analyzable. Since the SD value is low, (close to zero), then there is no discrepancy between the answers, and Harman's single factor evaluating the result shows 44% which is less than 50%, thus there is no bias in the collected data which proves that the questionnaire is valid and dependable. According to the rules of goodness of fit, evaluation and model estimates and all tests reveal that the internal consistency and reliability are satisfactory. All the tests reveal that the internal consistency and reliability, convergent validity, and discriminant validity are all in order, according to the principles of goodness of fit evaluation and model estimations. Also, the relationships between the independent variables and the dependent variable are correct, and dependable, as indicated by the statistical results of the questionnaire.

The search offered two hypotheses. Due to the results of the questionnaire and the Baltic dry index analysis Also in the previous studies, the first hypotheses have been evaluated and approved that there is a negative impact on the dry bulk freight market due to Covid-19 pandemic. As the coefficient of determination (R2) of the effect of the independent variables on the dependent variable R2 (greater than 0.1) was 0.413, which is considered an acceptable result. The second hypothesis evaluated and shows a negative impact on the dry bulk fright market at due to the Russian Ukraine war and the effectiveness of the questionnaire statistical analyses outcomes was enhanced due to its consistency with the stoical analyses of the Baltic dry bulk index for the years between 2018 till 2023.

The coefficient of determination of the effect of the independent variables on the dependent variables R2 (greater than 0.1) was 0.379, which is considered an acceptable result. Also, the results show that the predictive power of the model Q2 is fair since the result is greater than zero, as it reached 0.261. The goodness of fit of the model (GOF) reached 0.539 which is more than 0.36 so it is safely concluded that the GOF model has a higher level of fit to be considered as a sufficient valid global PLS model. Therefore, based on the tested results of the questionnaire, Baltic dry index analysis (2018-2023) and the previous studies, it was found that there is a negative impact on the dry bulk freight market due to Covid-19 pandemic and the Russian Ukrainian war in the entire world.

CONCLUSION AND RECOMMENDATIONS

The results of this research, as it came throw the answers on the electronic questionnaire which was distributed to the ship owners, ship brokers, ship operators, charterers, exporters and importers of dry bulk cargos, show that Covid-19 pandemic had a negative impact on the dry Bulk freight market as the freight decreased all over the world. The results also show that the Russian Ukrainian war had a negative impact on the dry bulk freight market as the freight increases all over the world. Also, the results came from the statistical analysis of the Baltic dry bulk freight index for the years between (2018-2023) which also matches the result of the statistical analyses of the questionnaire results for the market. The effectiveness of the questionnaire statistical analyses outcomes was enhanced due to their consistency with the stoical analyses of the Baltic dry bulk index for the years between 2018 and 2023. The researcher distributed about seven hundred questionnaires and received 472 answers. As The questionnaire result shows that 79 % of the answers came from males only, which gives an indication that the dry bulk shipping and trading business is mostly controlled by males. Since 42.4% of the questionnaire answers came from almost middle-aged people (35-45), this indicates that almost half of the answers came from people who have sufficient experience in the dry bulk shipping and trading field, thus the age of the participant in the questionnaire had a significant impact on the results of analysis. The effect of Covid-19 pandemic on the dry bulk freight market as per the statistical analysis is about 41%, while the effect of Russian Ukrainian war was almost 38 % and the dry bulk freight market was effected by other factors.

As this research aimed to find the impact of Covid-19 and the Russian Ukrainian war on the dry bulk freight market as such crises had an immediate effect on all the related parties, so the recommendations were divided into many segments based on the following categories:

Recommendations to Ship Owners, Managers, Operators, Ship Brokers

- Any waiting or delays due Covid-19 or any health disease at the loading or discharging port are to be on charterers time /acct.
- In case the loading or discharging operations stopped due to Covid-19 pandemic or any health disease then all-time lost and expenses

are to be on charterers account.

- In case of any additional war risk premium that is being forced by the insurance companies or owner of P&I club is to be shared 50% between owners and charterers.
- The owners are to include the contracts with the insurance companies and P&I club as a term or condition to increase the insurance to cover the hidden losses that can occur due to similar health or war crises.
- While getting loans from banks to buy a ship, ship owners should include in the load terms and conditions that if any world crises affect the freight negatively, then banks should postpone their instalments till the crises end up.
- When ship owners and operators do a future hedging on freight for the charterers, then a cancelation term should be included in the charter party.

Recommendations to Charterers

- Charterers must form tenders of long terms hedging on the freight with highly reputable ship owners and operators so they make sure that they will perform the agreed charter party terms in case future crises happen.
- Charterers must make the agreements with well-known ship owners and operators who own a big shipping fleet and have a stable financial status to make sure that such owners and operators will not be bankrupted or will not fulfill their obligations against the charter party agreement.
- The charterers of dry bulk cargos all over the world should add a special term to protect themselves from such crises that may cause them big losses, especially if they signed long term contracts as following, if any delay stoppages etc. due to Covid-19 to be on owners 'account and time.
- Any delays arising due to quarantine imposed on account of the vessel's/crew's previous trading or nationality or contagious disease including but not limited to Covid-19 virus shall be on owners' account together with any expenses incurred and all the time lost thereby.
- Any delays arising due quarantine imposed on vessel account, crew, previous trading, or contagious diseases including but not limited to Covid-19 virus same shall be on owners account and time.
- Owners are to confirm that the vessel and the crew are to comply with all orders, requests, directions, rules, and regulation of port authorities of port of call and if the vessel or vessel crew failed to execute the instructions, then all-time lost and all expenses that may occur will be on the owner/vessel account.

Recommendations to Cargo importers and exporters

- Dry bulk cargo sellers should try to sell of FOB basis so they avoid the impact of freight change, especially if they sell a huge quantity that should be shipped in many vessels for an extended period.
- Dry bulk cargos sellers should include in their contracts that in case any similar crises that increased the freight rates, then the same should be reflected in the prices.
- Dry bulk cargo buyers should be on CFR or CIF basis so they avoid involving themselves in the freight matter and in such a case they will be under less risk of expenses increment.
- When forming the contract, a clear term should be inserted there to clarify the rights of both the seller and the buyer in the event of a pandemic, wars and any other expected crises.

REFERENCES

Abrahamsson, B.J. (2019) *International ocean shipping: Current concepts and principles*, *International Ocean Shipping: Current Concepts and Principles*. Available at: https://doi.org/10.4324/9780429052057.

Allam, Z., Bibri, S.E. and Sharpe, S.A. (2022) 'The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption', *Resources*, 11(11). Available at: https://doi.org/10.3390/resources11110099.

Balbaa, M.E., Eshov, M.P. and Ismailova, N. (2022) 'The Impacts of Russian Ukrainian War on the Global Economy in the frame of digital banking networks and cyber attacks', in *ACM International Conference Proceeding Series*. Available at: https://doi.org/10.1145/3584202.3584223.

Byrne, B.M. (2013) *Structural Equation Modeling With AMOS*, *Structural Equation Modeling With AMOS*. Available at: https://doi.org/10.4324/9781410600219.

Chin, W.W., Chinn, W.W. and Chin, W.W. (1998) 'The partial least squares approach to structural equation modelling. In Marcoulides G. A. (Ed.)', *Modern Methods for Business Research*, 295(2).

Cohen, J. (1988) 'Statistical power analysis for the behavioural sciences. Hillside', *NJ: Lawrence Earlbaum Associates* [Preprint].

Dong, X. (2021) 'Research on impact of Covid-19 on Chinese international shipping companies and countermeasures der the promotion of government'.

Field, A. (2013) *Discovering statistics using IBM SPSS statistics*, *Statistics*.

Garson, G.D. (2016) *Partial least squares:regression and structural equation models. Asheboro:*, *NC: Statistical associates publishing*.

Hair, J. *et al.* (2017) 'An updated and expanded assessment of PLS-SEM in information systems research', *Industrial Management and Data Systems*, 117(3). Available at: https://doi.org/10.1108/IMDS-04-2016-0130.

Hair, J.F. *et al.* (2014) 'Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research', *European Business Review*. Available at: https://doi.org/10.1108/EBR-10-2013-0128.

Hair, J.F. *et al.* (2021) 'A primer on partial least squares structural equations modeling (PLS-SEM). Sage Publications', *Journal of Tourism Research*, 6(2).

Hair, J.F. and Brunsveld, N. (2019) *Essentials of business research methods*, *Essentials of Business Research Methods*. Available at: https://doi.org/10.4324/9780429203374.

Han, E.S. and goleman, daniel; boyatzis, Richard; Mckee, A. (2020) *Review of Maritime Transport 2020*, *Journal of Chemical Information and Modeling*.

Helal, H. (2022) *Assessment of the effect of non-technical skills courses on marine officers' performance*. PhD Thesis. Arab Academy for Science, Technology & Maritime Transport.

Henseler, J., Ringle, C.M. and Sinkovics, R.R. (2009) 'The use of partial least squares path modeling in international marketing. New Challenges to International Marketing (Advances in International Marketing, Vol. 20)', in *Advances in International Marketing*.

Henseler, J. and Sarstedt, M. (2013) 'Goodness-of-fit indices for partial least squares path modeling', *Computational Statistics*, 28(2). Available at: https://doi.org/10.1007/s00180-012-0317-

Kline, R.B. (2015) *TXTBK Principles and practices of structural equation modelling Ed. 4 ****, *Methodology in the social sciences*.

Marobhe, M.I. (2022) 'Investors' reactions to COVID-19 related announcements: evidence from the cargo shipping industry', *Review of Behavioral Finance*, 14(5). Available at: https://doi.org/10.1108/RBF-04-2021-0071.

Orhan, E. (2022) 'the Effects of the Russia-Ukraine War on Global Trade', *Journal of International Trade, Logistics and Law*, 8(1).

Pallant, J. (2009) 'SPSS survival manual, 3rd', *Edition. McGrath Hill* [Preprint].

Ringle, C.M. *et al.* (2020) 'Partial least squares structural equation modeling in HRM research', *International Journal of Human Resource Management*, 31(12). Available at: https://doi.org/10.1080/09585192.2017.1416655.

Rožić, T., Naletina, D. and Zając, M. (2022) 'Volatile Freight Rates in Maritime Container Industry in Times of Crises', *Applied Sciences (Switzerland)*, 12(17). Available at: https://doi.org/10.3390/app12178452.

Sarstedt, M. and Mooi, E. (2019) 'A Concise Guide to Market Research', *A Concise Guide to Market Research* [Preprint].

Sue, V. and Ritter, L. (2015) *Conducting Online Surveys*, *Conducting Online Surveys*. Available at: https://doi.org/10.4135/9781506335186.

U. Sekaran, R.B. (2006) 'Research methods for business. A skill building approach (5th ed.)', *New York: John Wiley and Sons* [Preprint].

Unggul Wicaksana Prakasa, S. *et al.* (2022) 'The Effect of Russia--Ukraine War on International Aviation Sectors', *KnE Social Sciences* [Preprint]. Available at: https://doi.org/10.18502/kss.v7i15.12132.

United Nations Conference on Trade and Development (2018) *Review of Maritime Transport 2018 | UNCTAD*, *Review of Maritime Transport 2018*.

United Nations Conference on Trade and Development (2020) *Review of Maritime Transport 2020 | UNCTAD*, *Review of Maritime Transport 2020*.

United Nations Conference on Trade and Development (2021) *Review of Maritime Transport 2021 | UNCTAD*, *Review of Maritime Transport 2021*.

Wang, X. *et al.* (2022) 'Quantitative analysis of the impact of COVID-19 on ship visiting behaviors to ports- A framework and a case study', *Ocean and Coastal Management*, 230. Available at: https://doi.org/10.1016/j.ocecoaman.2022.106377.

Wetzels, M., Odekerken-Schröder, G. and Van Oppen, C. (2009) 'Using PLS path modeling for assessing hierarchical construct models: Guidelines and empirical illustration', *MIS Quarterly: Management Information Systems*, 33(1). Available at: https://doi.org/10.2307/20650284.

Xu, L. *et al.* (2021) 'The effect of COVID-19 pandemic on port performance: Evidence from China', *Ocean and Coastal Management*, 209. Available at: https://doi.org/10.1016/j.ocecoaman.2021.105660.

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