

ARTIFICIAL INTELLIGENCE (AI) IS THE SMART SOLUTION FOR MARITIME INDUSTRY IN MODERN ERA

Hossain K A, PhD

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Abstract: Sea is always under threat from maritime activities, pollution, marine accident, and rising temperatures since recent development of civilization. Artificial Intelligence (AI) is considering as an effective and useful tools to monitoring, managing and decision making to optimize maritime resource extraction, ocean health by preserving environment, safety and security in modern era. AI facilitates to analyze huge data-sets acquire smartly from monitoring and tracking devices, underwater cameras, remote sensing system, environmental factors, etc. Now, the meticulous surveillance and monitoring of ocean health is a massive task where AI and Machine Learning (ML) play a crucial role than before. The particulars of marine environments specify technologies competent of understanding vast, interlinked data-sets to recognize trends and irregularity indicative of the sea's interest and smooth maritime activities. AI-powered solution with smart sensors, satellite images, smart models, etc are supreme in furnishing scientists and researchers with the tools essential for real-time surveillance, tracking and early recognition of maritime safety or security issues, vessel traffic, surveillance, and extending their observational reach. AI, ML and other smart technology will lead and dictate the future to preserve the sea and its resources for the mankind and safe operation of maritime industry by ensuring safety and security. It is an analytical study to evaluate the AI as a smart and effective solution for maritime industry along with efficient maritime operation in modern era.

Key Words: AI, ML, smart technology, ecosystem, maritime safety, security.

Introduction

Almighty has designed earth for life to better living with sustainability.¹ Salt water has cover around three-fourth of earth and which absorb unwanted temperature on it.² Earth is the home for all living organisms. The presence of seas is crucial for life and that is the mystery of creation. Again, seas play a fundamental role in regulating the global climate by ensuring habitation for a diverse array of marine life as well as influencing weather patterns. Again, oceans support a wide variety of ecosystems, like coral reefs, deep-sea vent, deep sea mountain, terrain, etc and which are home to countless species of plants, fish and animals. Human as earthly animal can see the dilapidation of embryonic environments on a daily basis. Technology otherwise is the collection of techniques which encompasses machinery, tools, ideas and techniques.³ A technological innovation is a new or improvises better product, service or process.⁴ Smart is something used as memorization tool or 'mnemonic device to set up criteria for efficient goal-setting and objective advancement.'⁵ Anything SMART means it is 'specific, measurable, assignable, realistic, and time-bound.'⁶ Smart technologies naturally more energy efficient, timelier, easier, accountable in the functions they perform, and more powerful when synchronized or collective.⁷ Automation and technological development made the job of industrial operators easier, faster, smarter in terms of physical efforts, but at the same time more complex and challenging, in terms of cognitive and mental efforts.⁸

AI is the generic term for intelligence displayed by machines, particularly computer systems.⁹ So, AI engages to create intelligent systems that can mimic human-like decision making processes as our brain do. It covers a broad range of techniques, methods and system to enable machines to learn from experience, reason, and history as well as make decisions which based on data.¹⁰ AI has been applied to fields including computers, electricity, steam or IC engines, and academia.¹¹ Today, AI is a versatile technology with a wide range of uses. Examples include credit scoring, e-banking, e-healthcare, e-commerce, e-agriculture, e-business, automation, industrial robots, language translation, image recognition, decision-making, and many other fields.¹² As a branch of AI, Machine Learning (ML) uses data-driven algorithms to enhance the precision and functionality of AI systems.^{13,14} ML uses a technique known as an algorithm to increase the power of AI systems.¹⁵ Again, Deep Learning (DL) is a subfield of ML which utilizes artificial neural networks (ANNs) that encourages by the human brain's configuration to process and learn from huge amounts of data.¹⁶ Natural language processing (NLP) is a discipline of computer science, exclusively related to AI.^{17,18} Machine vision is a systems engineering discipline which may be considered distinct from computer vision, a form of computer science.^{19,20} Main uses of

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machine vision are automatic inspection, industrial robot, organizational process guidance, etc.^{21, 22} ANNs are designed to examine huge data sets representing observations of natural phenomena and probable influencing factors.²³ DL is a subfield of ML, whereas ML is a subfield of AI. Again, the field of data science (DS) involves the achieving of useful knowledge and insights from structured and unstructured data. Again, Data Mining (DM) is commonly a part of the data science channel. DM is more about techniques and tools used to unfold patterns in data that were beforehand unknown and make data more functional for analysis. AI has become a transformative force which revolutionizing various industries including maritime and aspects of everyday lives. Finally, ML, DL, DS and DM are the interconnected fields that complement and balanced each other to drive and compel AI's advancements and innovations.^{24, 25}

Actually, the maritime industry is experiencing an important revolution powered by AI, which come as a game-changer. AI revolutionized entire business operation in general and in maritime sector in particular to resources management, maintenance, decisions making, increase efficiency, safety, security and sustainability.²⁶ It encompasses a broad range of applications in maritime industry which included predictive maintenance, route optimization, autonomous vessel operations, cargo handling, monitoring system, ocean surveillance, vessel operation, risk management, ensuring safety, decision-making, etc. Maritime stakeholders may examine huge amounts of data, extract valuable insights, and make data-driven decisions in real time by effective use of AI algorithms and ML techniques. Now a day, autonomous or smart ship is monitoring the sea, AI-driven satellite data analysis,²⁷ passive acoustics or remote sensing and other applications of environmental monitoring and surveillance to make use of ML successfully.²⁸ Interestingly, An AI-based satellite monitoring and surveillance tool called Global Plastic Watch is detecting and analyzing plastic waste locations and helping to reduce plastic pollution, mostly in the sea.²⁹ AI and ML are also being used to identify environmental problems and disaster early warning indicators.³⁰ It can also use successfully to detect and analysis of natural pandemics,³¹ earthquakes,³² landslides,³³ heavy rainfall,³⁴ long-term water supply vulnerability,³⁵ tipping-points of ecosystem collapse,³⁶ cyanobacterial bloom outbreaks,³⁷ droughts³⁸ and many more. The presence and preserve of seas has played a crucial role in shaping the globe's environment. Today, shipping, shipbuilding and ship recycling industry must steer and manage complex regulatory frameworks during ensuring the secure collection, storage, manages and analysis of vast data and information.³⁹ Moreover, the additional costs related with implementing and adopting AI solutions, needs many skilled man-powers to understand and manage AI-driven insights, and that create a challenge for shippers and players in this industry.⁴⁰ However, to overcome these obstacles requires collaboration and relation between researchers, academicians, industry stakeholders, investors, policymakers, technology providers, etc. moreover, those maritime sectors need to establish precise regulations framework, augment cybersecurity measures, and promote a culture of innovation, skill development, effective management and implementation.⁴¹ This paper will evaluate the AI as smart solution for problems of maritime industry and sea health in modern era including the concern issues like ocean observations and surveillance including maritime safety and security. The application of AI as remote sensing, smart sensors, intelligent underwater robots, vessel tracking, in smart ship, smart shipping, smart shipbuilding, including AI market, future prospects and challenges of maritime industry has been described in this paper.

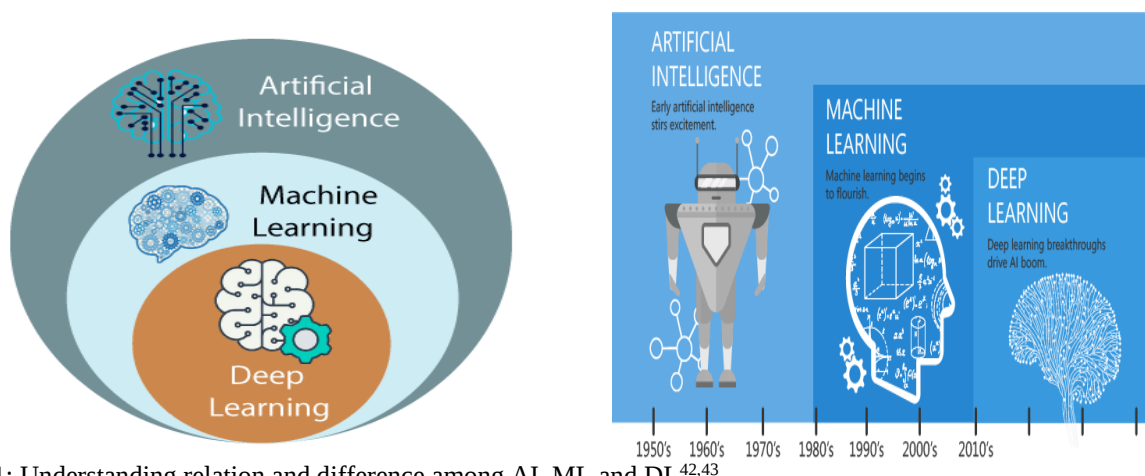


Figure 1: Understanding relation and difference among AI, ML and DL^{42, 43}

Marine Coastal Ecosystem

Marine coastal ecosystem includes different types of marine habitats with their own features, characteristics and species composition.⁴⁴ Those are characterized by high levels of biodiversity and productivity.⁴⁵ As we know that Over 70% of Earth's surface is made up of marine waters, which also offer 97% of the planet's water and 90% of its livable space.⁴⁶ Depending on the coastal features and depth of the water, marine habitats can be classified into several zones.⁴⁷ Actually, coastal zones play a significant role to

the human society and its development.⁴⁸ They have great environmental, economic, social, cultural and recreational importance.⁴⁹ They are considered among the most productive, exploited, inhabited and threatened areas due to their characteristics.⁵⁰ Moreover, many social, economic and environmental reasons, they led people to the coast where the environmental conditions like climate, natural environment, etc. and those are qualitatively better.⁵¹ Again, tourism growth is a key factor of the rapid expansion of built-up areas along the coasts.⁵² In addition to the socioeconomic benefits, coastal ecosystems also contribute in maintaining global biodiversity.⁵³

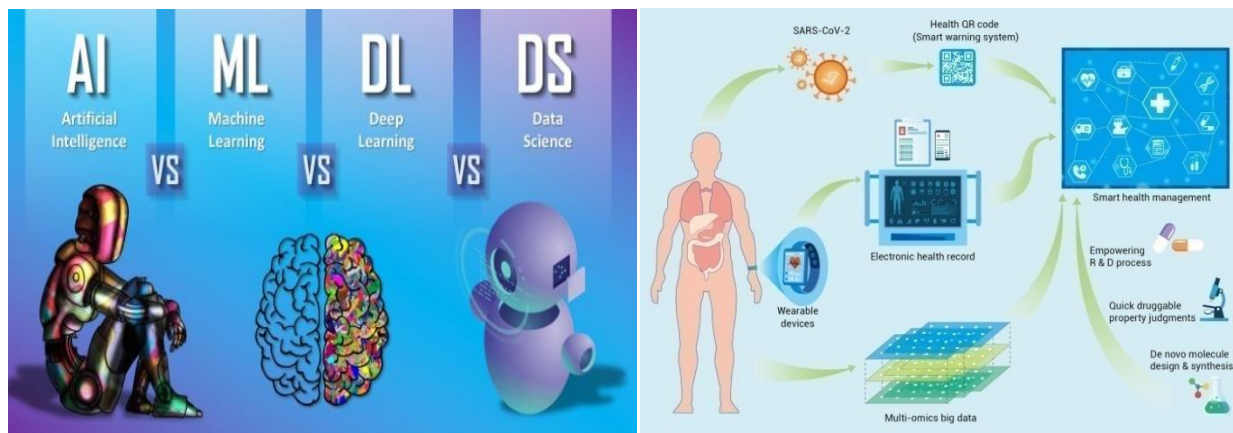


Figure 2: Family of AI and other smart interconnected fields⁵⁴ and AI as powerful paradigm⁵⁵

Coastal landscape and ecosystems are under severe pressure due to their environmental sensitivity, coastal people activity and uses concentration.⁵⁶ Increasing populations in the coastal zone, in addition with the expansion of the economic activities, those threaten even more the environmental and the social coherence of coastal zones.⁵⁷ Those pressures cause many miscellaneous social, economic and environmental impacts like landscape degradation, land use conflicts, degradation of natural and cultural heritage properties, land waste, coastal erosion, etc.⁵⁸ These pressures, enhanced by the effects of climate change and natural hazards, are compromising the viability, sustainability and conservation of coastal resources and increase socioeconomic risks.⁵⁹ However, threats to the coastal environment arise from natural hazards and the main triggering factor is the human-made interventions.⁶⁰ There are two major types of conflicts arises in the coastal zone namely conflicts among human activities and conflicts between human and environment.⁶¹ The importance of coastal zone has reflected by the use and benefitted by most of the coastal population and their economic activities in all maritime country like Bangladesh, Singapore, Indonesia, India, Britain, Japan or United States.

Use of AI to Preserve Healthy Ocean and Marine Life

AI gives marine scientists the ability to fully explore a new area of marine research. Scientists are using AI to help them tackle a number of issues, from plastic waste to climate change. Scientists are using AI to gather vast amounts of ocean data and find fresh insights to produce better solutions.⁶² The oceans give us several advantages, including the provision of minerals, gas, and oil. AI has the capacity to effectively harvest energy resources, create new medications, stop climate change, preserve fish, and identify endangered species.⁶³ At present, autonomous or smart ships can monitor the ocean, AI-driven satellite data analysis, passive acoustics⁶⁴ or remote sensing⁶⁵ and other related use of environmental monitoring and tracking are making use of ML.⁶⁶ AI systems have the ability to forecast natural disasters like storms, cyclone and tsunamis, providing communities with extra time to prepare and perhaps even avert needless loss of marine life. In the current research it has discover that, around 95% of the oceans are remain as unexplored.⁶⁷ In order to explore, comprehend, and find those parts of the seas are physically inaccessible to humans, scientist and researchers are now adopting AI to explore those effectively.⁶⁸ Now, scientist and researchers use AI algorithms, ML and other smart investigative tools to record data and useful information from underwater marine vehicles, robots and camera systems for exploration, monitor, collection and assessment.⁶⁹ AI helps in detection and identification new marine animal, plant, living species and mineral deep under the sea.⁷⁰ KAIKO is a top-tier remotely operated vehicle (ROV) with exceptional mobility and a focus on heavy lifting. It was invented and built by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) for exploration and investigation of the deep sea.⁷¹ The most recent iteration of this ROV is the 4th generation Mk-IV, and which has undergone multiple upgrades and is primarily meant for labor-intensive deep sea and marine resource surveys.⁷² At a depth of 10911 meters in the Mariana Trench, the first ROV KAIKO captured benthic animals like *Hirondellea gigas* and found hydrothermal vent organisms in the Indian Ocean effectively.⁷³

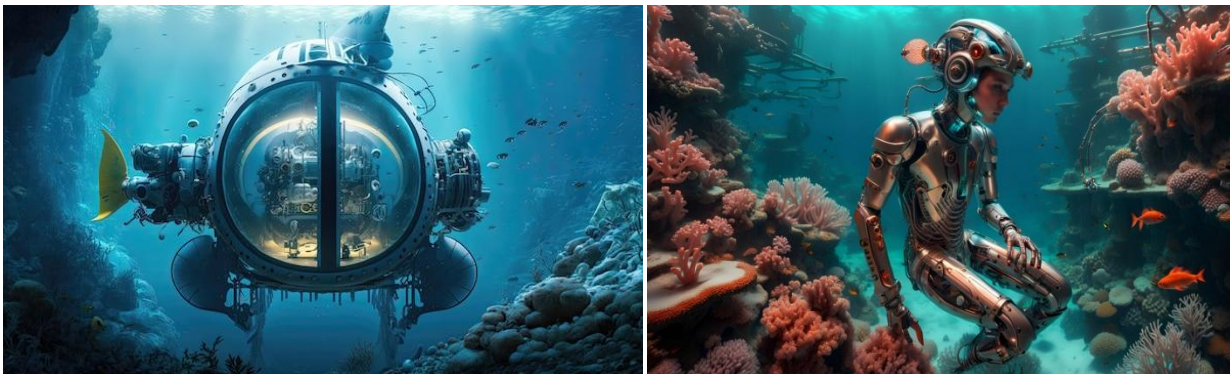


Figure 3: Underwater exploration by AI and smart technology operated vehicle⁷⁴ and robot⁷⁵

An underwater crab with six legs, created to scan and check submerged facilities like offshore oil and gas rigs off the Korean Peninsula, was unveiled by the Korean Institute of Ocean Science and Technology.⁷⁶ Their creation, Crabster, is a robot with AI that works underwater to repair undersea structures, like gas or oil pipelines or rig. The Crabster CR200 seabed exploration and investigation technology provides a substitute for propeller-based explorers for researchers and industry conducting underwater activities. The Crabster can move with enormous force, unlike ROVs and AUVs, which become unstable in strong tidal situations.⁷⁷ Big data, ML, DL and AI work together to enable advanced analytics and intelligent decision-making.⁷⁸ Today AI or ML algorithms handle huge datasets resourcefully and efficiently through diverse strategies like utilizing parallel processing enables algorithms to divide tasks among multiple processors speeding up computation.⁷⁹ AI technologies are being used by modern marine researchers to collect vast amounts of data on the ocean environment, including temperature, a variety of marine life, earthquakes, tsunamis, data about unknown minerals and many other things.⁸⁰ An AI program created by North Carolina State University of US researchers is capable of identifying tiny or marine creatures. Implementing AI and Big Data in commercial, research and business operations can significantly enhance efficiency, providing insights derived from complex data analysis that human capabilities alone cannot match.



Figure 4: Giant six legged robot Crabster CR200⁸¹ and AI will help maritime research⁸²



Figure 5: Microscopic marine organisms can be detect and analyze by new AI system^{83,84}

Today, ecosystems and human health are seriously threatened by plastic pollution, which has become a major worldwide environmental catastrophe. This dilemma is largely the result of the building industry, which is well known for using a lot of plastic products.⁸⁵ However, technological developments in AI present novel opportunities to address plastic waste and encourage environmentally friendly building methods.⁸⁶ Waste management in the construction sector is being revolutionized by the use of AI sensors and data analytics. Construction organizations can reduce the environmental impact of plastic waste by implementing specific measures and keeping a close eye on it.⁸⁷ A new degree of accuracy and efficiency in the management of plastic garbage is brought about by AI-powered smart bins and collecting devices.⁸⁸ In order to combat plastic waste and advance sustainable practices, the construction industry has a lot of potential when it comes to integrating AI and other smart technologies.⁸⁹ Now, Unmanned Surface Vehicles (USVs) and AUVs are using AI and ML to remove plastic and other types of pollution. USVs are robots which made specifically to gather commercial ocean data on the surface in an efficient and economical manner.⁹⁰ As a non-profit organization (NPO), water cleanup extracts plastic trash from the water using AI tools. Microsoft and Sustainable Coastline, a NPO with headquarters in New Zealand, are collaborating to repair coastal habitats. Autonomous ocean vehicles can differentiate plastic from other materials and objects by use of AI and ML. This helps identify areas with high concentrations of trash and address pollution at its source.



Figure 6: AI solution to identifying and tracking plastic pollution^{91,92}

The undersea realm needs adequate protection from plastic waste and coral bleaching. Marine life is negatively impacted by climate change in addition to terrestrial animal and plant species. Numerous aquatic species are at danger of going extinct. Today, AI methods are being used by scientists to monitor and safeguard mammals and marine life. AI has the potential to reduce illicit poaching. AlphaFold of UK has released 200 million protein structures expected for a slender year.⁹³ In the last 60 years, the scientists and researchers has been using advanced experimental methods powered by AI to determine the structures of over 180,000 proteins in atomic detail. This work has already improved our understanding of many fundamental processes in health and disease.⁹⁴ A joint effort between Queens College and Columbia University, OOICloud offers an AI-powered platform that allows scientists, oceanographers, and conservationists to access vast amounts of data for ocean research and management to safe marine life.⁹⁵ AUVs and sensors with AI capabilities can keep an eye on contaminants, pH levels, and water temperature in addition to providing information about the general health of the marine ecosystem. AI can help to detect and monitor plastic and automated cleanup as well. AI-driven robots can be created to gather plastic debris from the ocean on their own, providing a cleaner home for marine life. For ocean exploration, the Japan Agency for Marine Earth Science and Technology has created an underwater remotely operated vehicle called Kaico.⁹⁶ Numerous biological species that potentially have uses in industry and medicine have been found by this AI-powered vehicle.⁹⁷



Figure 7: AI can use for healthy Oceans^{98,99}

Nearly all of the heat trapped in the atmosphere by the trillion tons of greenhouse gases that humans have released is absorbed by the oceans.¹⁰⁰ Over 25% of marine species finds a home in coral reefs, which are a rich environment that also offers numerous advantages to people. The condition of coral reefs is continuously declining as a result of pollution and other human activities. Scientists are using AI to monitor and restore coral reefs. AI has demonstrated potential in numerous initiatives, including the mapping of sea-grass meadows from space and the discovery of undiscovered reefs that may contain heat-resistant coral. AI has proven to be helpful in recent times to researchers in locating previously undiscovered reefs that feature corals poised to survive in spite of warmer waters. One prominent example is the Allen Coral Atlas, which combines satellite data and field observations with ML techniques to map and monitor the world's coral reefs at a never-before-seen scale.¹⁰¹ Project CORai is an AI-powered solution to monitor sea life around coral reefs in the Philippines and which help government officials to make data driven best decisions to protect them effectively.¹⁰² This AI-based technology monitors, categorizes, and assesses coral reef health. Data from underwater cameras fitted with the Video Analytics Services Platform (VASP) is gathered for this project.¹⁰³ Using a live video feed, Google and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) have collaborated on another research that uses computer vision detection models to identify harmful crown-of-thorns starfish (COTS) outbreaks.¹⁰⁴



Figure 8: AI can use to monitor and protect coral reefs^{105,106}

The illicit seafood trade is expanding quickly, but global fish populations are rapidly declining. Researchers are using AI to help tackle this issue and guarantee effective fisheries and aquaculture management.¹⁰⁷ The marine species are seriously threatened by both illegal fishing and human influence. AI has the ability to instantly identify illicit fishing activity, enabling prompt action from the authorities. AI can be used to track and identify marine creatures.¹⁰⁸ AI can help scientists identify and monitor particular marine species, enabling them to learn more about the species' breeding patterns, migration patterns, and other possible dangers.¹⁰⁹ There is a threat of extinction for many types of aquatic life. AI has the ability to forecast the degree of overfishing threat in addition to monitoring poaching actions. In addition to reducing ocean damage and maximizing fishing efforts, AI techniques can assist fishermen in locating and predicting the best fishing zones. Oceanographers, scientists, and conservationists can access big data for ocean research and conservation through the Columbia University and Queens College partnership project OOICloud, which is an AI-enabled platform.¹¹⁰ So, by reducing illicit fishing and poaching, this data can support the preservation of the seas' delicate natural balance.¹¹¹



Figure 9: AI can use to combat overfishing¹¹² and preserve ocean¹¹³

AI Helps to Underwater Exploration

The ocean bed is not only home for plants and species but also home for battery metals or minerals like lithium, cobalt, copper, manganese, etc are significant for the planet's clean and green energy transformation. In August 2023, India became the first nation to send and land a spacecraft near the moon's South Pole. Again India has announced a mission called Samudrayaan or sea vehicle in Sanskrit and which is a platform, which is submersible to accommodated three people and allow to traveling in a depth of 6,000m by 2026.¹¹⁴ On the other hand, China is building an icebreaker with a submersible which aims to reach and explore the Arctic seabed this year. Actually underwater exploration will continue further, even after the Titan debacle. Actually, autonomous AI-driven submersibles can reduce the risks to human lives from deep sea monitoring, exploration and would allow faster mapping of sea-bed or ocean floors. Autonomous Unmanned Underwater Vehicle (AUV) has made a real revolution in the field of ocean research and deep sea exploration by the introduction of AI and smart technology.¹¹⁵ During the last two decades AUV were transformed seriously, costly and exclusively equipment for ocean academic research into a tool or devices for solving a wide range of issues in many fields like commercial, industrial, military, oceanographic, etc.¹¹⁶ AI is enlightening the depths of ocean. Scientists, marine biologists, and explorers have long been captivated by the ocean, with its mysterious species and hidden treasures. The depth, endurance, and effectiveness of traditional exploration techniques, which include remotely operated vehicles (ROVs) and human divers, are all limited.¹¹⁷ However, small submersibles, often without-crewed and driven by AI and other smart technology might be the future. AI-driven unmanned or smart underwater vehicle will be recharged automatically and will be sent deep under water and will be operated for months to years continuously in this modern era.

Use of AI to Fight against Climate Change

Earth is vital for the future of the planet. The oceans interact seriously with the climate of globe and consider them as better could offer effective solutions to climate change.¹¹⁸ Climate change is an important driver of many maritime related issues, like coral bleaching, Ocean accident, natural calamity and rising sea levels.¹¹⁹ It does no more astonish that climate change is a global crisis that is challenging to all from farmers to fishermen to industry experts to scientists to engineers to doctors and where poor people will be affected severely.¹²⁰ Now, a wide range of disciplines, skills, knowledge, intelligence and wisdom has been put to use in fighting it. Interestingly it's no more surprised that AI and other smart technology has emerged as one of the solutions; or at least, making viable solutions possible.¹²¹ In order to process massive volumes of climate data and to progress our capacity to predict and respond to severe weather occurrences, a new discipline called AI for climate prediction uses sophisticated algorithms and ML techniques.¹²² AI can assist coastal communities in adapting sustainably to the effects of climate change, including storm surges, flooding, and other tragedies, by offering more accurate forecasts. AI has the prospect to transform disaster control by improving avoidance, response and prevention endeavor.¹²³ In order to forecast and track natural catastrophes, ML models can evaluate data from smart devices, sensors, satellites, special tools and other sources. This enables more effective resource allocation and prompt disaster response.



Figure 10: AI can use underwater exploration¹²⁴ and fight against climate change effectively¹²⁵

Use of AI for Smart Solution of Port Operation and Management

All modern ports are enriched with advanced technology like specialized cargo-handling equipment and facilities, like gantry cranes, portable heavy lift crane, straddle carrier, reach stackers, forklift trucks, etc as well as with AI-power.¹²⁶ Ports usually have specialized functions like some cater mainly for passenger liners, ferries and cruise vessels; some specialize in container traffic; some cater general cargo or bulk; some ports mainly play an important role for nation's military or navy; some focus for any other purpose. Now, it is normal for ports to be either publicly owned in many developed countries, or port may be owned both by the state partly and by the partly cities themselves.¹²⁷ Smart ports are a new generation of digital ports that are designed to be more efficient, sustainable, and innovative than traditional ports. Smart ports are always augmented by smart and advanced technology. They use advanced technologies like internet of things (IoT), AI, ML, DL, DS, DM, big data, blockchain, and automation to improve their operations, optimize profits and reduce their environmental impact.¹²⁸ One of the key features of smart ports is their automation and inclusion of AI, which allows them to operate 24/7 without human intervention.¹²⁹ AI or ML powered solution can track vessel trade routes by integrating real-time data from blockchain databases and IoT sensors into AI algorithms. A port might maximize berthing time by following a vessel's trade path, which would provide an accurate expected time of arrival (ETA). The application of AI technology to precisely schedule a ship's arrival and departure could result in cost savings, minimize environmental effect and port congestion, and facilitate adherence to rules and standards. AI-driven Digital Smart Ports can manage increased freight and traffic, streamline staff work schedules, reduce human error, and boost supply chain efficiency. Actually, by using AI algorithms, the maritime sector will be able to see their operations from every angle.



Figure 11: Smart port will be game changer in any hub of the world^{130, 131}

AI helps to Develop Effective Vessel Traffic System (VTS) and Maritime Safety

The safety and efficiency of vessel traffic are paramount and act as heart of modern maritime operations. NeuralBoost is an AI based vessel traffic system invented by MakarenaLabs.¹³² It enhances vessel traffic services by offering real-time analysis of maritime data, significantly improving safety measures. Such modern and advanced technology swiftly pinpoints potential collision risks, navigational hazards, and anomalies, enabling proactive steps to avert accidents and guarantee the uninterrupted flow of vessel traffic.¹³³ Integrating NeuralBoost advanced tools into any vessel traffic services is necessary and useful to oversee and manage the complexities of modern maritime traffic.¹³⁴ NeuralBoost's technology transforms the way maritime data analyzed and turning vast amounts of information into actionable insights and that ensures vessel traffic services work effectively and can anticipate or mitigate

risks before they escalate. It also ensures fostering a safer maritime environment. It ensures a safer, more efficient pathway through the busiest waters, protecting vessels, cargoes, and crews against the dynamic challenges at sea. It is providing the clarity, but more foresight needed to navigate the future of maritime operations confidently. However, few benefits of NeuralBoost for vessel traffic services have been given below.

- It can help to identified risk and detects potential dangers in real-time, from collision risks to navigational hazards for marine platforms or vessels.
- It can enhance navigational safety for vessel by make sure comprehensive insights to navigate away from hazards and ensure vessels operation in safe waters.
- It can help to optimized traffic flow and use as aids in maintaining a smooth and efficient movement of vessels and minimize delays and improve operational timelines.



Figure 12: AI transforming shipping sector¹³⁵ and future of shipping traffic system¹³⁶

Smart Ship

Ships having numerous sensors attached to gather data about the vessel's condition, different indicators or sensor or system and that convert normal ship to smart ships. It is a new age and which calling us. Digital data, computer code, and new technological infrastructure which propel the modern world will be the components of smart ships.¹³⁷ These forces will unavoidably innovate and move the supply chain toward sustainability and environmental responsibility. In modern era, a large number of global commercial contracts might be the computer-coded smart contracts. We may refer to it as smart shipping together. Unlike Digital Twin, all of the data gathered from the ship is combined in one location, such as an office on land or the captain's bridge, and decisions are made only on the basis of real-time readings, without further scenario simulation. However, an IoT or AI platform that simplifies such procedure is required for this idea to succeed.¹³⁸ To run shipping in an intelligent, safe, and cost-effective manner, there is a sharp increase in the demand for automation in navigation and control technologies. Moreover, the development of information technology for intelligence, named as 4th industrial revolutions is encouraging the visualization of autonomous ships. Due to greater access to these technologies, nations like China, EU, Korea, Japan, etc. are influencing the development of environmentally friendly autonomous ships through public-private partnership. Smart Ships transform key areas like ship design and operation, redefining the global maritime industry and the roles of fundamental components.¹³⁹ After full implementation, smart ships intend to provide multi-layer optimization in fuel consumption, carbon or GHG emissions control, and energy efficiency by addressing maritime regulations and using global economic principles.¹⁴⁰ However, we need to be solves few problems in the way of broad adoption and practical application of AI and smart technology; like fear of job replacement, time and energy constraints, cybersecurity, data privacy and integration, talent shortage, skill in smart technology, reduced acting employment regulatory compliance, etc.¹⁴¹

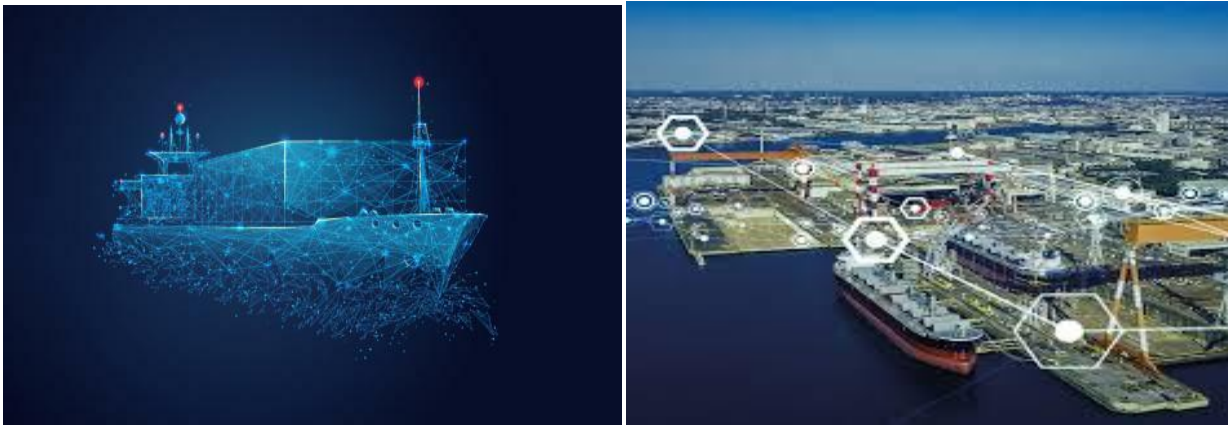


Figure 13: Smart

ship and future shipping industry^{142,143}

AI and ML use in Shipping Industry

Today, majority of ships have developed into remote offices that provide the captain and crew with a variety of tools and applications, including email, virtual networks, route planners, and dependable internet connectivity. But at present is the moment for shipping firms to consider better business solutions and long-term growth.¹⁴⁴ Now, AI and ML enter the scene and successfully solve every shipment issue as well as improve management.¹⁴⁵ Ship owners, business community, and other stakeholders that use AI and ML algorithms first will have a significant advantage due to their high intellect and industry knowledge. Algorithms using AI, ML, and DL can manage data spanning a vessel's operational history.¹⁴⁶ Many shipping companies today have effectively reduced the number of passenger and crew accidents, minimized fuel consumption, improved shipping management, crew management, and solved many other issues by utilizing AI, ML, and DL solutions. An ML-based method is used by the port of Rotterdam to estimate the time of arrival of boats.¹⁴⁷ Today, users can apply sophisticated algorithms and analyze data using AI or ML, which helps to inform the reasoning behind potential issues with maritime transportation. Improved voyage optimization will be possible with the use of advanced AI and ML algorithms. These algorithms will be able to predict voyage costs more accurately, minimize personnel performance, calculate the best route in under a minute, and provide recommendations for route, speed, and direction, among other things.¹⁴⁸

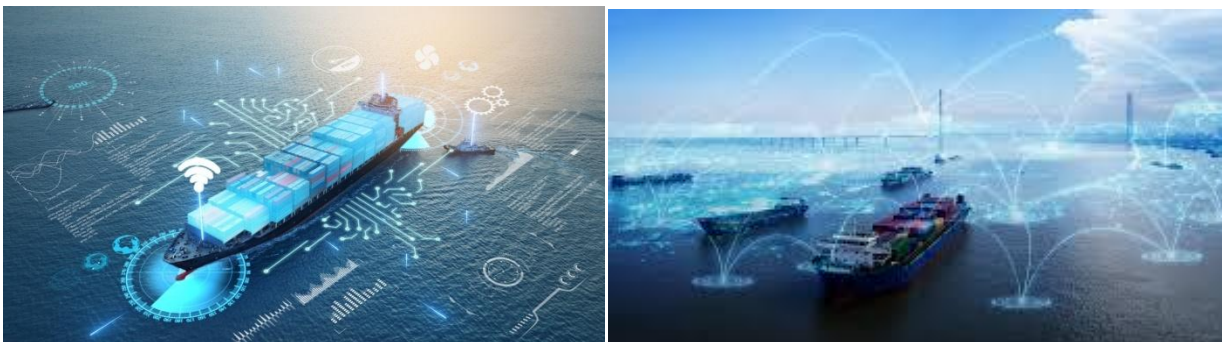


Figure 14: AI and other smart technology use in shipping industry^{149,150}

AI or ML has remarkable potential in maritime business field like maritime manufacturing and service industry. According to a joint report held in 2023¹⁵¹ by Lloyd's Register and maritime innovation consultancy,¹⁵² Thetius; the AI-driven systems and vessel autonomy markets will be worth a combined US\$ 5.01 billion by 2028.¹⁵³ AI and ML driven such automation can help to minimize the crew's exposure to such dangers. In near future, unmanned Maritime Autonomous Surface Ships (MASS) may also altogether remove all the risks involved at sea and unfavorable condition.¹⁵⁴ However, MASS is a short form used by the IMO¹⁵⁵ to explain merchant vessels which operate with minor or no human intervention, using sensors, special tools, software, and other communication systems to navigate, avoid collisions and perform the tasks and functions of the vessel effectively.¹⁵⁶ Now, AI drones are widely used to inspect tanks, hulls, and holds to help save money and time in smart shipping lines. Passenger tracking and monitoring in case of special need or emergencies is very useful.¹⁵⁷ Now a days, Bridge alerts when someone falls overboard, identification of illegal fishing

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or drug trafficking, recognizing fatigued and stressed crew members, stopping fires at very beginning, and pinpointing vessels and pirates in distress are few of the current AI monitoring and tracking device that the maritime industry are uses successfully.

AI and Future Shipbuilding

Shipbuilding is a complex and highly advanced form of primitive engineering that is designed to survive in the vast open seas. It integrates cutting-edge technology, which have always been significant in approaching the frontiers of what is possible. Many improvements will take place in the shipbuilding industry to control environmental pollution.¹⁵⁸ In the near future, we will witness smart ships as well as various vessels that are extremely cost-effective and environmentally friendly. We are all aware that Industry 4.0 has caused significant changes in the manufacturing industry.¹⁵⁹ Now, vessels are made from advanced, complex or even composite materials. Augmented reality (AR), virtual reality (VR) and robotics are used to create many types of ships or vessels virtually and that is useful to ship design.¹⁶⁰ AI or ML has given substantial benefits to the shipbuilding industry in terms of efficiency, accuracy, and safety. One area where AI is making great progress is design optimization and simulation. Naval architects and engineers can use AI algorithms to test many design changes and evaluate their performance in real time. AI has also been utilized to enhance the building process, with AI-powered robots which performing many critical and hard work like welding, cutting, and painting.¹⁶¹ AI-powered technologies can be used to monitor and optimize ship performance, recognizing potential concerns before they face problems and recommending corrective actions. This can assist to minimize fuel usage, promote safety, and extend the vessel's lifespan.¹⁶² AI-powered simulation tools can consistently forecast a vessel's behavior under different scenarios, allowing for the optimization of critical characteristics including hull form, propulsion systems, and structural integrity.¹⁶³



Figure 15: AI and other smart technology will transform future shipbuilding^{164, 165}

AI or ML has the potential to transform the shipbuilding industry by increasing efficiency, cost-effectiveness, and safety through predictive maintenance, automation, data analysis, better management, effective monitoring and better decision making.¹⁶⁶ Carbon and other GHG emissions can be managed and reduced, and environmental contamination can be optimized through the use of smart technologies. Smart technology in shipbuilding will readily improve the safety and security of the maritime industry.¹⁶⁷ Different types of equipment on the ship can be linked together via sensors, and we can also use AI-powered sensors to examine the quality of the devices and their performances.¹⁶⁸ Fleet members on shore can operate ships using AI-powered sensors. On the other side, 3D printing technology is used to generate virtual images of various objects. It would be extremely beneficial to design multiple pieces of equipment, as it might lower manufacturing costs. The virtual image would be extremely valuable in reducing manufacturing costs in the shipbuilding industry. The primary benefit of using the 3D printing feature is that we can cut development costs. Robotics plays an important part in many industrial operations, including manufacturing. It can also be used to do dangerous and monotonous duties. There are various dangerous duties in shipbuilding, like welding, cutting, grinding or tank inspection. We can use robots to complete these tasks.¹⁶⁹ Use of robots is suitable and effective in maintaining ship security, inspecting vessels, and preventing defects. Engineers can deploy robots in ship to work in hazardous areas where human life is at risk. Robots can perform a variety of activities in shipbuilding, including blasting, cutting, welding, painting, lifting massive weights, assembling and other construction work.¹⁷⁰ The ship's engine can be operated by using AI or ML power software, allowing the captain and engineers to monitor the ship's state.¹⁷¹

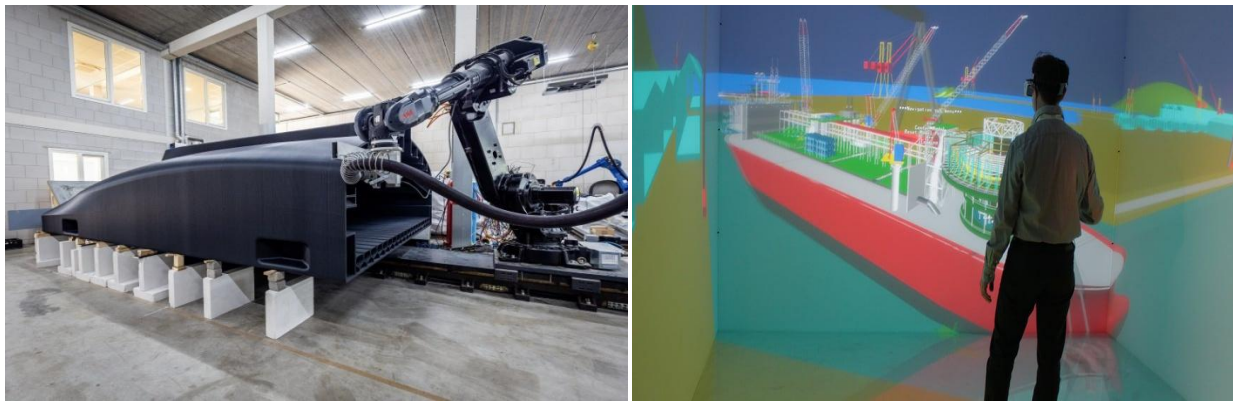


Figure 16: Smart

technology (3D printing)¹⁷² and use of VR in shipbuilding¹⁷³

Forecast of AI Market of Maritime Industry

AI and other smart technology change the face of the modern maritime industry in three ways. Such as: AI provides partial autonomy to full autonomy units, AI evaluates and optimizes processes and AI forecasts future trends. AI is expected to become a reality by 2060. It's expected to become a critical aspect of the maritime sector to improve ease of doing, using and safety in future also. Maritime businesses need to invest all best AI solutions to remain competitive, sustainable and accountable to the game.¹⁷⁴ AI and other smart technology can help maritime companies to make proper decision making, optimize operations, sustainable management by smart completion of tasks and continue accountability.¹⁷⁵ AI market has been classified into four segments on the basis of product and service, like as specialized AI applications, AI consulting services, AI hardware, and AI platforms.¹⁷⁶ Maritime industry is adopting new technology like AI and that will dramatically reshape the entire supply chain, not just on the industry or company level, adding USD 15 trillion to the global economy by 2030.¹⁷⁷ AI, ML or DL uses an organization's historical and real-time data to help, make ease, mitigate risks and serves as a collaboration tool that assists in decision-making processes. AI will shape the future of global shipping.¹⁷⁸ The global AI in logistics market size is expected to be worth around USD 549 billion by 2033, from USD 12 billion in 2023, and which is growing at a CAGR of 46.7% during the forecast period.¹⁷⁹ Today, more than 250 million companies are either using or are exploring AI and other smart technology in their business operations. So, around 77% of companies in the globe are either already using or in the process of planning to use AI integration. Interestingly, China has the highest rate of AI or ML algorithm adoption in compares to other nation. The global AI market is expected to reach USD 1.85 trillion by 2030.¹⁸⁰

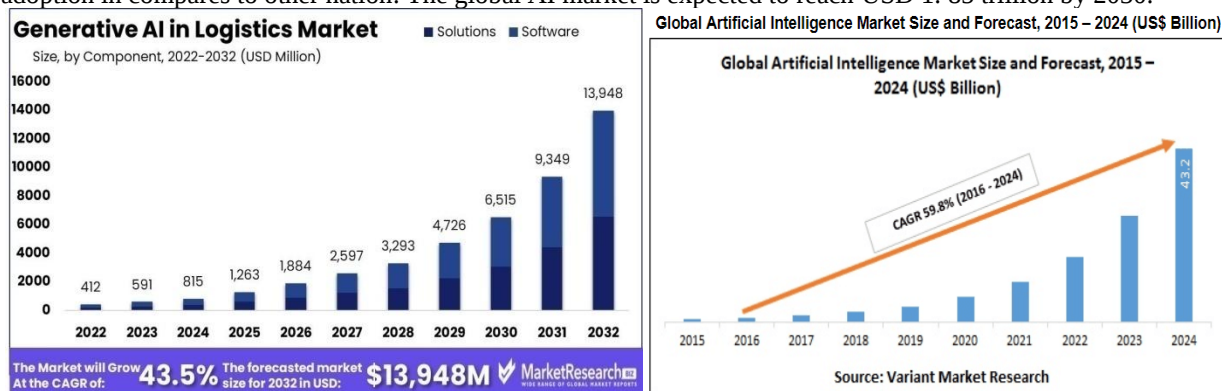


Figure 17: Forecast of AI software and solution in global market¹⁸¹ and growth in AI global market¹⁸²

AI Use to Develop Effective Surveillance System

The amount of data in the maritime domain is rapidly increasing due to the increase in devices that can collect marine information, like weather, port, sensors, buoys, ships, satellites, etc. It is difficult to manage vessel and marine related data due to high heterogeneity and AI or other smart solution is come as a blessing. Maritime surveillance encompasses the monitoring, detection, and tracking of vessels, activities, and threats within maritime domains. Effective surveillance is essential for various purposes, including national security, law enforcement, environmental protection, and maritime commerce. However, traditional surveillance methods, such as radar, AIS, and visual observation, have limitations in terms of coverage, accuracy, and efficiency.¹⁸³ The dynamic nature of maritime environments, characterized by vast expanses of open sea, diverse vessel types, and complex operating conditions, further complicates surveillance efforts. AI and other smart technologies like ML, DL and big data analytics offer new opportunities and viable solution¹⁸⁴ to enhance maritime surveillance capabilities. By analyzing large volumes of diverse data from various sources, AI

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algorithms can identify patterns, anomalies, and potential threats in real-time. AI powered systems can augment traditional surveillance methods by providing advanced data processing, decision support, and predictive analytics capabilities.¹⁸⁵ Moreover, AI enables autonomous and adaptive surveillance systems that can continuously learn and improve over time. AI applications in maritime security cover a wide range of tasks, including followings.

a. **Vessel Tracking and Identification.** MASS an emerging area of digital advancement in shipping and shipbuilding industries.¹⁸⁶ However, AI driven systems can analyze satellite imagery, radar data, and AIS signals to monitor vessel movements in maritime domain. ML algorithms can classify vessels, detect suspicious behavior such as deviation from regular routes or unexpected stops, and identify vessels involved in illegal activities like smuggling or piracy. Those smart technologies are help to tracking and monitoring of vessel movements in real-time, including vessel identification, classification, and trajectory prediction.¹⁸⁷ Such AI-driven solution has already become a game changing set up in shipping industry in 21st century.

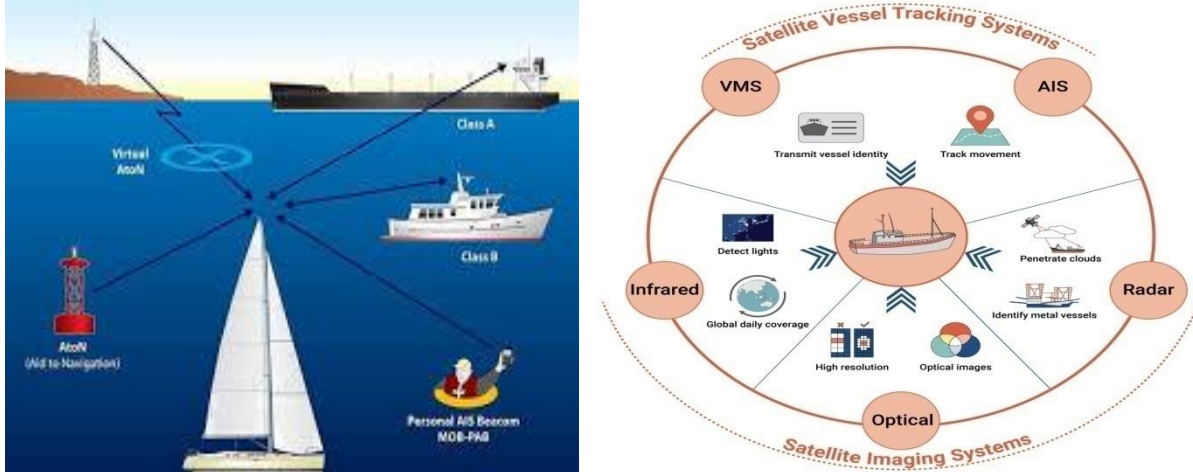


Figure 18: AI and other smart technology for NATO¹⁸⁸ and satellite¹⁸⁹ vessel tracking system

b. **Anomaly Detection.** The surveillance of large sea areas normally requires the analysis of large volumes of heterogeneous, multidimensional and dynamic sensor data, in order to improve vessel traffic safety, maritime security and to protect the environment.¹⁹⁰ AI algorithms can analyze patterns in maritime data to identify anomalies that may indicate security threats,¹⁹¹ like unauthorized incursions into restricted areas, unusual vessel behavior, or sudden changes in cargo operations. These systems can raise alerts to authorities for further investigation. Identification of suspicious behavior patterns, like deviations from typical vessel routes or abnormal speed changes can be done effectively by using smart technology.¹⁹²

c. **Predictive Analytics.** Data capturing and its analysis has always been an important part of maritime industry since the early ages. By analyzing historical maritime data along with environmental factors, AI can generate predictive models to anticipate potential security threats, like piracy hotspots or areas prone to illegal fishing. This information can help authorities allocate resources more effectively for proactive measures.¹⁹³ On the other hand, Nowadays the shipbuilding industry has become more technology-heavy and the competition in this field-initiated adoption of automatic control systems on ships where various data is collected analyzed and processed to create more efficient ships, optimized workflow and environment friendly engines and vessels.¹⁹⁴ Again, with the increasing interconnection of marine logistics, information exchange and data transfer across diverse stakeholders is significant to make sure competent supply chain processes, supervision, management and solution.¹⁹⁵ Such AI-driven solution has already become a game changing platform in maritime sector in 21st century.

d. **Intelligent Surveillance Systems.** AI driven surveillance cameras equipped with object recognition algorithms can monitor ports, coastal areas, and critical infrastructure for suspicious activities in real-time. These systems can automatically identify and track objects of interest, such as unauthorized vessels or individuals, and alert security personnel accordingly.¹⁹⁶ Fusion of multi-source data, including radar, AIS, satellite imagery and environmental sensors has to enhance situational awareness and threat assessment.

e. **Risk Assessment.** Maritime activities at sea and in coastal areas, ranging from shipping to offshore installations, pose a degree of risk to the surroundings and hold the possibility to result in accidents.¹⁹⁷ ML mainly, automated machine learning or Auto-ML offers a range of possibilities for analyzing large volumes of historical maritime accidents data with advanced algorithms for integrating predictive analytics in operational and policy decision-making for improving maritime safety.¹⁹⁸ AI and other smart technology can analyze diverse sources of data, including weather patterns, economic indicators, and geopolitical developments, to assess the overall risk landscape for maritime security in Bangladesh.¹⁹⁹ This holistic approach enables authorities to prioritize resources and develop strategic plans to mitigate potential threats effectively.

f. **Response Optimization.** Today, in big data and smart solution a huge amount of data need to be collect, store, analyze, and process by using inheritance application software and that is complex and complicated task. Big data technology is showing efficiency by processing big data into a form that users can understand and utilize.²⁰⁰ In the event of a security incident or emergency, AI powered system can facilitate rapid response by optimizing resource deployment and coordination among various agencies. AI-driven solution and decision support systems can provide real-time situational consciousness and recommend the most effective response strategies based on the available resources and the nature of the threat.

g. **Cybersecurity.** As maritime systems become increasingly digitized, AI can play a crucial role in identifying and mitigating cybersecurity threats, like hacking attempts on port infrastructure or maritime communication networks. The rolling threat of cyber-attacks got a shacked from the recent advancements in AI.²⁰¹ Now, AI has been applied in almost every discipline of different sciences and engineering matters. The involvement of AI not only automates a meticulous task but also improves effectiveness by many times.²⁰² AI-driven cybersecurity solutions can detect anomalous network behavior, prevent cyber attacks, and safeguard critical maritime assets.²⁰³ AI-driven solution is going to become a game changing system in maritime industry in 21st century.



Figure 19: Cyber threat and Cybersecurity in maritime sector^{204, 205}

h. **Geospatial AI Solutions.** AI is changing basically the way of IT solutions which are implemented and operated across both application and geospatial domain. This contribution outlines AI-driven techniques for 3D point clouds and geospatial digital twins as generic parts of geospatial AI.²⁰⁶ Now, AI technology can be used to simplify and accelerate workflows for geo-data processing and geo-information systems.²⁰⁷ Geospatial AI leverages high-resolution satellite imagery to monitor maritime activities. Algorithms detect vessels, track their movements, and identify anomalies like illegal fishing, smuggling, drug trafficking, etc. Real-time analysis enhances situational awareness. AI models learn from historical data to recognize patterns. Detecting irregular vessel behavior like entering restricted zones helps prevent security threats. Geospatial AI assesses environmental factors like sea surface temperature, currents, pollution, etc. Early warnings for oil spills, coral bleaching, or illegal dumping will benefit both safety and ecology. Such AI-driven solution has already become a game changing platform in maritime industry in 21st century.

AI Use to Develop Effective Maritime Safety and Security System

Maritime Security is a wide and vital as well as unformulated concept. Actually, it has become a large task linking many entities from global, local, public and private sectors.²⁰⁸ The object and goal of maritime security are to preserving the freedom of the seas, and to facilitating and protecting trade/commerce, as well as to maintaining good governance at sea or ocean.²⁰⁹ The utilization of AI in maritime surveillance offers several many potential benefits. AI algorithms can analyze data from multiple sources and identify subtle patterns or anomalies that may be missed by human operators or traditional surveillance systems.²¹⁰ AI driven surveillance systems provide real-time insights and alerts, enabling maritime authorities to make informed decisions and respond promptly to security incidents.²¹¹ Automation and optimization of surveillance tasks through AI technologies help streamline operations, reduce false alarms, and allocate resources more effectively. AI systems can adapt to changing maritime environments and evolving threats, continuously learning from new data and improving performance over time. There are several examples, successful and case study from around the world that demonstrate the effectiveness of AI in enhancing maritime security. Here are a few noteworthy case studies:

a. **Project GUARDIAN.** Last two centuries the United States (US) Coast Guard has safeguarded their Nation's maritime interests in the heartland, in the ports, at sea, and around the globe and serving for world maritime interest. They are trying to protect maritime economy and the environment for the Ocean. They also defend their maritime borders, and save those in threat.²¹² Project Guardian

has been implemented successfully very recently by the US Coast Guard to enhance maritime domain awareness. They have invented and use AI-driven analytics which improve threat assessment and resource allocation.²¹³ Such AI-driven solution has already become a game changing set up in maritime law enforcement department in 21st century.

b. European Union's (EU) Copernicus Program. Copernicus is a earth observation module of the EU's space program, and they are looking at earth and its environment. It benefits all European citizens and even all over the world. It offers information, data and relevant services which draw from satellite earth observation and along with non-space data.²¹⁴ EU Utilizes AI for environmental monitoring, vessel tracking, and search and rescue operations.²¹⁵ They demonstrate the scalability and effectiveness of AI in large-scale surveillance. Data and other information provided by the Copernicus services are very useful to end users for a wide range of applications in many sectors²¹⁶ and which includes urban area management, sustainable development and nature protection, regional and local planning, agriculture, forestry, fisheries, river, oceanography, health, civil protection, infrastructure, transport, tourism and many more.²¹⁷

c. Port of Rotterdam of Netherlands. The Port of Rotterdam, one of the largest ports in the world, has implemented AI-driven systems to enhance security and efficiency. These systems analyze data from various sources, including sensors, cameras, and shipping schedules, to detect anomalies and potential security threats.²¹⁸ AI algorithms are used to monitor vessel movements, identify patterns of suspicious behavior, and provide real-time alerts to port authorities. This proactive approach has improved the port's ability to prevent illegal activities such as smuggling and terrorism.²¹⁹

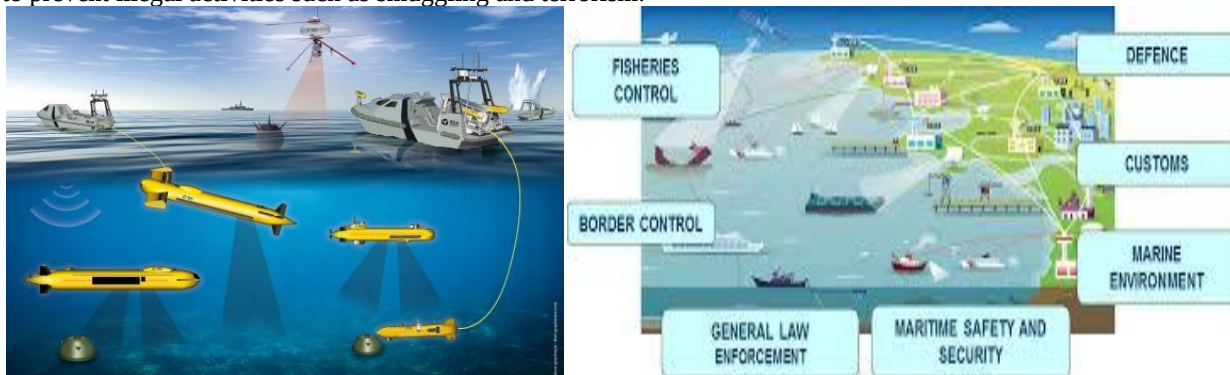


Figure 20: Role of unmanned maritime system strengthening EU security²²⁰ and EU Maritime Domain Authorities²²¹

d. Singapore Strait. Singapore, a global maritime hub, has deployed AI powered surveillance systems in the Singapore Strait to enhance maritime security and safety. These systems utilize a network of sensors, including radar, AIS, and CCTV cameras, to monitor vessel movements and detect potential security threats.²²² AI algorithms analyze data in real-time to identify suspicious behavior, such as unauthorized incursions into restricted areas or deviations from regular shipping routes.²²³ These insights enable authorities to respond quickly to security incidents and maintain the safety and security of the strait. Such AI-driven platform has become a very effective solution in maritime sector in 21st century.

e. European Maritime Safety Agency (EMSA). The EMSA is a European Union group or agency consigned to decreasing the risk of maritime accidents, dangerous incidents, marine pollution from ships and loss of human lives at sea by serving to implement the relevant EU legislation and regulation.²²⁴ EMSA utilizes AI and ML technologies to support maritime surveillance and security operations in European waters. The agency operates a range of satellite-based and terrestrial sensors to monitor vessel traffic, pollution, and maritime safety.²²⁵ AI algorithms analyze data from these sensors to detect anomalies, identify potential risks, and provide decision support to maritime authorities.²²⁶ EMSA's AI-based systems help improve situational awareness, enhance response capabilities, and ensure the safety and security of European maritime regions. Such AI-driven solution has become a effective platform in maritime law enforcement department in 21st century.

f. MARSUR: Enhancing Maritime Surveillance Cooperation. The European Defence Agency (EDA) and the European Union Satellite Centre (SatCen) have initiated a new phase of cooperation within Maritime Surveillance Information Exchange System (MARSUR). MARSUR, launched in 2005, has evolved into a multi-faceted information exchange platform involving 22 European navies. Under MARSUR III, 16 EU navies are developing capabilities for automatic exchange of maritime surveillance information and decision-making support. The bilateral agreement between EDA and SatCen facilitates secure data exchange, including classified information, to improve the common 'Recognized Maritime Picture' and enhance maritime security. Such AI-driven solution has become very popular system for maritime agency in 21st century.

g. European Union Maritime Security Strategy (EUMSS). It is a maritime security strategy of the European Union and that is abided by member states.²²⁷ It was adopted by EU member states in June 2014. The EUMSS presents a format to the EU's actions

within maritime security to encourage wider and more rational and coherent approaches to recognized actual maritime security challenges.²²⁸ Maritime security strategies have been adopted by a many countries such as France, India, United Kingdom, United States of America and many more.²²⁹ Now, the EU has revised its strategy for maritime security. A key focus is increasing the flexibility and security of critical maritime infrastructure, including gas pipelines, undersea cables, ports, offshore energy facilities, LNG terminals, etc. Now a day, cooperation on developing a regional surveillance and monitoring plan for underwater and offshore infrastructure is very vital. The European Commission (EC) and the high representative of the EU for foreign affairs and security policy adopted is a joint communication on 'an enhanced EUMSS for developing maritime threats' since March 2023, and it hope that, maritime sector will be benefitted further in coming days ahead.²³⁰ . Such AI-driven solution has become very popular platform for maritime agency in 21st century.

h. Maritime Safety & Security Information System (MSSIS). It is a generously and freely shared, unclassified, almost real time data and maritime information collection and distribution network. Its member countries contribute, share and distribute data from Automatic Identification System (AIS), coastal radar, and other maritime related systems.²³¹ It combines the information from participating nations into a single data stream through secure internet based servers. Through MSSIS, share and participating governments able to view real time AIS information around the globe in broad range of geographic display options, including text, photo overlays, electronic charts, even Google Earth.²³² So, those displays capable to incorporate additional features like user provided radar overlays. However, MSSIS was developed by the Volpe National Transportation Systems Center at the US Department of Transportation's Research and Innovative Technology Administration and is available to nations and global to advance global maritime safety, security, trade and environmental stewardship.²³³ Today, global sharing of AIS information among governments through a common and open exchange and that provides a solid foundation for all to greater worldwide trust, cooperation as well as open dialog.²³⁴ As a result, it improved stability, security, trade, and environmental stewardship.

i. Satellite Imagery and Remote Sensing. Remote sensing is the process of gathering data about the earth's surface without being in contact with it. Remote sensing process includes the illumination or energy source and that passes through the atmosphere and interacts with the target.²³⁵ Again, the electromagnetic energy emitted from the target is collected by the satellite sensors are transmitted in electronic form to a receiving and processing station into an image.²³⁶ The processed image is interpreted electronically or digitally to take out the information about the illuminated target. By this why, satellite imagery and remote sensing have revolutionized maritime surveillance and monitoring system.²³⁷ This technology provides unparalleled insights into our vast oceans. By harnessing its power, we can enhance maritime domain awareness, protect marine ecosystems, better management, reduce marine accident and ensure safety and security at sea.²³⁸

j. NATO's Maritime Surveillance Enhancement Initiative. The digital ocean initiative has been launched in 2023 to improve NATO's maritime situational awareness from seabed to space. It aims to transform allied maritime domain awareness by improving coordination between national and allied capabilities employed for maritime surveillance between the partners.²³⁹ This includes satellites and AI-driven autonomous systems that operate in three dimensions as below, on, and above the sea effectively. They emphasis to increase NATO's ability to see, sense and act to better protection of sea lines of communication, and which is vital for the security of the Euro-Atlantic area.²⁴⁰ NATO has begun an initiative to augment maritime domain awareness (MDA) and smooth activities to relevant fields. The Digital Ocean effort aims to improve coordination between Allied and national capabilities for maritime surveillance. This includes assets such as satellites, autonomous systems, and underwater sensors.²⁴¹

k. AI and Smart Conservation. Now, climate change has become an ever more persistent threat to global biodiversity. Animal populations in rapidly changing Arctic area are usually considered as a litmus test for the reaction of wildlife to climate change. Those wildlife histories are inextricably tied to sea ice, like polar bears, walrus, and certain caribou populations. As Arctic species navigate their increasingly random and fast-diminishing sea ice habitat, they concurrently face pressure from shipping, fishing, mining, tourism industries and other activities take place to the open ocean. Conservation practitioners need to develop adaptive management plans which are effective in these rapidly changing environments.²⁴² In recent years, advances in the field of AI-driven sea ice forecasting have enabled more accurate forecasts of sea ice conditions. One example is IceNet. It is an in-development operational AI model, which forecasts daily pan-Arctic sea ice concentration (SIC) up to three months into the future at a 25 km² grid-cell resolution.²⁴³ IceNet forecast maps have the potential to inform dynamic conservation and management plans, by providing early-warning of ice-dependent species seasonal movement patterns.²⁴⁴ By linking satellite observations of SIC with GPS movement records, the team was able to establish what SIC the caribou wait for before beginning their autumn migration. The end goal is a human-expert centered decision-support tool, which can be used for quick and easy assessment of forecast information to inform conservation, management and policy and which is possible with the help of AI-driven system or solution. Following the success of the caribou migration case study, the team is working with stakeholders to explore applications for other Arctic species and more such special challenges. Such AI-driven platform has become very popular system for maritime sector in 21st century.

I. AI based Maritime Security Solution in India. AI algorithms are capable to forecast probable marine incidents and accidents by examining historical data, weather patterns, vessel movements and other activities. The ability to anticipate future events enables the Coast Guard (CG) to strategically assign resources, reducing potential dangers and improving India's maritime area's safety and security. India, with its extensive coastline and strategic maritime interests, has been actively exploring AI-driven solutions to improve maritime security successfully. Their initiatives in this regards is remarkable and exemplary. The Indian CG has been deploying AI and ML algorithms to strengthen and boost up its surveillance and monitoring capabilities along the country's vast coastline and Exclusive Economic Zone (EEZ) very effectively. These systems analyze data from various sources, including radars, satellites, and AIS, to monitor vessel movements and detect suspicious activities like smuggling, piracy, drug trafficking, abnormalities, and illegal fishing. India's state-run defence technology behemoth Bharat Electronics Limited (BEL) has newly done a deal to strengthen the Indian Navy's maritime domain awareness.²⁴⁵ India has implemented the National Automatic Identification System (NAIS) to augment and improve MDA, marine safety and maritime security.²⁴⁶ NAIS is a network of coastal and satellite-based AIS receivers that track and monitor vessel movements in Indian waters. AI and data analytics are used to process NAIS data in real-time, identify abnormal vessel behavior, and generate alerts for potential security threats. These insights help maritime authorities take proactive measures to safeguard India's maritime interests.²⁴⁷ Major Indian ports such as Jawaharlal Nehru Port Trust (JNPT) and Kandla Port have been exploring AI-based solutions to improve security and operational efficiency.²⁴⁸ AI-powered surveillance systems, including video analytics and facial recognition, are being deployed to monitor port perimeters, identify unauthorized access, and enhance cargo security. These initiatives demonstrate India's commitment to leveraging AI and advanced technologies to strengthen maritime security, protect critical infrastructure, and safeguard its maritime interests in the Indian Ocean region.²⁴⁹

Future Prospect and Challenges

Today, entire maritime sector has become interested to applying advanced or smart technologies like AI, ML, DL, DM, DS, etc to achieve sustainability, efficiency, and cost-effectiveness as well as to solve regulatory compliance issues. Global maritime industry has come a long way since the days of oars and sail. All technology and development has replaced its predecessor as new one was more efficient, effective, offered benefits, user friendly, better, cheaper, cost-effective and safer. AI optimization follows same trend in modern era. It's already helping to optimize fuel, maintenance, operations, tracking, monitoring, paperwork, port calls, logistics, voyage planning, managing, decision-making, etc. So, with regulatory and commercial pressure towards optimization, these uses will only expand further in future. Again, the maritime industry by its nature is the most dangerous work environments among other industries on the planet. Seafarers at sea and other maritime workers at ashore has involved in high-risk tasks, like oil-spill cleanup and search-and-rescue (SAR) operations, firefighting, tank inspections and solve various maintenance, accident and incident problems.²⁵⁰ AI-driven robotics and ML, DL, DM, etc can take over high-risk and problematic tasks, from tank entry to underwater hull inspection to deep ocean activities. In modern age, automation will reduce the number of crew exposed to the dangers. In future unmanned or smart vessels might even eliminate the risk of crew life going to sea at all. At present, AI drones are being used for hold, hull and tank inspections, saving time and money along with ensuring safety. In future, cargo loading, unloading, inspection, tracking planning and stowage and management will be done safely and effectively by AI-powered tools and system. So, the use of AI in marine sector holds massive promise, revolutionizing safety measures, optimizing operational management, and contributing to a more safer, sustainable and accountable maritime industry.²⁵¹ By accepting AI and other smart technologies, maritime organizations like shipping, shipbuilding, port, coast guard, navy, solution provider can improve operational efficiency, reduce maintenance and fuel costs, optimize benefits and enhance safety as well as minimize their environmental impact and move towards the green industry.

The maritime industry has travelled a long way up till now. But there is still enough room and opportunity to go ahead further. AI and other smart technology are already being used onto land in many ways that are not so far available in the maritime sector. AI is remains appropriate, useful and becoming fastener in healthcare, from medical chatbots to cancer diagnosis or education or industrial field in modern era. The captains of the ships are not lawyers. Again, lawyers ashore are already using AI. Simple chatbots can assist public with their legal decisions. However, the maritime industry is still lagging behind from the industry ashore. It is an aspect ready for interruption considering the complex legal environment that captains deal with when underway. Stability is vital for ships. Before departure, captain, engineer and crew onboard gauge the stability according to estimated or reported cargo weights, where AI can help instantly. Commercial pressure, miscalculated stability, and inappropriately declared cargo weights and ships displacement can all result in dangerous marine accidents at any time during the voyage at high sea. Today, AI, ML, DL or other smart technology systems can allow real time calculation of stability as they can monitor the movement of the ship to save time and improve safety. But miscalculation or error in system powered by AI may create big disaster at port or in high seas. Developing and deploying AI driven surveillance systems require expertise in data science, computer vision, and domain-specific knowledge of maritime operations ant that create complexity.²⁵² AI power system has sometime needed ethical and legal considerations seriously. AI-driven surveillance raises concerns about privacy, data protection, and the potential misuse of surveillance, monitoring and execution capabilities for authoritarian purposes.²⁵³ In modern era, AI should complement human decision-making rather than replace it. So, it requires relationship and smooth understanding between AI systems and human operators to ensure effective integration and user acceptance otherwise some unwanted disaster may happen.



Figure 21: AI has both opportunity and challenge in maritime industry^{254, 255}

At present world of advanced technology, AI is important to research to harvest its potential and advantage; whereas avoiding possible drawback.²⁵⁶ In modern era, a big number of scientists, entrepreneurs, stake-holders and investors involved in the field of AI, including global figure like Stephen Hawking, Jack Ma, Bill Gates and Elon Musk, have signed an open letter warning that greater focus is needed on its safety and social benefits.²⁵⁷ Today, many economists, researchers and scientists agree that there is precious research to be done on how to optimize the economic benefits of AI by avoiding or extenuating undesirable effects, like inequality, unjust and unemployment in the society.^{258, 259} Great scientist Stephen Hawking,²⁶⁰ Microsoft founder and great hi-tech industrialist Bill Gates,²⁶¹ and SpaceX founder and great future-tech thinker Elon Musk²⁶² have articulated anxiety about the possibility where AI could develop to the point that humans could not control it and uncertainty may arise as singularity may occur.²⁶³ As great mathematician and scientist Vernor Vinge, discover to an imaginary point in the future when AGI reaches a level of super intelligence, gain own processing power and self-improvement capability that is beyond human understanding or command and that is known as singularity.²⁶⁴

Existential risk from artificial general intelligence (AGI) is one of the big challenges of AI. It is the idea that substantial progress in AGI could result in human extinction or an irreparable global catastrophe.²⁶⁵ If AI can exceed humanity in general intelligence as well as which can act or become superintelligent,²⁶⁶ then it will be complicated and dangerous issues as well as that can not possible to control. It will be the same consequence that, the fate of the mountain gorilla depends on human goodwill. If such situation may arise, then the fate of humanity will be depend on the actions of future superintelligent machines.^{267, 268} In 2015, Baidu Vice President Andrew Ng has noticed the world by declaring that ‘AI existential risk is like worrying about overpopulation on Mars when we have not even set foot on the planet yet.’²⁶⁹ So, the idea of popular stories and science friction about AI may be going to be real as AI takeovers the world and entire humanity in future. Recent advancements have made the threat of AGI and superintelligent machines have become more real. At the extreme, the possible future scenarios comprise substitution of the entire human workforce due to automation,²⁷⁰ takeover by superintelligent AI (ASI), and the notion of a robot uprising.²⁷¹ We need to find out the types of safeguards, algorithms and architectures which programmers can implement to maximize the probability that ‘improving AI would continue to behave in a friendly manner after it reaches superintelligence.’²⁷² In July 2023, the US government protected intended safety commitments from major tech companies in US and that including OpenAI, Amazon, Google, Meta, and Microsoft.^{273, 274} Most of the related scholars and technologists surveyed and believed that, we will be capable to develop AGI by 2060. However, if human-machine interfaces or other human-augmentation technologies like nano-tech end up being a bottleneck, it might not be possible to have a singularity until the end of the century.

In general, roles, regulations, instruction and procedures have come a long way to improving safety and security. However, they can never solve every problem perfectly. Again, maritime industry problem like, tracking passengers in emergencies, identifying illegal fishing, unnoticed pirates, vessels in distress, stopping fires as soon as they begin, recognizing stressed or fatigued staff, accidents, and many more simple but critical difficulty or crisis can be solved by AI tracking, surveillance and early warning tools effectively and successfully. Here, AI is really a smart solution.²⁷⁵ The maritime industry already has come a long way, although we need to go further. AI is already used in innumerable ways in ashore, whereas there are not yet much available in the maritime industry. Although we know that, maritime industry is in international nature, that’s why it faces exclusive barriers to adopt AI. So, as the technology has full-grown up, it will include every aspect of the different segments within the industry, by improving safety, usability, sustainability, accountability and efficiency.²⁷⁶ As an example, when Steve Jobs unveiled and make public the iPhone or smart-phone in 2007, no-one foresaw and forecast the innumerable uses as it become today. In near future, we are going to see that, AI become as familiar as smart-phones. Again, at sea, port and harbour, the major obstacle and challenge to adopt AI are not technical or legal; main barrier is

human and our attitude.²⁷⁷ So, unless we address the maritime industry's struggle to change, those traditions and practices will become an anchor holding us back. So, let's change our attitude and accept AI and other smart technology spontaneously in maritime sector to make this century remarkable.

Conclusion

The merchant shipping industry, global trade via sea and maritime industry as a whole faces numerous safety and security challenges, including piracy, smuggling, drug trafficking, cyber threats, environmental issues, etc. AI, ML, DS and other smart technology offer viable and sustainable solutions to many maritime challenges. Now, data related to ship performance, navigation systems and maintenance can help shipping companies to monitor and control vessels' performance and take necessary steps to improve the operational efficiency of the vessels and ease the shipping management system.²⁷⁸ Maritime surveillance plays a critical role in safeguarding coastal borders, ensuring maritime safety, security and combating all sort of illicit activities at sea. However, traditional surveillance methods face numerous challenges, including limited coverage, resource constraints and the complexity of maritime environments. In recent years, the utilization of AI, ML, DS, Big data and other smart technologies has emerged as a promising and very useful approach to enhance maritime surveillance and security capabilities. The vastness of the oceans makes regulation difficult, allowing bad people or criminals to exploit vulnerabilities. The potential and capability of AI and other smart technology can also assist and address many unsolved challenges facing by maritime sectors. With the development and implementation of smart technology in future, AI's role in monitoring and managing sea health will improve further. From supporting conservation efforts to predicting and responding to climate change and natural disasters, AI offers a powerful tool and suggestions for protecting oceans, diverse ecosystems, safe marine life and optimize minerals extraction. In modern era, we live in such a fertile and confuse world, even an e-mail sent from an infected server to another company's address can cause disruptive results or even total server-down. Extensive survey need to be conduct among scientists, researchers, engineers, programmers, companies, business man, stakeholders, sea fearers and the members of shipping and maritime community who are affected by the introduction of smart technology. We need to create education programs and smart infrastructure mainly for underdeveloped countries for sea fearer and maritime community with new standards in modern era.

In modern era, there is a greater risk of cyber threats due to inclusion of smart technology in shipping industry and maritime sector as well as increasing interconnectivity between ships, AI systems, smart devices, autonomous service and machinery. IMO has enforced enormous numbers of regulations to local, national and regional bodies around the globe; even though ship-owners need to have own cybersecurity systems for their safety and security. Now, hackers have the ability to steal sensitive information, disable the ship's merchant fleet, ports, and any companies external communications, or even confusion with the navigation, tracking and surveillance systems, and such incident potentially causing harm to the crew, ship, the company as well as maritime industry as a whole. There are few common cyber threats that can be posed to ship, system, shipping company or maritime industry. Such as: hackers can change ship data, may send false weather information to ships, create 'ghost ships', carrying out a denial-of-service (DoS) attack on the entire system, even making existing vessels disappear, falsifying emergency-position-indicating-radio-beacon signals (EPIRB), etc. There are few more common challenge may arise due to huge automation or introduction of smart technology. As a result, crew, semi-skilled workers, sea-fearer or port service provider being replaced by technology, especially when robots and autonomous elements are introduced. So, employees may experience anxiety, stress and worry due to such fundamental fear. Sometimes, employees may sabotage AI programs or they may become very cautious to use AI or smart technology. Actually, every technology primarily creates unemployment. But, in course of time, to run, to operate, to maintain and manage the new device and technology, need huge employment and that is paramount. So, before any AI initiatives, employees need to deal with these concerns through open discussion, essential training and logical motivation. At the same time, legal framework needs to be developed with strict regulatory measures in order to prevent companies from compromising their cyber security for financial benefits and run the maritime industry efficiently.

In this modern era, integrating AI into the shipping industry marks a central shift and transform towards more efficient operations, better safety, sustainable growth and optimize business benefits. Actually, miscellaneous applications of AI, ML, DL, ML, DS and other smart technology can ensure and achieve effective and optimize predictive maintenance, route mapping, better navigation, smart shipping, cargo handling, port equipment uses, operational efficiency and environmental conformity maritime activities. It is obvious that, the role of AI will expand and growth further and will offering new solutions for future challenges. The potential and prospect of AI to drive innovation in shipping is enormous, and which promise of achieving operational efficiency, reducing costs, significantly contributing towards environmental sustainability and attain business benefits. As AI and smart technology evolves more in future, the maritime and shipping industry's journey towards digitization and smart operations will certainly redefine global trade and commerce dynamics, making it more resilient, lively, useful, friendly and green. By proper utilizing and controlling AI's capabilities in maritime sector, we can work together to create a more sustainable and viable future for our beloved earth and to ensure and conserve the oceans for future generations. However, AI may present various risks and challenges, such as job displacement, privacy concerns, and potential misuse of technology. Addressing these risks requires a multidisciplinary approach, involving collaboration, cooperation between researchers, industry professionals, policymakers, business people, government and whole community and society. I hope in

the future, we can utilize AI and other smart technology at its full potential to make the health of oceans better and solve many of maritime security and safety issues as we don't know but which may rise in future. Ecologists and conservationists may harness the power of AI to observe ocean dynamics and restore it. We need to train our workforce and future generation with the knowledge and skill of AI and other smart technology in modern era to prepare them to utilize and deploy its power to save the earth.

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Dr Hossain K A, PhD was former Head of NAME Dept and professor /researcher / examiner at MIST and BUET.
Email:kahossain756@gmail.com

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