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FOCUSED RESEARCH ON TECHNOLOGICAL INNOVATIONS IN SHIPPING INDUSTRY: REVIEW AND PROSPECTS

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Summary

Introduction. *Maritime transportation has always been an important component of global trade and commerce. The emergence and development of new technologies, as well as growing demands for efficiency and sustainability, have led to a period of transformation in the industry. The introduction of new technologies is no longer a choice, but a necessity for maritime transport enterprises to remain competitive and meet the requirements of a rapidly changing market. The advantages of using innovative technologies in maritime transport are numerous, allowing for better control of the ship and her propulsion system, which in turn reduces the risks of harmful impact on the ecosystem. The latest technologies can significantly improve the efficiency of maritime operations, which includes optimizing shipping routes and reducing fuel consumption. Shipping companies are able to use improvements in both hardware and software to optimize their fleet monitoring and management operations through satellite data and shipboard sensors that connect equipment, which increases safety of navigation, helps to address environmental issues in shipping and improves the operational efficiency of transport operations. Purpose. This article offers an overview of the background of technological innovation, the current state of the maritime transportation industry, and the challenges it faces in adopting new technologies. It also looks at some of the recent technological advances and their potential impact on the industry and the prescriptive opportunities that maritime*

transport has to offer. Results. The process of introducing the latest technologies is a way to overcome regulatory barriers and high investment costs, modern ways for transport companies to navigate the complex landscape in order to realize the full potential benefits of such technologies and a constant search for a balance between improving operational efficiency and solving environmental problems. Conclusion. In assessing the future of such technologies, it should be noted with confidence that the introduction of new technologies has the potential to fundamentally change maritime transport, so adopting these changes and utilizing them contributes to a more sustainable, efficient and competitive industry.

Key words: *Maritime transportation, freight and passenger carriage, innovative technologies, shipping technology, autonomous ships, sustainable development, safety of shipping, ship navigation.*

ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНИХ ІННОВАЦІЙ В ГАЛУЗІ СУДНОПЛАВСТВА: ОГЛЯД ТА ПЕРСПЕКТИВИ

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Анотація

Вступ. *Морський транспорт завжди був важливою складовою світової торгівлі та комерції. Поява і розвиток нових технологій, а також зростаючі вимоги до ефективності та сталого розвитку спричинили період трансформації галузі. Впровадження нових технологій більше не є вибором, а необхідністю для підприємств морського транспорту, щоб залишатися конкурентоспроможними і відповідати вимогам ринку, що швидко змінюється. Переваги використання інноваційних технологій на морському транспорті численні, вони дозволяють якісніше контролювати судно і силові установки, що в свою чергу знижує ризики шкідливого впливу на екосистему. Новітні технології здатні значно підвищити ефективність морських операцій, що передбачає оптимізацію судноплавних маршрутів і скорочення споживання палива. Судноплавні компанії в змозі використовувати вдосконалення як апаратного, так і програмного*

забезпечення для оптимізації своїх операцій з моніторингу та управління роботою власного флоту завдяки даним з супутників і датчикам встановленим на судні, які з'єднують обладнання, що підвищує безпеку мореплавства що сприяє вирішенню екологічних проблем судноплавства і підвищує операційну ефективність транспортних операцій. ***Мета.*** *Ця стаття пропонує огляд передумов технологічних інновацій, аналіз поточного стану галузі морського транспорту та викликів, з якими вона стикається при впровадженні нових технологій. Також розглядаються деякі з останніх технологічних досягнень та їхній потенційний вплив на розвиток галузі, зокрема, на можливості, відкриті перед морським транспортом.* ***Результати.*** *Процес впровадження новітніх технологій це шлях подолання регуляторних бар'єрів та високої вартості інвестицій, сучасні способи орієнтації транспортних компаній в складному ландшафті, з метою реалізації повною мірою потенційних переваг таких технологій та постійний пошук балансу між підвищенням операційної ефективності та вирішенням екологічних проблем.* ***Висновки.*** *Оцінюючи майбутнє таких технологій, необхідно з упевненістю зазначити, що впровадження новітніх розробок має потенціал докорінно змінити сферу морських перевезень, тож прийняття цих змін та їх використання сприятиме створенню більш стійкої, ефективної та конкурентоспроможної морської індустрії.*

Ключові слова: *морський транспорт, вантажні та пасажирські перевезення, інноваційні технології, технології транспортування, автономні судна, сталий розвиток, безпека судноплавства, процес судноводіння.*

Introduction. New technologies in the maritime industry include autonomous ships, marine robotics, new materials, blockchain, IoT, advanced communications, artificial intelligence, virtual reality and augmented reality. These technologies are being used to improve navigation, fuel efficiency and safety. The maritime industry has seen the introduction of new ship classes, including autonomous ships and digital twins. These technologies are expected to revolutionize the industry in the coming years.

The introduction of innovations and their development in the marine transport industry is the subject of the works of many scientists. Thus an overview of the main technological trends transforming the maritime industry is devoted to the work [1]. In [2] researched exploring technology in maritime sector and its role in coping with the COVID-19 pandemic. Smart ship technologies for the maritime industry studied in [3]. Wärtsilä encyclopedia of ship technology aimed at strengthening the growth and ensuring the future of commercial shipping and adapting the industry to the new realities in [4]. The rapid development of information technology, which the shipping industry is experiencing as an important period of change in the development of the transition to intelligence and wisdom, is explored in [5]. The importance of emerging technologies to the increasing of corporate sustainability in shipping companies reserched in [6]. Innovation through collaboration: application in the maritime industry, future in maritime education and training and priority areas of innovations in maritime industry examined in [7–9]. Studies in national governance and emerging technologies given in [10]. Rights of salvage and innovation in the united states admiralty courts explored in [11]. Navigational safety assessment and autonomous ship concept researched in [12, 13].

Thus, a review of the literature on the topic of research indicates that the subject is very relevant, and its impact on the development of the shipping industry is difficult to overestimate.

Materials and methods. The maritime transport industry is constantly evolving, and new technologies are being developed to improve efficiency, safety, and sustainability. Prerequisites for the introduction of new technologies in the maritime transport industry are primarily in the development of infrastructure. New technologies often require changes in the infrastructure of ports and terminals. For example, the installation of shore power systems to support electrification of vessels, or the deployment of autonomous mooring systems to accommodate autonomous ships. Maritime transport is a highly regulated industry, and new technologies must comply with international and national standards and regulations. Standards for cybersecurity, safety, and environmental protection are particularly important for new technologies in the maritime sector. New technologies often require high-speed and reliable connectivity to transmit data between ships, ports, and other stakeholders in the maritime transport supply chain. The availability of satellite communications and 5G networks can enable new technologies such as remote vessel monitoring and control. The successful implementation of new technologies requires a skilled workforce that can operate and maintain these technologies. Training programs and certification schemes are needed to ensure that seafarers, port workers, and other stakeholders have the necessary skills and knowledge to work with new technologies.

The adoption of new technologies requires significant investment from the maritime transport industry, including ship owners, ports, and logistics companies. Funding for research and development, pilot projects, and large-scale deployment is needed to accelerate the adoption of new technologies. The successful implementation of new technologies requires collaboration between different stakeholders in the maritime transport industry, including ship owners, ports, logistics companies, technology providers, and regulators. Collaboration can help to overcome barriers to adoption and accelerate the development of new technologies.

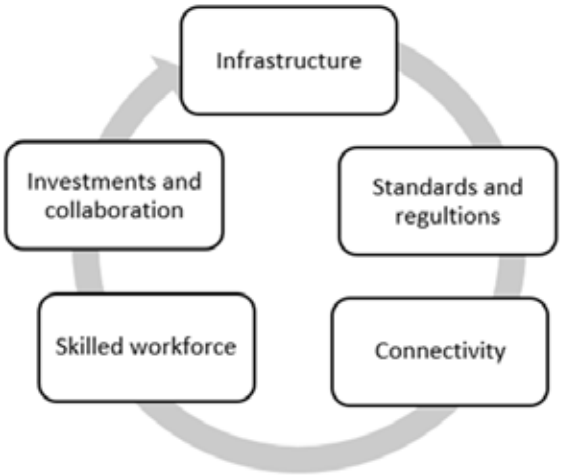

Fig. 1. Prerequisites for new technologies on the maritime transport

The maritime industry faces a number of challenges, including a shortage of workers, new environmental regulations, safety risks, and rising costs. In addition, the industry faces a constant imbalance of supply and demand, environmental imperatives, and employment issues related to an aging workforce. In 2023 and beyond, people will remain the focus of the industry while introducing technology and solving environmental problems. Thus, the maritime industry is undergoing a technological revolution that is transforming the way shipping companies operate. Technology is setting up trends and challenges in maritime management, with smart fleet operation and autonomous vessels being some of the most promising areas of development. The International Council on Clean Transportation has identified several technologies and operational strategies aimed at increasing ship efficiency, including wind-assisted propulsion, air lubrication systems, and hull coatings. These technologies can help reduce CO_2 emissions from ships and make the marine sector safer for the environment.

Several factors contributed to the emergence of innovation in the maritime industry, including the following:

1. Advancements in technology. The maritime industry has been greatly impacted by technological advancements, which have led to the development of new and innovative tools, equipment, and software that have made shipping safer, more efficient, and more environmentally friendly. Examples of such technologies include automated cargo handling systems, satellite communication systems, and computerized navigation and tracking systems.

2. Environmental concerns. Growing concerns about the impact of shipping on the environment, such as pollution, greenhouse gas emissions, and oil spills, have led to the development of new technologies and practices that aim to reduce the environmental impact of the maritime industry. These innovations include hybrid and electric ships, ballast water treatment systems, and waste management technologies.

3. Economic pressures. Economic pressures have also played a role in driving innovation in the maritime industry. Shipping companies are constantly looking for ways to increase efficiency, reduce costs, and improve profitability, which has led to the development of new technologies and practices that can help them achieve these goals. Examples of such innovations include containerization, just-in-time inventory management, and the use of big data and analytics to optimize shipping routes and improve supply chain management.

4. Globalization. The increasing globalization of trade has created new opportunities and challenges for the maritime industry, which has led to the development of new technologies and practices that can help shipping companies had better manage the complexities of global trade. These innovations include blockchain technology for secure and transparent supply chain management, digitalization of documentation and customs procedures, and the use of autonomous ships and drones for shipping and port operations. These and other factors have contributed to the birth of innovation in the maritime industry, helping to make shipping safer, more efficient, and more sustainable.

In recent years, there have been several innovations in the maritime transportation, aimed at making the process more efficient, cost-effective, and environmentally sustainable.

With the increasing use of digital technologies, the maritime industry has embraced digitalization in areas such as documentation, cargo tracking, and communication. This has led to greater transparency, improved efficiency, and reduced paperwork. Automation has been implemented in some ports and terminals, leading to faster turnaround times and reduced waiting times for vessels. Automated systems also enable real-time tracking of cargo and provide accurate data on container movements. The use of liquefied natural gas (LNG) as a fuel source for ships is gaining popularity due to its lower emissions of pollutants and reduced fuel costs. LNG-powered vessels are currently being used for both container and bulk cargo transport. Advanced analytics tools are being used to analyze data from shipping operations, which can help to optimize route planning, reduce fuel consumption, and improve overall efficiency. Blockchain technology is being used to improve the security, transparency, and efficiency of maritime supply chains. By creating a tamper-proof digital ledger, blockchain can help to reduce fraud, increase trust between parties, and improve supply chain visibility. The industry is exploring ways to reduce its environmental impact by using renewable energy sources, such as wind and solar power. Some vessels are also being retrofitted with scrubbers, which remove sulfur and other harmful emissions from exhaust gases. With all these innovations, the maritime shipping industry is transforming itself, making it more sustainable, more efficient and more cost-effective.

The COVID-19 pandemic has created unprecedented challenges for professionals across the maritime sector. However, technology can greatly improve the efficiency of maritime operations by creating a more sustainable and resilient shipping industry. Several international companies and port authorities from different parts of the world have recently signed a Memorandum of Understanding to ensure the interoperability of various global maritime technology platforms, which will require developing common data standards and Application Programming Interfaces (APIs).

The maritime industry is now looking to deploy more and more new generation vessels that could become a major component of the global freight transportation of the future. Since the 1960s, vessel tonnage has steadily increased due to economies of scale and fuel efficiency, with some container ships now boasting a capacity of 24,000 TEU. In port, these giant vessels are systematically connected to the shore power grid, reducing emissions

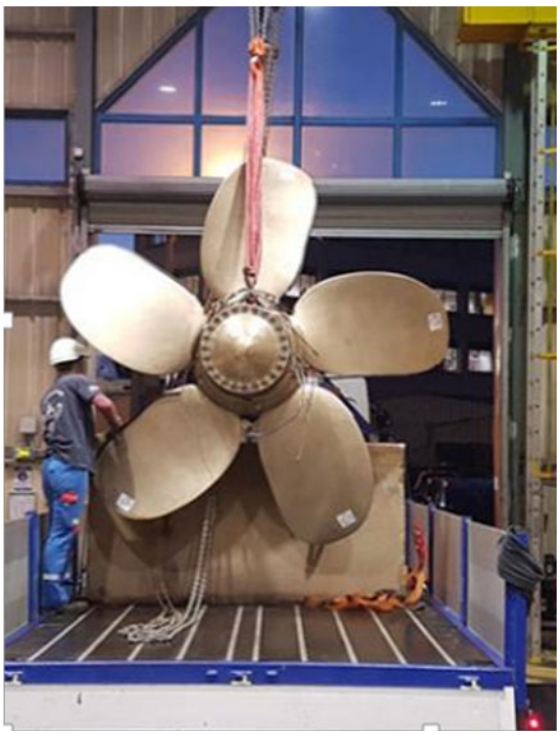

Fig. 2. 3D-printed screw of the new generation

while in port. This vision of the future will be achieved by modernizing the existing tonnage and building new vessels. The modernization and refitting of ships in service can be accomplished with lower material costs and fewer emissions thanks to additive manufacturing technology. This production method, which is already in use in various industries, can be used to manufacture anything from small machine parts to giant ship propellers.

More recently, a new generation 3D printed propeller, manufactured by the Naval Group in Paris in 2021, has been tested and certified. Naval Group produced this next-generation propeller with a 2.5-meter span, supported by five 200-kilogram blades, using a metal 3D printing process. Installed on the tripartite-class mine hunter, this propeller will now accompany the vessel on all of its operational missions. This screw is a technological achievement, as it is the largest metal 3D printed screw ever produced and the first screw to be made using additive manufacturing technology to equip a warship in service.

As part of its contribution to the maritime industry, the EU is funding projects to take advantage of new lightweight and high-performance materials that will be used in shipbuilding, for example to develop the first hollow propeller blade demonstrator. This innovative result was achieved using additive manufacturing (AM), a process in which 3D objects are created by adding layer after layer of material. Although additive manufacturing is increasingly present in industry, programming and designing complex parts such as propeller blades for a ship presents a significant challenge. The goal of the project is to produce propeller blades that increase the operational capabilities of the vessel.

Achieving high quality requires careful design, so modern technology has been involved in every step of the manufacturing and testing process. Drawing on technical expertise and innovative capabilities in 3D printing technology for the maritime industry, worked closely with Naval Europe Group's Inventor's Office throughout the process to define a production test and inspection plan for 3D printed parts, overseeing production steps and testing.

The AM process that researchers are using to improve ship propulsion is called wire arc additive manufacturing (WAAM). The process involves melting metal wire using an electric arc as a heat source. Once melted, the wire is extruded into beads that stick together to create a layer of metal. This is then repeated layer by layer to create a 3D metal part. WAAM is used to design large components – in this case, propellers up to 6 meters in diameter - those traditional manufacturing techniques are not capable of. This development will make it possible to produce propellers that are more complex in the future.

By improving ship design, from propellers to engines, the level of underwater noise emissions generated by ships will be significantly reduced, with less impact on wildlife mating, hunting and navigation. Excessive underwater noise levels can be particularly dangerous for marine life such as whales and dolphins, as it interferes with their communication, hunting, migration and echolocation. In addition to protecting the marine ecosystem, managing shipboard noise and vibration sources can improve crew well-being. An additional step to protect animal welfare will be a systematic approach by the human population to clean up the oceans from plastic waste. In

the future, the waters are planned to be patrolled and cleaned by small, safe electric vessels that will collect plastic and other waste to be sorted and recycled or disposed of responsibly. Through rig-to-shore programs, remnants of human presence, such as idle oil and gas platforms, will remain homes to corals and fish that can repopulate them. Under these programs, all hazardous materials are removed and the structure is left to nature.

There are several innovative technologies that are being developed or already in use in maritime passenger transportation. Here are some examples such as electric and hybrid ferries, which are becoming more common as a way to reduce emissions and noise pollution. For example, the Ampere, the world's first all-electric ferry, operates in Norway, and there are plans to build more electric ferries in other parts of the world. Autonomous ships are being developed to improve safety and reduce the cost of crewing. Several companies, including Rolls-Royce and Kongsberg, are working on autonomous ship projects. Virtual reality (VR) technology is being used to enhance the passenger experience on cruise ships. For example, Royal Caribbean has installed VR bungee trampolines and virtual reality headsets on its ships. Advanced propulsion systems, such as fuel cells, are being developed to reduce emissions and improve efficiency. For example, the MS "Color Hybrid", which operates in Norway, is the world's largest plug-in hybrid ship and uses both batteries and liquid natural gas as fuel. Air lubrication systems use a layer of air bubbles to reduce friction between the hull of a ship and the water, which can reduce fuel consumption and emissions. These systems are being tested on several ships, including the Viking Grace ferry.

Energy storage systems: Energy storage systems, such as batteries and flywheels, are being developed to improve the efficiency of ships and reduce emissions. For example, the Edda Ferd offshore vessel, which operates in Norway, is equipped with a hybrid battery system.

Overall, these innovative technologies have the potential to make maritime passenger transportation more sustainable, efficient, and enjoyable for passengers.

Smart ship technologies are also transforming the shipping industry. Autonomous technology for ships, IoT (internet of things), and data analytics represent some of the modern features that companies are adopting to improve shipping efficiency. By incorporating these features into their operations, shipping companies can improve time management and increase output from this domain. For example, implementing smart technology that accurately routes, deploys, and controls supply vessels would allow logistics divisions to be used in a more efficient manner.

Wärtsilä is one company leading innovation in ship technology. They believe that the marine industry must adapt to new technologies to remain competitive in today's market. Wärtsilä's recent acquisition of L-3 MSI brings a broad range of competencies within their portfolio. With 180 years of experience behind them as a technology leader in the marine industry's global transition to greater efficiency, lower operating costs, and enhanced environmental performance they are uniquely positioned to influence its future.

Some of the most promising maritime technologies include artificial intelligence, big data analytics, IoT on ships, and digital route optimization. Sensor technologies are also a popular choice for maritime-related industries. According to the experts, the top 10 trends in the maritime industry for 2023 include autonomous shipping, green shipping

and smart ports. ABB is one of the most innovative corporations in the maritime industry, offering a full range of digital solutions. Revolutionary technologies that are set to transform the maritime industry include blockchain, augmented reality and unmanned surface vehicles.

The future of maritime technology is bright: transforming technologies will lead to advances in ship design, propulsion and energy. Digitalization will facilitate automation and lead to smart ships, positively affecting safety and environmental performance. Communications will play a key role in the future of maritime technology, providing smart shipping, IoT, advanced communications, and artificial intelligence. New technologies that will revolutionize the maritime industry include blockchain, augmented reality, and unmanned land vehicles. The industry must adapt to these changes to remain competitive.

Results and discussion. The maritime industry is expected to see a wide range of trends in the coming years, including AI, clean energy sources, and autonomous ships. Other trends include digital sensoring, port automation, and blockchain. Industry experts predict that collaboration, green transition, security, and energy cost trends will be important in 2023. Green technology, electric ships, big data and predictive analytics are among the forthcoming innovations in the shipping industry.

Innovation in maritime transport can be achieved through the development and implementation of algorithm. Here are some steps that can be taken to implement an algorithm for innovation in maritime transport:

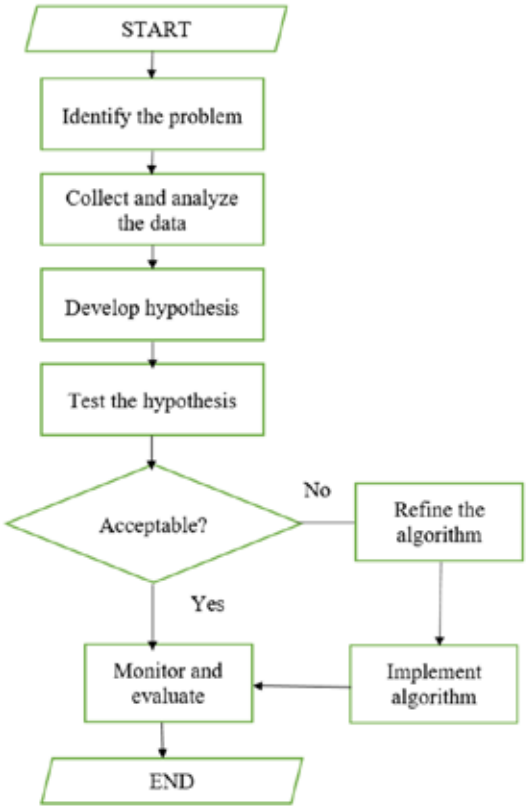

Fig. 3. Innovation technologies implementation algorithm

Starting with identifying the specific problem that needs to be solved in maritime transport, it could be anything from reducing fuel consumption to optimizing shipping routes. Gather data related to the problem identified which could include information on ship performance, weather patterns, shipping routes, and cargo volumes. Analyze the data using statistical analysis and data visualization techniques to explore the data and identify patterns and correlations. Based on the data analysis, develop a hypothesis about how to solve the problem. For example, the hypothesis that adjusting vessel speed to weather conditions can significantly reduce fuel consumption. Develop an algorithm or formula based on your hypothesis and test it using real-world data. This could involve running simulations or conducting experiments on actual ships. Based on the results of your tests, refine your algorithm or formula to improve its accuracy and effectiveness. Once you have a robust algorithm or formula, implement it on a wider scale in the maritime industry. This could involve collaborating with shipping companies or working with government agencies to promote the adoption of the new technology. Finally, monitor the performance of your algorithm over time and evaluate its impact on the industry. Use this feedback to continue refining the algorithm and improving its effectiveness. By following these steps, innovative algorithms can be created to help solve maritime transportation problems and move the industry forward.

Conclusion. Several strategies can be used to promote technological innovation in the maritime transport sector, primarily by encouraging and investing in research and development activities to develop new technologies and improve existing ones. This can include partnerships with universities, research institutes and other companies. Governments can provide financial incentives and funding for companies that invest in new technologies and innovations. This can include tax breaks, grants and subsidies. Collaboration between industry players should be encouraged to share knowledge and resources, and to work together to develop new technologies. Governments can also create regulations and standards that promote innovation and new technologies. These can include emissions standards, safety standards, and performance standards. Companies can use open innovation strategies to collaborate with external partners to develop new technologies. This can include partnerships with startups, universities, and other companies in the industry. The use of digital technologies such as big data, IoT and blockchain can help improve efficiency, reduce costs and increase transparency in the maritime transportation industry. The development and adoption of sustainable technologies that promote environmental sustainability, such as low-emission fuels, renewable energy and green ports, are just a few of the basic areas that can be used to promote technological innovation in maritime transport.

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