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Emerging technologies - changing the status quo and shaping the future of the maritime transport

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Abstract. Maritime transport is of crucial importance to modern society, as trade and the world economy depend on its reliability and sustainability. The general public has limited perceptions of the influence and role of shipping as an essential element in social and economic development. This paper aims to provide a useful insight into the current emerging technologies that can significantly shape the future of shipping. To achieve this goal, artificial intelligence (AI), big data analysis or blockchain can be widely applied in various segments to improve the efficiency and safety of maritime operations, with the need for increased computing power capable of processing large quantities of data in a very short time and solve complex algorithms and simulations. In addition, as the lack of key experts is a significant challenge in shipping, emerging technologies such as augmented reality and virtual reality (AR/VR) can bring added value, especially in the training of shipping experts.

1. Introduction

Even though the maritime sector is of crucial importance to modern societies since world trade and economy depend on the maritime industry's reliability and sustainability, the general public has a limited perception and appreciation of its influence and role as an essential element in terms of social and economic development, and as a potential source of excellent employment and career opportunities, with several million people currently working in activities and companies directly and indirectly related to oceans and seas worldwide. Thus, there is a significant need for advancements in connectivity and on premise systems, in order to enable the integration of emerging technologies in the otherwise disconnected and remote maritime sector.

The maritime industry has experienced significant qualitative and quantitative expansion over the past forty years and is projected to continue growing in the future due to the increasing demands of China and India's developing economies. This growth will lead to a higher level of maritime activities and will have a significant economic value and impact in the future. Quantifying the whole worth of the

global maritime industry is challenging due to its extensive impact on several elements of modern civilizations and their progress.

Shipping services, port operations, and logistical services are essential components for economic progress. Offshore infrastructure, such as oil and gas exploration or exploitation platforms, wind and wave farms, undersea pipelines, and power cables, are crucial energy supplies and play a major role in the transition to new green energy. Most global data flows rely on subsea telecommunications cables to facilitate financial transactions, emails, cloud storage, and video conferencing.

Maritime transport is changing rapidly due to technological developments like Big Data, Blockchain, artificial intelligence, 6G Connectivity, but also due to changing preferences of transport companies getting used to demanding more and more 'custom–fit' mobility and transport services. [1] Additionally, there is the urgency to realize sustainable and green technology used in maritime transport, reducing its carbon footprint, as is clearly noted in the European Green Deal.

The new technology solutions have the power to fundamentally change the maritime transport sector. In addition, these are also claimed to have beneficial environmental and economic impacts. However, potential unintended and rebound effects should be considered with respect to these beneficial impacts.

There are still significant challenges to implement the new technology solutions and underlying emerging technologies in a way that maximizes the benefits for maritime transport and at the same time minimizes any disruptions. Privacy issues, data security, lack of harmonization in national legislation, poor cooperation between stakeholders and lack of user acceptance are just some examples of issues that may hamper the wide-scale implementation of these solutions.

The current maritime transport requires adaptations to accommodate the full-scale implementation of the emerging technologies. The key is the realization of a well-functioning digital infrastructure meeting the requirements of the various relevant Smart Mobility applications and aligned with its specific context.

This paper aims to provide useful insight into the current emerging technologies that can significantly shape the future of shipping and their impact.

To achieve this goal, artificial intelligence (AI), big data analysis or blockchain can be widely applied in various segments to improve the efficiency and safety of maritime operations, with the need for increased computing power capable of processing large quantities of data in a very short time and solve complex algorithms and simulations. As the lack of key experts is a significant challenge in shipping, emerging technologies such as augmented reality and virtual reality (AR/VR) can bring added value, especially in the training of shipping experts.

2. Application of new technologies

The future poses numerous obstacles, including imbalances in supply and demand, environmental imperatives, and a shortage of skilled labor. However, it also offers significant opportunities for the maritime and shipping industries. Emerging technologies have the potential to address these difficulties.

The rate of innovation is very strong, particularly due to the introduction of new digital industrial technologies referred to as Industry 4.0. The advent of business 4.0 is revolutionizing the shipping and port business, requiring a comprehensive approach and in-depth knowledge of emerging technologies to effectively adapt to the changes and attain sustainable growth in the maritime sector.

For this purpose, artificial intelligence (AI), Internet of Things (IoT), 3D printing, robotics, big data, analytics, and blockchain can be extensively applied to various segments to improve operational efficiency and further improve the efficiency of maritime operations. Additionally, since lack of expert workforce is a significant challenge in the maritime industry, immersive reality technologies like augmented and virtual reality (AR/VR) can bring an added value specifically in the area of training, engineering, and inspection, in addition to core maritime logistics matters.

Industry 4.0 is set to completely transform interconnected systems, boost competitiveness, and enhance ship design, construction, propulsion, and energy efficiency. Upcoming ships will incorporate propulsion efficiency technologies, intelligent materials, and hybrid energy storage systems to maximize performance, leading to an increasing number of ships with improved capabilities.

2.1. Artificial Intelligence (AI)

Artificial Intelligence encompasses rule-based AI and machine-learning AI in a broader context. Rule-based AI involves the process of making judgments based on predefined rules provided by humans. Additionally, it streamlines tasks that necessitate both physical equipment and human decision-making. It can be characterized as a robotic device used in an office setting.

Machine learning artificial intelligence utilizes self-learning algorithms to create models without human interaction. Rule-based AI provides benefits such as expedited work automation, human instruction, and decreased expenses. Nevertheless, it does not possess the ability to learn independently, provide explicit information, or make decisions on issues that cannot be taught.

Machine learning can be classified into three primary categories: supervised learning, unsupervised learning, and reinforcement learning.

Artificial Intelligence (AI) is currently the leading trend in the maritime sector, thanks to its extensive range of applications throughout the industry, mainly:

2.1.1. Navigation and Route Optimization, including autonomous navigation. AI equipment can learn from past behaviors to apply actions, enabling autonomous ships and crew efficiency. It can review routes and navigational patterns, allowing Deckhands to focus on other tasks. AI can optimize routes, use local weather, traffic, and fuel use for faster and safer travel.

2.1.2. Fuel Consumption. AI and machine learning have the capability to track and analyze fuel usage in ships. They can provide recommendations for optimizing resource allocation and cost management, as well as discover areas of inefficiency in ship operations that can be improved.

2.1.3 Equipment and Ships Maintenance. AI technology can improve ship efficiency and safety by analyzing equipment performance and detecting unusual changes in fuel and energy use. This can alert crews to necessary maintenance and ensure equipment is receiving the necessary attention, reducing costs and increasing visibility, rather than waiting for the next maintenance cycle.

2.1.4. Port Density and Traffic. AI uses radar and GPS scanners to provide detailed results about maritime areas. It records navigational patterns, enabling safer navigation. This data benefits ships by allowing faster docking and reducing collision risks. Traffic pattern analysis assists the crew in steering clear of regions with high traffic, hence improving safety on the sea.

AI and machine learning are transforming the maritime industry by enhancing the ability of crew members and boats to effectively manage operations. These benefits include cost reduction through AI data tracking and insights, which can identify inefficient resource use and costly operations. Crews can then determine strategies to reduce fuel usage, reducing costs and allowing ships to save on expenses.

AI and machine learning, streamlining routes and port access, and automated navigation also enhance efficiency. Efficiency is also improved through AI and machine learning. Crews can focus on other tasks, while real-time data collection allows for proactive problem-solving. AI can also support sustainability by tracking fuel consumption and emissions, helping crews understand the environmental impact of their actions.

Lastly, AI eliminates human error by ensuring accurate data tracking, preventing errors that can impact present decisions and make historical data unreliable. Overall, AI and machine learning are revolutionizing the maritime industry by enhancing efficiency, sustainability, and accuracy.

2.2. Internet of Things (IoT)

By leveraging data science to enable informed decision-making and the Internet of Things (IoT) to improve safety, efficiency, and sustainability via the interconnectivity of devices such as cameras and sensors, the maritime industry is undergoing a significant transformation.

Data science and the Internet of Things are transforming the maritime industry by facilitating ship tracking and monitoring. Sensors and cameras are installed on ships to gather information regarding cargo, location, speed, and petroleum consumption. [2]

By employing data science methodologies to analyze this data, one can discern patterns, optimize routes, decrease petroleum consumption, and avert delays. [3] Port operations are also being transformed by IoT and data science through the collection of information regarding ship traffic, cargo flow, and atmospheric conditions.

By utilizing this information to forecast ship arrival times, optimize cargo handling equipment, and enhance port efficiency, shipping companies can realize cost savings. In addition to identifying potential safety issues and forecasting hazards in high-risk areas, IoT devices can monitor ship conditions. In addition, information gathered by IoT devices can be utilized to optimize fuel usage and determine the most efficient shipping routes in order to minimize emissions and the environmental impact of cargo. Overall, IoT and data science are transforming the maritime industry [4], enhancing safety, security, and sustainability.

2.3. Big Data and data analytics

Big data is a term used to describe the vast amount of structured and unstructured data that is generated in both our personal and professional life. This data is categorized based on its velocity and variety. Organizations must evaluate this data to identify hidden patterns, unknown relationships, uncertainties, and market trends. According to a survey by Ericsson, the marine sector has not kept pace with other transportation industries in adopting information and communication technology, despite the significant benefits it offers through big data.

The industry generates 100-120 million data points daily from ports and ship movements, which can be analyzed to identify efficiencies, such as quicker routes or preferred ports, resulting in a 5-10% increase in performance. [5]

Big data is being utilized in key areas such as chartering, operations, voyage operations, and vetting in the maritime industry.

Charterers need to find the right ship for cargo at the most economical price, relying on limited information from brokers and ship owners. Big data analytics can improve decision-making by integrating information, position reports, estimated arrival times, ship details, and market information into an exchange portal.

Ship owners can utilize big data analytics to calculate fuel consumption by considering variables such as bunker cost, freight rates, and timetables. Furthermore, it assists in making informed decisions on ship maintenance by utilizing performance data, hence enhancing efficiency and cost-effectiveness. Terminal operators and port agents can utilize dashboards to monitor ships, facilitating efficient decision-making in terminal and berth assignment, cargo management, and route monitoring.

Solutions use advanced algorithms to analyze data and optimize operations, reducing fuel consumption. Ship owners give utmost importance to ensuring the safety of charterers, being well-prepared for pollution incidents, and making informed decisions about navigation by utilizing data analytics in order to choose the most suitable ship.

The utilization of big data analytics is enhancing the process of decision-making and enabling accurate cost predictions for ships over their whole lifespan. Ports such as Hamburg, Cartagena, Rotterdam are adopting these solutions to enhance their port and terminal operations.

Predictive analytics tools have the potential to revolutionize the maritime sector by optimizing operations, bolstering ship safety, and safeguarding the environment. The extensive level of customization provided by these solutions is anticipated to stimulate demand. The expansion of globalization will increase the need for goods transit, necessitating the use of sophisticated data processing and predictive analytics to optimize time efficiency and reduce costs.

Ships provide huge quantities of electronic data, encompassing AIS, radar, and IoT sensors. The data can be categorized into three distinct groups: ship management, port and cargo management, and spatial imaging analysis. Ship management utilizes logs, manifests, system parameters, and bunker statistics to

optimize bunkering and maintenance operations. Port and cargo management utilizes data obtained from port authorities, freight forwarders, and trading houses to enhance the efficiency of cargo handling and optimize port facilities. Spatial imaging analysis utilizes data from position monitoring devices, pictures, and radars to conduct efficient routing and analyses traffic patterns.

Data analysis facilitates the monitoring and automation of compliance with environmental requirements, empowering shipping corporations to make well-informed choices regarding ship upgrades and fleet management in order to meet sustainability goals.

One of the most advanced in the field private company uses data analysis to optimize voyage planning, reduce fuel consumption, and improve ship scheduling. By analyzing historical and real-time data, it identifies efficient and cost-effective shipping routes. The system uses AI and machine learning for predictive analytics, allowing shipping companies to identify potential delays and optimize the behavior of the ship in real-time. Additionally, data can be used to reduce maintenance costs and equipment downtime through predictive maintenance models, governed by proprietary AI. [6]

One thing is for sure, emerging cloud technologies will have a profound impact on the design, production, and operation of ships and their various components.

Nonetheless, we should also be aware of the fact that the maritime industry encounters several significant obstacles in embracing big data: Cyber dangers Inaccurate representation of data, Investment in big data analytics has decreased due to the presence of current obstacles. Insufficient adoption of technology across different organizations, Insufficient number of workers with expertise in big data/Shortage of skills.

2.4. Blockchain

Blockchain is a decentralized technology that allows transactions to be recorded on multiple computers at the same time, making it easier to convert old economic, legal, and political systems into digital formats. Blockchain employs cryptographic techniques to store data in a series of interconnected blocks. Each block consists of three components: the hash value of the preceding block, the transaction record within the current block, and a newly produced hash value derived from a temporary random number known as a nonce. Blockchain can be categorized into public Blockchain, where participation is anonymous, and permissioned Blockchain, where participation requires authorization. [7]

Public Blockchain is mainly used for cryptocurrencies, while permitted Blockchain is faster and is used in various business fields like supply chain and intellectual property management.

Blockchain implementation in the shipping sector enhances operational efficiency by digitizing and streamlining paper-based documentation processes, reducing time, cost, and errors. This leads to a transparent, secure, and efficient supply chain, minimizing fraud and data corruption risks and ensuring better visibility and traceability.

The blockchain ecosystem connects all stakeholders in the supply chain, enabling real-time sharing of cargo details, trade documents, and shipping milestones, ensuring secure, immutable, and auditable information through blockchain technology, facilitating seamless communication and collaboration.

Blockchain technology can help improve transparency and reduce transaction costs in the maritime industry.

Blockchain technology represents a significant innovation in the maritime industry, providing an advanced solution to improve transparency and efficiency of operations. By using Blockchain, every transaction and activity related to the transportation of goods can be securely and immutably recorded, ensuring detailed tracking of every step in the supply chain.

One of the major advantages of implementing Blockchain technology in shipping is its ability to reduce operational and transaction costs. By eliminating intermediaries and manual processes, Blockchain can help simplify workflows and speed up transaction authorization and settlement processes.

Blockchain can also play a crucial role in combating fraud and theft in the maritime industry. Due to its secure and immutable nature, this technology can provide increased protection against illegal activities and ensure data integrity at every stage of the supply chain.

2.5. Augmented and Virtual reality (AR/VR)

Virtual reality and augmented reality are emerging technologies with increasing applications across industries. In the shipbuilding sector, these technologies are proving invaluable for enhancing efficiency, safety, and quality. Virtual reality offers an immersive digital environment, enabling comprehensive training simulations, complex product testing, and validation. By replicating real-world scenarios, VR empowers users to learn and practice skills in a safe, controlled setting. [8] Augmented reality overlays digital information onto the real world, providing real-time data and insights and data for quality control, product and tool location, warehouse management, and visualization of hidden areas. In shipbuilding, AR is particularly beneficial for maintenance operations, where it offers detailed 3D visualizations of machinery.

This technology significantly reduces the risk of errors, improves safety protocols, and accelerates repair times. By granting immediate access to schematics, maintenance records, and sensor data, AR optimizes workflows and minimizes downtime.

The combined power of VR and AR is revolutionizing shipbuilding, driving operational efficiency, and delivering substantial cost savings. As these technologies mature, their impact on the industry is poised to grow even more significant.

Augmented reality (AR) is transforming ship repair by facilitating remote support capabilities. Engineers have the ability to engage in communication with experts on land using augmented reality (AR) headsets, which results in a decrease in periods of inactivity and leads to savings in both time and money. This technology enables engineers to directly access and resolve issues on the ship.

Another facet of its benefits is the transfer of knowledge and training [9]. Augmented Reality (AR) is transforming marine education by offering interactive instruction to new crew members, minimizing the time needed to learn and providing a comprehensive understanding of a ship's systems. Additionally, it facilitates the acquisition of expertise from seasoned crew members, hence facilitating the development of interactive manuals for upcoming crew members. [10]

The maritime sector started adopting augmented reality technology for marine maintenance and repairs in order to remain at the forefront of the continuously changing maritime transport. This technology improves accuracy, minimizes periods of inactivity, and simplifies the process of teaching and sharing knowledge, so enabling efficient and successful maintenance and repairs.

3. Future Opportunities

International ports are turning to the use of cutting-edge technologies to develop to improve global competitiveness, reduce environmental impact, and improve working conditions. These smart ports will benefit from the implementation of advanced communication infrastructures, such as 5G networks, and the use of sophisticated information systems, such as TOS (Terminal Operating Systems), PCS (Port Community Systems), AIS (Automatic Identification Systems) and TMS (Traffic Management Systems). The use of liquefied natural gas (LNG) is gaining popularity as an alternative fuel solution for ships due to its positive environmental impact.

Renowned manufacturers such as Mitsubishi, Wartsila, Rolls- Royce, and MAN Diesel & Turbo, through their research departments, have succeeded in developing compressed natural gas (CNG) engines equipped with fuel optimization systems to increase energy efficiency. An example of good practice is the Port of Rotterdam, which is committed to achieving carbon neutrality by implementing digitization, energy transformation, and increasing performance through innovation. This approach involves digitizing operational processes, integrating technological systems, connecting logistics chains, and establishing global connections between ports. The main objective is to increase operational efficiency, ensure data sharing under security conditions, and minimize inefficiencies. By using the

The strategy of the Port of Rotterdam, priority is given to the energy, logistics and innovation sectors, for the implementation of projects to reduce the waiting time that allows ships to enter the port. [11] These efforts are essential to maintain competitiveness and sustainability in today's global shipping environment. The objective is to develop highly productive container terminals by utilizing artificial

intelligence (AI), the Internet of Things (IoT), and automation technology, such as remotely operated cargo handling machines.

Shipping businesses are utilizing the Internet of Things (IoT) and big data to enhance safety and efficiency in ship operations by developing technology that supports maritime navigation. Maritime Autonomous Surface Ships (MASS) are advanced ships that are equipped with high levels of automation. They are capable of carrying out various activities such as monitoring their surroundings, keeping track of equipment, and managing cargo.

Since May 2018, the International Maritime Organization (IMO) has been analyzing the regulatory aspects of automated ships. They have identified four primary levels of automation: a ship with automated processes and decision support, a remotely controlled ship with seafarers on board, a remotely controlled ship without seafarers on board, and a fully autonomous ship.

4. Conclusions

The maritime industry is undergoing a profound transformation driven by digital technologies. The integration of automation, artificial intelligence, big data, IoT, robotics, and blockchain is propelling the sector towards intelligent, efficient, and sustainable operations. These advancements are facilitating the creation of autonomous ships, optimizing ship design and manufacturing, and enhancing safety standards.

Big data analytics plays a pivotal role in driving data-driven decision-making. By harnessing vast amounts of data from various sources, maritime companies can gain valuable insights, improve predictive maintenance, and optimize operations. Moreover, blockchain technology offers enhanced security and transparency in maritime transactions, streamlining processes and reducing administrative burdens.

Emerging technologies, virtual reality and augmented reality are revolutionizing training, maintenance, and inspection processes. Immersive simulations provide realistic training environments, while augmented reality overlays digital information onto the physical world, assisting technicians in performing complex tasks. The convergence of these technologies, enabled by improved connectivity, is overcoming the industry's historical isolation and ushering in a new era of maritime operations.

Adopting clean energy sources and implementing energy-efficient technologies together effectively decrease the industry's emissions.

The convergence of these technologies, supported by advancements in connectivity and cybersecurity, is enabling the creation of a more connected, efficient, and sustainable maritime industry. As the industry continues to evolve, it is essential to address challenges such as data privacy, cybersecurity, and the need for a skilled workforce to fully realize the potential of these technologies.

Europe's marine sector must enhance its competitiveness and further meet environmental requirements, energy efficiency standards, safety measures, and human element considerations through advanced research, development, and innovation. Therefore, a member state or the European Union as a whole can gain a competitive edge by keeping an eye out for new prospects and emerging technologies that can be applied to the maritime sector.

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