# ARTIFICIAL INTELLIGENCE (AI) IS THE SMART AND ECO-FRINDLY SOLUTION FOR AGE-OLD MARITIME INDUSTRY IN 21ST CENTURY

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**Abstract:** The ocean and its water extents more than a third of our earth's surface. Oceans always play a vital role in captivating carbon dioxide from the atmosphere, regulating climate, and providing home for marine living. However, Ocean and it's contained are under threat from pollution, 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 and maintain ocean health by preserving environment in 21st century. Now a day, AI algorithms and smart technology scientists and researchers can monitor and model Ocean environment with extraordinary accuracy, tracking changes over time and space that are important to the health and existence of marine life and even earth. The activities and life of marine species always remains one of the most mysterious areas for researchers due to the enormity and cloudiness of the Ocean, and that becoming obvious, and AI get the credit. Today, AI and other smart technology facilitates including analysis of huge datasets obtained from tagging and tracking devices, underwater cameras, or remote sensing technologies, providing new insights into migration patterns of species, predator prey relationships, coral reef history, their response to environment, seabed exploration, and many more research subjects. Now, the meticulous surveillance of ocean health is a massive task where AI and Machine Learning (ML) play a crucial role than before. The particulars of marine environments stipulate technologies able to interpret vast, interlinked data to recognize trends and variances analytic of the ocean's security and prosperity. AI-powered sensors, satellite imagery, and projecting models are supreme in furnishing scientists with the tools essential for real-time tracking, observing and early recognition of environmental matters, vessel traffic, surveillance, extending their observational reach and logical capabilities away from traditional methodologies. Such smart technology will lead and dictate the future to preserve the ocean and its resources for the mankind. It is an analytical study to evaluate the AI as a smart and effective solution for ocean resource conservation as well as efficient maritime surveillance.

**Key Words.** AI, ML, DS, smart technology, ocean health, GHG, ecosystem

## Introduction

Earth has designed by Almighty for living and it's full of live. Oceans cover around three-fourth of earth surface and which absorb unwanted temperature of this planet.[1] Geo-scientist discovered that, the earth formed around 4.5 billion years ago with a red-hot and molten mass. After that, it has cooled and water vapor in the atmosphere has condensed and has fallen as rain. Ultimately, rainwater has covered the low-lying areas of the earth's surface to form oceans. On the other hand, plate tectonics play a major role to shaping our planet's surface. The movement of tectonic plates has created basins, which are then filled with water, and eventually leading to formation of oceans.[2] Interestingly, Almighty has gifted water cycle to our planet, which involves the continuous movement of water between the atmosphere, land, and oceans. This wonderful and most scientific cycle helps to maintain the balance of water on earth and ensures the oceans remain filled with water. Earth is the home for living organisms. The presence of oceans is crucial for life and that is the mystery of creation. At the same time, oceans 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. Finally, these ecosystems contribute to the biodiversity of the earth. However, it has been estimated that, 96.5% of world's water by volume belong to oceans and only 2.5% as freshwater. Virtually 70% of this freshwater remains as ice and glaciers. Today's water scarcity is also caused by over-exploitation, excessive use and unequal access to water among different community and nations.[3] Actually, the future of humanity and civilization is extremely reliant on the oceans. The oceans are always not only important for our planet but also for human populations. Oceans drive key global systems that affect us on land. Human as earthly animal can see the dilapidation of embryonic environments on a daily basis. However, it is not the case for submerged environments.[4] This makes it difficult for us to appreciate the degradation of marine environments caused by human activity like pollution, overfishing, dumping, many economic activities, over exploitation, shipping, and other misuse.[5]



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Technology is the application of scientific knowledge to the practical for human life. As per Collins dictionary 'technology is the branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society, and the environment, drawing upon such subjects as industrial arts, engineering, applied science, and pure science.' [6] Technology otherwise is the collection of techniques. It may encompasses machinery, tools, ideas and techniques development is concerned with their becoming still more and more complex and complicated in terms of structure, procedures and operations involved.[7] Again, innovation is more than a buzzword or exhortation. 'Innovation is a new thing or a new method of doing something.'[8] Innovation may define as the adding extra steps for developing new services and products in the marketplace or in the public. New innovations are usually emphasis and beautify technology to ease human life. However, technological development is the overall of invention, innovation and diffusion of technology or process.[9] A technological innovation is a new or improved product or process whose technological characteristics are significantly different. Smart is something used as a mnemonic device to establish criteria for effective goal-setting and objective development.[10] Anything SMART means it is Specific, Measurable, Assignable, Realistic, and Time-bound.[11] Usual meaning of smart technology is to the incorporation of computing and telecommunication technology into other technologies that did not before have such capabilities.[12] Smart technologies naturally more energy efficient, timelier, easier, accountable in the functions they perform, and more powerful when synchronized or collective.[13] American great inventor and scientist Thomas Alfred Edison, individually or jointly, held a world record of 1093 patents. Additionally, he established the first industrial research laboratory in the history. In fact, Edison promoted the advancement of technology. Anything that has to do with inventions or innovations is related to technological advancement.[14] The process of transforming an idea or product from a hypothesis into a workable version is known as development.[15] 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.[16] We must remember that, 'technological developments can be quickly understood if experimental or theoretical results are presented in an image format instead of as a numerical result.'[17]

In broadest sense, AI is the generic term for intelligence displayed by machines, especially computer systems.[18] So, it involves creating intelligent systems that can mimic human-like decision-making processes. It encompasses a wide range of techniques and methods to enable machines to learn from experience, reason, and make decisions based on data.[19] AI has been applied to fields including computers, electricity, steam or IC engines, and academia.[20] 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.[21,] AI enables technology such as machines that can observe, comprehend, act, and learn scientific disciplines. Once more, entire credit for the phrase Machine Learning (ML)'s rising popularity in 1959 goes to Arthur Samuel. As a branch of AI, ML uses data-driven algorithms to enhance the precision and functionality of AI systems.[22] So, it is a division of AI which focusing on developing algorithms that allows computers to learn patterns from data without being openly programmed.[23] ML uses a technique known as an algorithm to increase the power of AI systems,[24] and phishing scams, or spam may all be combated using her.[25] It may examine the contents of phishing and spam carefully in an effort to find harmful components.[26] On the other, handRina Dechter coined the phrase Deep Learning (DL) and shared it with the ML community in 1986. However, Yann LeCun et al. used the conventional back-propagation approach in 1989.[27] Just a multi-layer neural network makes up DL. So, it is a subfield of ML which utilizes artificial neural networks (ANNs) that inspired by the human brain's structure to process and learn from huge amounts of data.[28] Brain neurons are the source of the word 'neural network.' The general idea behind a neural network is to build a network of neurons, where a neuron is just a cell that processes information or data from another neuron after receiving an input signal in the form of data.[29] Again, Natural language processing (NLP) is an interdisciplinary subfield of computer science, exclusively AI.[30, 31] It is principally concerned with providing computers the ability to process data encoded in natural language by using either rule-based, statistical or neural-based approaches of ML and DL.[32] Since 2015, the statistical approach was replaced by the neural networks approach.[33] On the other hand, machine vision as a systems engineering discipline can be considered distinct from computer vision, a form of computer science.[34,35] It is the technology and methods used to provide imaging-based automatic inspection and analysis for such applications as automatic inspection, process control, and robot guidance, usually in industry.[36,37] So, machine vision process includes planning the details of the requirements and project, and then creating a solution. During run-time, the process starts with imaging, followed by automated analysis of the image and extraction of the required information.[38,39] Primary uses for machine vision are automatic inspection and industrial robot/process guidance.[40, 41]

Multiple layers of neurons are used in DL to bridge the input and output of the network.[42] Higher-level features can be gradually extracted from the raw input by the several layers.[43] For example, in image processing[44], lower layers may identify edges, while higher layers may identify the concepts relevant to a human such as digits or letters or faces.[45] Actually, ANNs are powerful prediction tools that establish relationships between causative factors.[46] ANNs are designed to analyze large data sets representing observations of



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natural phenomena and possible influencing factors.[47] They can identify and quantify hidden patterns and correlations without prior information about the dynamics of the underlying causes.[48] Once these patterns and correlations are established, the neural network can be used as a prediction tool for unobserved situations.[49] ANNs can also be used to examine the sensitivity of the output to input data of various possible contributory factors and thus provide information about the factors that most powerfully influence the targeted phenomenon.[50] However, DL is a subfield of ML, whereas ML is a subfield of AI. Again, the field of data science (DS) requires utmost attention. So, DS involves the extraction of knowledge and insights from structured and unstructured data. It combines elements of statistics, computer science, and domain expertise to interpret and draw meaningful conclusions from data. The multidisciplinary area of data science employs all methods available for data analysis and information extraction. DS adopts a broad perspective and seeks to ask more insightful questions about data in order to gather additional information and insights from it.[51] Businesses or any other challenge can handle massive amounts of big data, both structured and unstructured, to find patterns with the help of DS. To meaningfully interpret large data and data from numerous sources, DS tools are vital. Again, Data Mining (DM) is commonly a part of the data science channel. However, DM is more about techniques and tools used to unfold patterns in data that were beforehand unknown and make data more functional for analysis. Ultimately, DS has a more general use. It's a field of study just like computer science or applied math, Whereas DM is more about narrowly focused techniques inside a data science process but things like pattern recognition, statistical analysis, and writing data flows are applicable.[52,53] Ultimately, AI has become a transformative force which revolutionizing various industries including maritime and aspects of everyday lives. Moreover, within the domain of AI, several key components play decisive roles in shaping its potential and prospect.[54] 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.[55]

The maritime industry is undergoing a significant transformation powered by AI, which has 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.[56] 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 can analyze vast 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 ocean, AI-driven satellite data analysis,[57] passive acoustics or remote sensing and other applications of environmental monitoring and surveillance to make use of ML successfully.[58] 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 ocean. Additionally, it assists in determining who and where improperly disposes of plastic garbage, which ends up in the ocean.[59] AI and ML are also being used to identify environmental problems and disaster early warning indicators.[60] It can also use successfully to detect and analysis of natural pandemics,[61] earthquakes,[62] landslides,[63] heavy rainfall,[64] long-term water supply vulnerability,[65] tipping-points of ecosystem collapse,[66] cyanobacterial bloom outbreaks,[67] droughts[68]and many more. As we know that, oceans cover a significant portion of planet's surface, which is essential for supporting life on our beloved earth. So, the presence and preservation of oceans has played a crucial role in shaping the globe's environment and providing the conditions necessary for life to flourish. We must remember that there is more biomass in the ocean than on land and we need to conserve it. On the other hand, shipping and shipbuilding industry must steer and manage complex regulatory frameworks during ensuring the secure collection, storage, manages and analysis of vast data and information. 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. However, overcoming these obstacles requires collaboration and relation between industry stakeholders, policymakers, and technology providers. Additionally, those maritime sectors need to establish right regulations framework, enhance cybersecurity measures, and foster a culture of innovation, skill development and effective management.

The shipping industry is crucial for global trade and has increasingly adopted AI to enhance effectiveness, safety, and environmental sustainability as well as profit optimization. There are many case studies which showcasing the various applications of AI in the maritime sector in general and at shipping industry in particular. In the vast ocean and its globalized trade and commerce, the shipping and shipbuilding industry provide its lifeblood, moving economic growth and empowering international business. Now, it has experienced a transformative wave driven by AI, ML and other smart technologies, which revolutionize and ease operations, optimizing efficiency, reshaping the maritime landscape and becoming game-changer of global business. The adoption and implementation of AI, ML or Big data in the maritime and shipping industry has rushed forward. Today efficiency, real-time data, effective planning and maintenance, cost reduction, and sustainability in maritime sector are an urgent need.[69] Moreover, AI and ML driven smart solutions are very much essential and paramount for autonomous platforms, smart ship, smart shipping, smart shipbuilding, smart port, useful maritime operations along-with perfect surveillance, watchful maintenance systems and optimize cost for shipping industry. Again, shipping companies and maritime industry are leveraging AI, ML and other smart technology for route optimization, fuel consumption minimization, cargo scheduling, merchant fleet management, safe operation along with other critical



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functions and problems. AI-enabled predictive analytics are also empowering shipping companies and maritime business stakeholders to anticipate needs, mitigate risks, and optimize resource allocation to enhance operational competitiveness and finest decision-making. AI, ML and other smart technology now become an eye-opening prospect and opportunity for shipping companies and other maritime stakeholders, and they need to be considered it very critically. Maritime operations have been extremely optimized even tiny matters like fine-tuning container routing or re-routing, best-suite fuel-consumption models economically viable and environmentally acceptable. This paper will evaluate the AI as smart solution for maritime industry and ocean health in 21st century elaborately including the concern issues like ocean observations and surveillance, the application of AI to remote sensing satellites, smart sensors, intelligent underwater robots,[70] vessel tracking, smart ship, shipping and shipbuilding. The discussion will also encompass the recent development of AI and other smart technology and related useful devices, relevant effective research, and their effective uses, along with potential, prospect and future challenges of AI and other smart technology.

**Literature Review and Methodology**

Today, data becomes the driving force of the modern and smart world, and almost everyone has staggered upon a few terms like DS, DL, ML, AL and DM at some point. And DS is the broad scientific study that focuses on making sense of data. DS is a broad field that envelops all activities and technologies that help build all such systems. DS and therefore DM can be used to build the needed knowledge base for ML, DL, and accordingly AI. On the other hand, data scientists work with vast amounts of data to make sense of it. Again, with the right data analytics tools under the cover, data scientists can collect, process, examine and analyze data to make deductions and forecasts based on discovered insights as well as smart solutions.[71] Interestingly, with the help of forecast analytics, businesses can expose data patterns they had no idea existed or subsisted. Data scientists first collect historical data, compare similar situations to the expected ones, make calculations, do analysis and plan on supply to cover demand as well as find suggestions for decision making process.[72] So, sophisticated AI and other smart technology or systems introduce autonomous, independent and almost crewless ships, which can operate independently without human dealings and the mistake rate is lower than that of human operated ships.[73] AI is gradually transforming the conventional operational process of the maritime industry into self-govern system. Therefore, the amount of research on the application of DS, ML and AI has increased significantly since 2012.[74] Following this movement, data-centric innovative technologies and many new innovative business models has been developed.[75]This transformation is reshaping and converting the entire maritime industry and providing new opportunities to progress productivity, efficiency, user friendly and sustainability along with new challenges.[76] Studies on the combination of AI, ML, DS and DM application in maritime sector are not usual and that has created a gap in the academic literature due to the importance of DS, ML, AI and other smart technology in maritime operations, surveillance, preservation, management, safety and security issues.[77] DS, ML and AI improved maritime surveillance, monitoring and operation and that can contribute to the economic, commercial and environmental aspects of the maritime business.[78] Maritime trade accounts for about 80% of world trade[79] and the industry faces many challenges due to its immensity and diversity[80] as well as continuously growing regulatory requirements.[81]

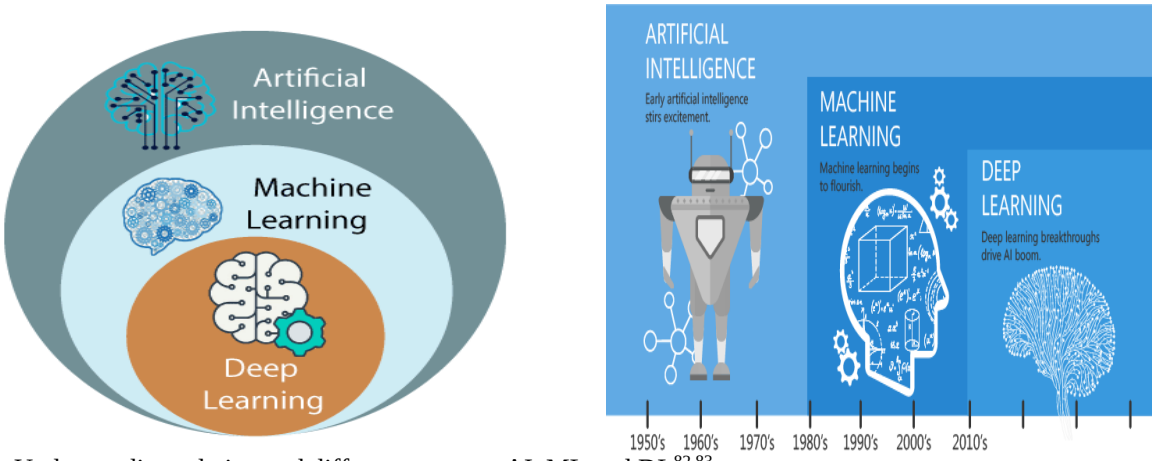


Figure 1: Understanding relation and difference among AI, ML and DL[82,83]

AI, ML, DS and other smart technology offer viable and sustainable solutions to some of these challenges. Now, data about ship performance and navigation systems 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.[84] Maritime industry generates large amounts of data and diverse information globally. If we can properly utilize those data and information, that will help us decision-making process as well as we can improve maritime safety, security, reduce environmental impacts and optimize expense. To the best of our knowledge, in the maritime context there have been very few review studies on AI, DS, big data[85] and digitalization.[86] Most of the investigative study and evaluation is more comprehensive than previous studies in terms of quality and multiply of included studies that use big data, AI and other smart technology in the maritime framework. Most of the previous study seems as



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reviewed studies that use only Automatic Identification System (AIS) data and other limited use of such technology in maritime sector.[87] Some researchers did not follow any systematic approach to literature selection, and that usually lead to biased or as usual findings. Few researchers overtly focused on digitalization, although they used big data and DS in their keyword search.[88] Future researcher need to consider and include AI and other aspects of smart technology in the maritime domain more widely with contemporary development and examples for better understanding of the specific objective and goal setting. The research and exploration of seas began centuries ago, with the aim of business and military function. But now, it's an organized discipline and significant branch of earth sciences.[89] However, from the ancient, human have studied, used and exploited marine resources of seas and maritime research as well as ocean science and engineering has become an inseparable literature in modern age.[90]

Maritime surveillance plays a critical role in safeguarding coastal borders, ensuring maritime safety, security and combating all sorts 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 capabilities. The merchant shipping industry, global trade via sea and maritime industry faces numerous safety and security challenges, including piracy, smuggling, drug trafficking, cyber threats, environmental issues, etc. Despite huge international efforts, around 100 different types and size of ships and vessels are lost annually, leading to fatalities and injuries compared to land-based industries.[91] The vastness of the oceans makes regulation difficult, allowing bad people or criminals to exploit vulnerabilities. Author of this paper has been taken effort to evaluate the use AI to preservation of ocean including its contain and highlighting its potential benefits and future directions. This paper will also explore the use of AI as smart solution of coastal maritime surveillance, ocean health conservation, safety of maritime industry along with improving threat detection, tracking and protect maritime environments as well as maritime resources. Prospects and challenges due to inclusion of AI and smart technology will also be high-lighted consequently.

With the time strains and pressures is increasing in the coastal zones due to population growth, increase in coastal economy and continuous expansion of human activities. Again, it becomes more intense by the effects of climate change.[92] These pressures lead coastal people, government personnel and related stakeholders into taking actions to protect and further develop the coastal zones.[93] Those actions are not always within the framework of usual plans. Interaction between Land and Sea is an important factor that should be taken into account during the implementation of those Plans.[94] We know that, coherence between coastal terrestrial and marine planning is a prerequisite, to manage coastal zone successfully as it is the link between marine and terrestrial space.[95]This paper aims to identify and analyze the use of AI for successful monitoring, management and preservation of ocean and it's contain. The methodology follows[96], a holistic analytical procedure that include the analysis of use of AI and other smart technology in maritime sector, coastal zone management, as well as consequences and implementation of AI to assess the interactions between future land and sea uses.[97] Author has also taken effort to correlate and investigate innovative AI solutions customized to the unique challenges and opportunities in maritime operations and overall management in maritime industry. Specific effort has been taken to evaluate how AI, ML and other DS driven technology are reshaping and optimizing conventional practices, improving operational and managerial performance in 21st century.[98] This investigative study will help to find out the AI based smart solutions for maritime industry and the way to more useful, connected, committed, intelligent, environment friendly and flexible maritime ecosystem.

**Marine Coastal Ecosystem**

Marine coastal ecosystem may be defined as a marine ecosystem and that occurs during the land meets the ocean. It includes different types of marine habitats with their own characteristics and species composition.[99] Those are characterized by high levels of biodiversity and productivity.[100]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.[101]Depending on the coastal features and depth of the water, marine habitats can be classified into several zones.[102] Actually, coastal zones play a significant role to the human society and its development.[103] They have great environmental, economic, social, cultural and recreational importance.[104] They are considered among the most productive, exploited, inhabited and threatened areas due to their characteristics.[105] 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.[106] Again, tourism growth is a key factor of the rapid expansion of built-up areas along the coasts.[107] In addition to the socioeconomic benefits, coastal ecosystems also contribute in maintaining global biodiversity.[108]



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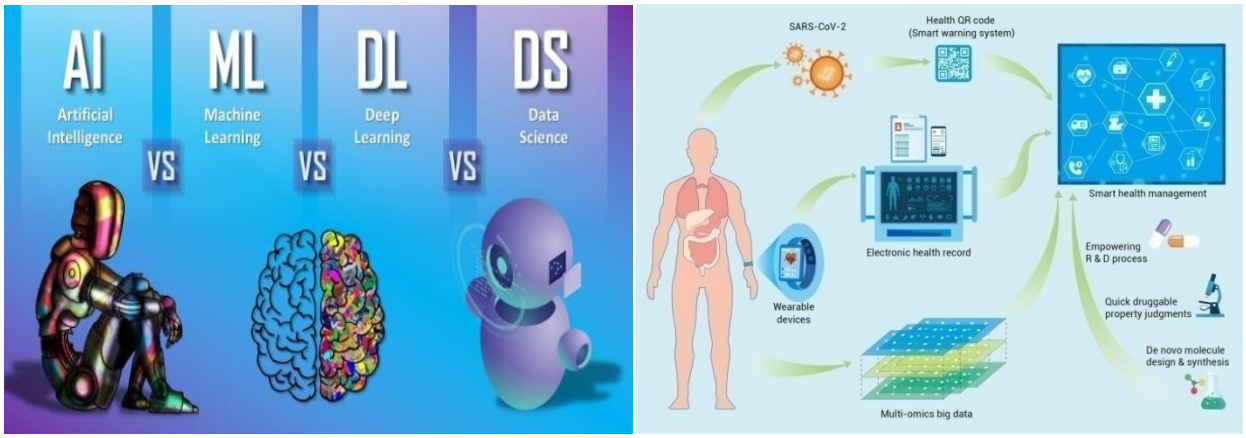


Figure 2: Family of AI and other smart interconnected fields[109] and AI as powerful paradigm[110]

Coastal landscape and ecosystems are under severe pressure due to their environmental sensitivity, coastal people activity and uses concentration.[111] 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.[112] 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.[113] 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.[114] However, threats to the coastal environment arise from natural hazards and the main triggering factor is the human-made innervations.[115] There are two major types of conflicts arises in the coastal zone namely conflicts among human activities and conflicts between human and environment.[116] 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 for Healthy Ocean and Marine Life**

AI united with promising ML or other smart techniques as known from computer science is largely affecting various aspects of many fields like science, technology, industry, agriculture, business and even our day-to-day 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.[117]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.[118] At present, autonomous ships is monitoring the ocean, AI-driven satellite data analysis, passive acoustics[119] or remote sensing[120] and other applications of environmental monitoring are making use of ML.[121]Marine ecosystems and coastal communities can suffer greatly from oceanic events. AI can assist in the forecasting of wind, wave, and cyclone activity. AI systems can forecast natural disasters like storms, cyclone and tsunamis, providing communities with extra time to prepare and perhaps even avert needless loss of marine life.

Figure 3: Discover Deep Ocean by AI[122] and use of deep sea robot[123]

**AI Use for Explore the Ocean.** In the current research it has discover that, around 95% of the oceans are remain as unexplored.[124]In order to explore, comprehend, and find those parts of the oceans and maritime industries that are physically



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inaccessible to humans, scientist and researchers are now adopting AI to explore those effectively.[125] 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.[126] Now, AI helps in detection and identification new marine animal, plant, living species and mineral deep under the sea.[127] Today AI and other smart technology are helping to discovering and collecting data about many living species and non-living substances. Those data are very beneficial for food, medical and industrial applications.[128]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 of the deep sea.[129] The most recent iteration of this ROV, the 4th generation Mk-IV, has undergone multiple upgrades and is primarily meant for labor-intensive deep sea and marine resource surveys.[130]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.[131]

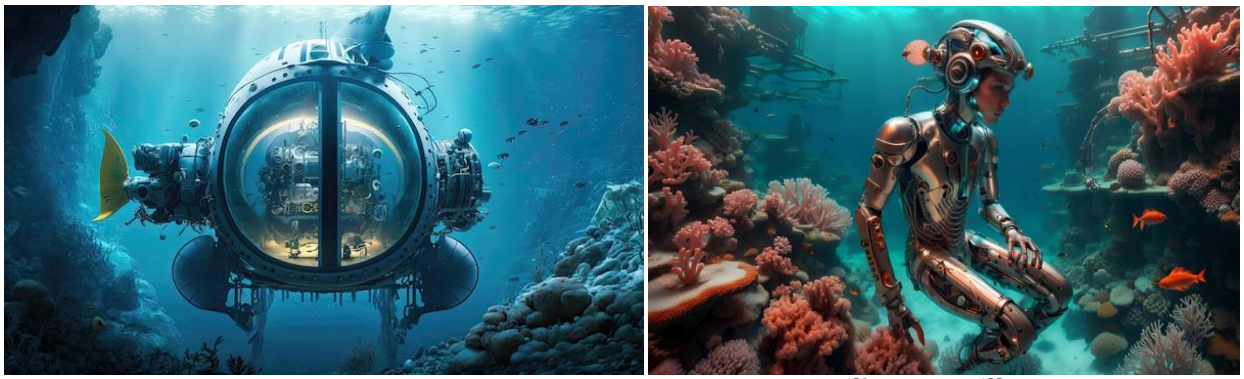

Figure 4: Underwater exploration by AI and smart technology operated vehicle[132] and robot[133]

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.[134] 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 technology provides a substitute for propeller-based explorers for researchers and industry conducting underwater activities. It presents an opportunity to increase the efficiency of oil rig inspections and reduce the chance of mishaps or infrastructure damage for the offshore sector. The Crabster's primary reasoning is that, like its real-world counterparts, it will be well-equipped to withstand inclement weather. The Crabster can move with enormous force, unlike ROVs and AUVs, which become unstable in strong tidal situations.[135]

Figure 5: Giant six-legged robot Crabster CR200[136] and AI will help maritime research[137]

**AI Use for Collect Large Computational Data on Marine Species.** Big data and AI work together to enable advanced analytics and intelligent decision-making.[138] Today AI algorithms handle large datasets efficiently through various strategies for example utilizing parallel processing enables algorithms to divide tasks among multiple processors speeding up computation. Sampling methods like mini-batch gradient descent, process subsets of data, are reducing memory requirements.[139]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.[140] Those important data that cover the entire oceans can prove to be very useful for insights into pH changes, identify marine species and patterns,[141] fish stocks information, sea plants, mineral, etc. The next stage involves integrating the AI into a robotic system to enhance our comprehension of the world's



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waters. Scientists and researchers, including one from India, have created an AI tool that can automatically identify minute marine organisms at the species level. The study, which was published in the journal Marine Micropaleontology, reveals that the AI software is specifically capable of detecting six species of foraminifera, or forams creatures that have been common in Earth's oceans for over 100 million years.[142]An AI program created by North Carolina State University 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 6: New AI system can identify microscopic marine organisms[143,144]

**AI Help to Reduce Plastic Pollution.** Oceans and marine life are being severely harmed by plastic pollution. Scientists and researchers, estimate that each year, the annual death toll from plastic waste is approximately one million seabirds and 100,000 marine species. 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. [145] However, technological developments in AI present novel opportunities to address plastic waste and encourage environmentally friendly building methods.[146] Scientists and researchers could gather more data and analytics to gain deeper insights with the help of ML models.[147]AI is being used to develop better-informed methods to lessen ocean plastic pollution. AI can offer significant insights into the sustainability of diverse material possibilities through the analysis of multiple parameters, including resource consumption, emissions, and waste generation. Professionals in the construction industry, including architects and engineers, can utilize this information to prioritize the adoption of sustainable plastic substitutes and make well informed and viable decisions.[148]

Figure 7: AI solution to identifying and tracking plastic pollution[149,150]

Using recycled plastic in building can be done sustainably with the help of AI-controlled 3D printing technologies. Now, the 3D printers can streamline the printing process and guarantee the correct usage of recycled plastic resources by integrating AI and ML



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algorithms. By analyzing the characteristics of the recycled plastic, these systems may modify the printing conditions to provide the best possible structural integrity and performance.[151] This method lessens reliance on fresh plastic resources, promotes the circular economy, and allows for the production of structures and building components out of recycled plastic. The construction sector may adopt sustainable practices and address plastic pollution by utilizing robotics and AI in plastic recycling and 3D printing.[152] By improving the efficacy, precision, and adaptability of plastic recycling procedures, these advances foster a more ecologically conscious and sustainable approach to building.

Waste management in the construction sector is being revolutionized by the use of AI sensors and data analytics. Construction sites may measure and monitor the development of plastic waste in real-time by utilizing AI and other smart technologies. AI and ML algorithms examine sensor data to find trends, patterns, and opportunities for development. In doing so, trash reduction, recycling and disposal procedures are optimized, and proactive waste management techniques are made possible. Construction organizations can reduce the environmental impact of plastic waste by implementing specific measures and keeping a close eye on it.[153]A new degree of accuracy and efficiency in the management of plastic garbage is brought about by AI-powered smart bins and collecting devices. Utilizing sensors, computer vision, and ML algorithms, these intelligent devices can automatically sort and handle plastic garbage. AI makes it possible to identify and distinguish between various plastic material kinds, facilitating appropriate recycling and disposal. These intelligent solutions boost recycling rates and lower contamination by automating the garbage collecting and sorting process.[154] They improve sustainability and cost-effectiveness for the construction sector by streamlining the plastic waste management process. The building sector develops sustainably and is propelled forward by these smart ideas.

In the context of reducing plastic waste, AI and other smart technologies have the capacity to evaluate and interpret enormous volumes of construction data, enabling data-driven decision making. Construction workers may learn a lot about material consumption, trash production, recycling rates, and environmental impact by utilizing AI and ML algorithms.[155] The construction sector can significantly reduce plastic waste and promote sustainable construction practices by combining data-driven decision making with collaborative platforms. 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.[156] AI applications, such as collaborative AI platforms, intelligent waste management, predictive analytics for sustainable design or AI-driven material selection, offer creative answers to the worldwide plastic pollution challenge. 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.[157] Similar to this, AUVs are robots that scientists and researchers have preprogrammed to gather data from particular regions of the deep ocean while they are on land or on a ship.[158]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. AI is being used to identify the origins, reasons, and remedies for coastal pollution and it will continue further.[159]

As of right now, 71% of the earth is made up of seas, which also hold an abundance of plastic to the point where, "in just a few years, we might end up with a pound of plastic for every three pounds of fish in the sea."[160] In addition to the estimated 150 million metric tons of plastic that are currently moving through our seas, over 8 million metric tons of plastic enter every year further.[161]By creating cutting-edge robotic technology and AI surveillance and monitoring strategies to detect pollution in our seas and rivers and offer a quicker means to clear it up. By this way, several up-and-coming businesses and organizations are revolutionizing the field of ocean conservation.[162]Autonomous Ocean vehicles can differentiate plastic from other materials and objects thanks to AI and ML. This helps identify areas with high concentrations of trash and address pollution at its source. Among many other environmental concerns, plastic pollution continues to endanger the oceans on our world.[163]But as individuals, we can try to manage our waste, consume less, and support ocean conservation organizations rather than letting our oceans fill with more and more junk and garbage. The quantity of trash that finds its way into our rivers and oceans is something we can regulate and restrict.[164] We can use cutting-edge AI technology to assist us clean up our problem; because we already know that millions of tons of rubbish are already going through them. Together, industry and business leaders, researchers, legislators, stakeholders and technology suppliers can drive change and pave the way towards a future free of marine pollution. We can create a more sustainable and comfortable future where marine pollution is efficiently and effectively addressed and our global marine environment is in line with the ideals of environmental stewardship and sustainability by embracing AI, ML, etc and cooperating each other.



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**AI Help to Save Marine Life.** We must be conscious of the various dangers that our oceans confront. 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. These days, AI has potential fixes. AI methods are being used by scientists to monitor and safeguard mammals and marine life. AI has the potential to reduce illicit poaching. Today, the tedious process of figuring out how proteins fold themselves into origami like forms inside cells has been completely transformed by the AI tool AlphaFold of UK.[165] Previously, it used to be possible to take months or even years to determine the structure of a single protein. AlphaFold has released 200 million protein structures expected for a calendar year.[166] In the last 60 years, the scientists and researchers has been using advanced experimental methods 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.[167] Through the provision of shared data portal and automatic species identification, Flukebook.org is an online research platform in Europe, powered by AI that assists conservationists in their study and protection of whales and dolphins.[168]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.[169]

AI and ML are promising development in the field of marine conservation as technology advances further. We may strive toward a future in which our oceans serve as a thriving, healthy ecosystem for all life on Earth rather than only serving as a source of inspiration for scuba divers by utilizing artificial intelligence. It can be labor-intensive and ineffective to manually monitor large oceanic areas.[170]Researchers and conservationists can examine underwater photos with AI's assistance. Innumerable underwater images and videos can be successfully scanned by sophisticated algorithms to identify and measure marine animals, assess the health of the coral, and spot any irregularities. Researchers can get real-time data collection with AI's assistance. 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. Artificial Intelligence can help detect and monitor plastic. Large areas of floating plastic garbage can be found and tracked using satellites and AI. AI can help with 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.

Figure 8: AI can use for healthy Oceans[171,172]

**AI Help to Save Coral Reefs.** Over 25% of marine species find 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 because 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. 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.[173]They discovered AI is helpful in identifying particular environmental conditions that reefs will tolerate as the oceans warm. AI-based image identification algorithms are being used in coral reef mapping to examine hundreds of underwater photos. These algorithms enable the construction of precise maps of the composition and health of reefs by differentiating between live coral, dead coral, and non-coral substrates. One prominent example is the Allen Coral Atlas, which combines satellite data and field observations with machine learning techniques to map and monitor the world's coral reefs at a never-before-seen scale.[174]



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Coral reefs provide microscopic portion of the ocean's surface, are very useful for ecosystems and supreme importance to marine biodiversity and global food security. However, they are threatened by various factors such as ocean warming and pollution.[175]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. Accenture developed a creative approach to rebuilding the reefs in collaboration with business and technology partners as well as a coral conservation charity in El Nido, Philippines.[176]The company Accenture has developed underwater cameras equipped with its own video analytics platform that can classify and count marine life as it passes through the reefs, and monitor changes.[177]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. AI is currently being used by researchers to identify, count, and categorize marine organisms. A new AI technology developed by marine biologists can be used to monitor and safeguard coral reefs. 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 COTS outbreaks.[178]Scientists and researchers can respond more swiftly to expanding populations by closely monitoring reefs, preserving the vital Great Barrier Reef ecology. Around 25% of marine species, including fish, invertebrates, and marine mammals, are supported by coral reefs, while making up less than 1% of the enormous ocean floor. These productive maritime ecosystems support commercial and subsistence fishing, as well as the tourism and leisure industries. They are also a rich source of antiviral chemicals for drug discovery studies and provide protection to coastal areas against storm surges.

Figure 9: AI can use to monitor and protect coral reefs[179,180]

**AI Use for Sustainable Fishing.** 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. [181]The marine species are seriously threatened by both illegal fishing and human influence. Via the analysis of satellite imagery, AI and ML can assist in the monitoring of fishing activity. AI has the capability to instantly identify illicit fishing activity, enabling prompt action from the authorities. AI can be used to track and identify marine creatures.[182]AI can help scientists identify and monitor targeted marine species, enabling them to learn more about the species' breeding patterns, migration patterns, and other possible dangers. Presently, scientists employ artificial intelligence's remarkable capability of pattern recognition to comb through satellite imagery and map the masses of plastic debris endangering our oceans in real time.[183] AI can save the oceans by offering vital insights. Organizations from many sectors are collaborating closely to use AI technology to collect pertinent data and turn it into goals that can be implemented.[184]

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. The analysis and provision of critical information from maritime data is the primary role of AI in most of the use cases previously stated.[185]With the insights provided by AI techniques, data conservationists may monitor species populations, determine the effects of human activities, and contribute to the preservation of endangered species. Astute researchers can use computational sustainability to examine vast amounts of data acquired from these instruments to forecast, comprehend aquatic life abnormalities, and arrive at well-informed conclusions. Additionally, by reducing illicit fishing and poaching, this data can support the preservation of the seas' delicate natural balance.[186]



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Figure 10: AI can use to combat overfishing[187] and preserve ocean[188]

**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. which are critical for the planet's clean energy transition. Leonardo Da Vinci recorded the phenomenon and discovered that holding a tube underwater allowed the listener to detect passing ships at a great distance in the late 15th century.[189] Sonar was an old technology which invented in the 1910s. It uses sound waves to determine the depth and underwater condition or how the seabed looks like. With this technology, a surface vessel can roughly map even the deepest points of the ocean. Seabed 2030 turns data like this into a map and makes it public.[190] India became the first nation to land a spacecraft near the moon's South Pole in August 2023 and has announced a mission called Samudrayaan or sea vehicle in Sanskrit for a submersible with three people to travel to a depth of 6,000m by 2026.[191] On the other hand, China is building an icebreaker with a submersible which aims to reach and explore the Arctic seabed this year. However, underwater exploration will continue further, even after the Titan debacle. Autonomous, AI-driven submersibles can minimize the risks to human lives from deep-sea exploration and would allow faster mapping of 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.[192]

The trends in the development of AUV to explore deep water beneath the sea has evolved and changed since its inception successfully. [193] 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 including commercial and military fields. [194] Technology has always been essential in the field of underwater exploration, where the mysteries of the deep blue continue to captivate our imagination. AI has emerged as a revolutionary force that is altering the game in recent times. Now, future of AI for underwater exploration, examination is very hopeful, and AI has significant influence on perception observation, evaluation and interactions within the underwater environment.[195] 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.[196] AI can help in this situation. In the field of oceanography, AI driven AUVs are revolutionary.[197] These self-navigating robots can explore the depths on their own thanks to their sophisticated sensors and machine learning algorithms. Without human assistance, they gather priceless information on submerged shipwrecks, geological structures, and underwater ecosystems.[198] However, small submersibles, often without-crewed and driven by AI and other smart technology might be the future. The last few years we have seen a huge acceleration. Yet, there's still a long way to go.[199] 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.[200]However, 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.

**Use of AI to Fight against Climate Change**

Climate change is an important driver of many maritime related issues, like coral bleaching, Ocean accident, natural calamity and rising sea levels. [201] 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. Now, a wide range of disciplines, skills, knowledge, intelligence and wisdom has been used 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.[202] 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.[203] 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. Moreover, the



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development of adaptive methods to lessen the impact of climate change on marine ecosystems can be guided by these forecasts. Natural calamities like hurricanes, cyclones, tsunamis, or oil spills can have devastating effects on ocean ecosystems. AI has the potential to transform disaster management by enhancing prevention and response efforts.[204]In order to forecast and track natural catastrophes, ML models can evaluate data from sensors, satellites, and other sources. This enables more effective resource allocation and prompt disaster response.

Figure 11: AI can use underwater exploration[205] and fight against climate change effectively[206]

Earth is vital for the future of the planet. The oceans interact seriously with the earth's climate and understanding them better could offer potential solutions to climate change. New animal and plant species are also constantly being discovered in the great deep. We are aware that as the effects of climate change worsen and global temperatures rise, it is more important than ever to address environmental deterioration. Protecting our seas is one of the most important things we can do to stop this. Oceans are vital to the survival of the earth in the face of increasing climate change. The vast oceanic bodies produce over half of the oxygen we breathe and absorb 90% of the heat produced by different sources of emissions. But overfishing, more frequent oil spills, and rising plastic waste are gradually starving the marine ecosystem. [207]One technology that can aid in saving the oceans is artificial intelligence. In the 95% of the world's oceans that have not yet been explored, AI can be useful. These days, astute academics are analyzing data from camera systems or marine exploring vehicles using AI algorithms. The technique facilitates the identification of novel species of marine animals and plants in the deep sea, as well as the understanding of behavioral anomalies and the causes of those anomalies. For ocean exploration, the Japan Agency for Marine Earth Science and Technology has created an underwater remotely operated vehicle called Kaico.[208] Numerous biological species that potentially have uses in industry and medicine have been found by this AI-powered vehicle. An NPO called water cleanup employs AI techniques to detect plastic trash and clean up the water. [209] The objective of NPO was to implement AI algorithms which is very effective to identify the sources and causes of coastal pollution and build up solutions to take corrective measures.

**AI Effectively Useful for Oceanography Development**

An important advancement has been made in oceanographic research with the use of AI. Conventional approaches to investigating the ocean's diverse elements frequently have drawbacks, such as the impossibility or safety of human presence in the deep sea and the sometimes-overwhelming amount of data that needs to be processed. AI is essential in this situation because it can process massive datasets, identify patterns that are invisible to the human eye, and carry out operations that would be hazardous or time-consuming for people. This capacity is essential since, according to the National Oceanic and Atmospheric Administration (NOAA) of United States, more than 80% of the Earth's ocean is still uncharted, unseen, and unexplored. Oceanography's use of AI is currently driving cutting-edge research in several important fields. [210]Oceanography's use of AI is currently driving cutting-edge research in several important fields. The detailed study of undersea ecosystems is one of these. Oceanographers can use AI to sort through data from biological sampling, satellite imaging, and acoustic surveys to learn more about the intricate relationships that exist within these ecosystems. This method informs conservation measures to protect these delicate settings in addition to helping to understand the fundamental dynamics of marine biodiversity.

While the apocalyptic worlds of The Terminator and The Matrix may still be a way off, real-life AI is now capable of feats well beyond what the human brain is capable of. AI-powered machines eventually conquer humans. [211]Assistant Professor Georgy Manucharyan of the School of Oceanography is currently employed by NASA on a project that uses cutting-edge AI research to investigate ocean dynamics. [212]While Dr. Manucharyan is intrigued by the potential of this technology to further his studies on ocean turbulence, he declined to comment when asked how he got involved in the project. "They have developed an AI that beats the best of



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the human-made algorithms," he states, "but we knew that human-made computerized algorithms could beat any human chess player." It's an incredible accomplishment! In order to convey his excitement for his new research, Dr. Manucharyan described how he believed it would be able to address a major issue facing contemporary oceanographic investigations. "We actually don't observe the ocean really well," he clarified the Ocean is extremely diverse, and space and time determine every aspect of it, including heat, nutrients, and salt dispersion. Thus, the intricate reality of the ocean is genuine. Recent technological developments have tried to address this issue by creating autonomous platforms, such as satellites or fleets of robotic floats, that can monitor ongoing changes in oceanographic data. However, these sensors are only able to monitor relatively tiny areas of the ocean at a time and expanding them to provide the optimal level of temporal and spatial coverage would be extremely costly.

When AI can bridge the gaps between observations, it can be useful. Dr. Manucharyan thinks that we could create highly nonlinear models of the ocean for use in a variety of scientific projects, such as data interpolation when there are significant gaps in observations or estimation of unobserved quantities like turbulent heat fluxes, by feeding AI the sparse data that is currently available.[213]He compared the approach to "reconstructing the murder scene," in which a picture of the past is painted vividly by piecing together insignificant details. Additionally, he believes that by thoroughly comprehending these past occurrences, we may be able to foresee future ones. One of the most intriguing opportunities this new method offers is the ability to forecast advanced maritime weather. Since scientists are essentially creating machines that can be utilized to accurately answer difficult academic questions that humans are unable to solve themselves, the future of AI in general is intriguing. Imagine it like having a conversation about physics with Albert Einstein, suggested Dr. Manucharyan. You can still have faith in his responses even though it is impossible for you to know what is going through his head. In the long run, he thinks, AI might even aid in the creation of novel concepts that are not exclusive to the humanities; these devices might even enable us to comprehend the nature of art and social relationships more fully. While we are not quite to the point where we are worshiping a ruling class of robot overlords, the possibilities that this technology seems to hold for us are seemingly endless. Nevertheless, building a strong public understanding of AI will be essential to ensuring the prosperity and advancement of humanity in the decades to come.[214]

Today, AI is bringing about a revolution in the analysis of intricate undersea ecosystems, ocean health monitoring, and marine species behavior research. These days, AI is processing data from sonar, satellites, and underwater drones. It is also revolutionizing oceanographic research. This investigation will highlight the present situation as well as the enormous potential for future developments in this fascinating interdisciplinary topic. Oceanographers and marine biologists have historically faced many difficulties when exploring undersea environments. The most challenging of these has been the harsh surroundings. Because the deep seas are inhospitable, devoid of light, and under tremendous pressure, direct human exploration is hazardous and resource intensive. Furthermore, because of the oceans' immense size and the diversity of their ecosystems, data gathering is frequently sporadic and inadequate, and the analysis that follows calls for a comprehensive understanding of intricate biological, chemical, and physical interactions.

**Use of AI for Smart Solution of Port Operation and Management**

In past, ports tended to be just simple harbors, whereas modern ports tend to be multimodal distribution hubs, with transport links by using sea, river, canal, road, rail and air routes.[215] Today, most of the world's seaports have embedded with advanced technology and modern equipment or facilities. Most of the successful ports are located to optimize access to an active hinterland.[216] It is as usual that, all ports will grant easy navigation to ships, and will give shelter from cyclone, tsunami or heavy waves. By nature, ports are situated habitually on estuaries, where there are shallow water and that need regular dredging.[217] Deep sea ports are less common, and those can handle larger ships with a greater draft. 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.[218] Ports usually have specialized functions like some cater mainly for passenger ferries and cruise ships; 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 may developed countries, or port may be owned both by the state partly and by the partly cities themselves.[219] The growth in ship sizes a prevalent technical change since the 1990s, when post-Panamax containerships were first introduced. A growing level of merchant ship types like containerships, bulk carriers, car carriers, and even cruise ships require dedicated port terminal facilities. Now, recent trend concerns automation and other advanced technology. [220] All such things have been placing pressure on ports to upgrade and improve their service and facilities.

Smart ports are the new generation digital ports, and which are more efficient, sustainable, and inventive than traditional ports. Smart ports are always enhanced with smart and innovative technology. They use modern technologies like as AI, ML, DL, DS, DM, IoT, big data, blockchain, and automation to improve operations, maximize profitability, and reduce environmental impact.[221]One of the key benefits of smart ports is their automation and AI integration, which enables them to run continuously without human intervention.[222]This boosts efficiency while lowering labor expenses.[223]Data is crucial for optimizing operations and making the best



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use of all resources. Smart ports are more ecologically friendly, and they are frequently designed with the intention of lowering their carbon footprint and maintaining the marine environment.[224] They also use renewable energy and other eco-friendly technology to lessen their GHG as well as environmental footprint. Smart ports are also intended to be more integrated with logistical and industrial areas.[225] They use advanced technologies to facilitate the movement of goods and information between ships, ports, and other supply chain locations. They also have an open innovation mentality, allowing them to continuously improve their operations by incorporating new technologies and ideas. Even a small interruption in the cargo flow in large maritime ports could have serious repercussions. Grocery store shelves and service station gas tanks would run dry in a couple of days due to the breakdown of the zero-inventory, just-in-time delivery system that powers global trade.[226] A cyber-attack that targets energy supplies would probably rock the world economy.

AI transforms data using potent algorithms to mimic human thought processes. Because port activities are redundant, a large amount of historical and current data is generated, which can be fed into these AI systems and algorithms. Vehicles, Lorries and even a handful of the present port administration systems have already been automated by AI. For example, Autonomous cranes and container trucks are already utilized by Port of Los Angeles for cargo transportation inside the terminal. AI is also used by the Port of Rotterdam for their digital smart port operations. Smart port operation, which enables a business to build a digital simulation of what can happen in the real world, is a subset of AI when robots are designed to duplicate and emulate human decision-making processes. ML 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). Since most ships now arrive later than expected, AI will have a significant impact on improving port operations worldwide. In their November 2020 Global Liner Performance Report, Danish business Sea-Intelligence stated that across 34 trade lines, the average reliability of a global carrier arriving on time dropped to 50.1%. Therefore, without AI support, the shipping industry would be facing a chaotic world if half of all aircraft landed at their destinations several days later. The worldwide shipping sector faces significant challenges with vessel 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. Additionally, this would allow authorities to use automated decision-making to ensure that cargo is unloaded at the appropriate time and location.

AI-driven Digital Smart Ports can manage increased freight and traffic, streamline staff work schedules, reduce human error, and boost supply chain efficiency. AI increases productivity in general. Retrofitting is the term used to describe AI and automation projects for ports and shipping industries. This is the process by which already-existing facilities, such as ports, integrate AI technologies into a conventional system to produce a more orderly and safer atmosphere. Businesses can employ AI to develop software-based platforms and modules that marine actors can use to enhance their commercial operations. Again, by using AI algorithms, the maritime sector will be able to see their operations from every angle. Once more, ports may use AI to process their data and make precise judgments, schedule shipping arrival and departure times, find the best storage options, and load and unload containers and cargo quickly from any port. Because the shipping sector is so old, integrating AI into routine port management systems presents difficulties. Having high-quality data is essential to using AI systems.[227] Ports and the maritime sector, however, offer a wealth of historical and current data; the crucial factor is quality. Powerful AI algorithms require high-quality data to be fed into them to function. However, port needs data that is reliable, relevant, and of excellent quality. [228] Standardization is a major concern when it comes to AI use in ports. As of right now, the maritime industry lacks any standards for technology. Normally, when ports implement cutting-edge and intelligent technology, it is tailored to their specific operations. With the assistance of AI specialists, Port may have developed several scalable solutions that can be utilized by various maritime players.

Today most of the renowned and smart shipping companies are effectively and successfully using AI and ML model as smart technology. Maersk started to use AI in several areas of its business around the globe.[229] On the other hand, with the use of sensors and ML algorithms, CMA CGM has created an AI platform called to track the location, temperature, humidity, and other characteristics of the goods being transported in the containers in real time.[230] Hapag-Lloyd began integrating AI into its marine route planning system to optimize ship routes and lowers operational costs by utilizing weather, shipping traffic, and fuel data.[231] MSC has created an AI platform to keeps an eye on ship safety and averts mishaps by using sensor data and ML models. It also gives ship and shore workers real-time alerts about emergency circumstances.[232] Again, Evergreen Line's predictive maintenance system allows assessing the health of the machinery and predicts when maintenance is necessary using sensors and ML algorithms and their AI-powered container tracking technology enables instantaneous and real-time tracking for all containers shipped using Evergreen.[233] Interestingly, with the use of this system, customers can enter their container number, booking number, or Master Bill of Lading, and the system will instantly produce and display the location of their overseas shipments.[234]



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Today, Errors are not tolerated in port operations or shipping management. In contrast to chat algorithms, port efficiency and safety are not subject to free experimentation. Appropriate training is necessary for AI optimization to produce dependable outcomes. AI and ML can be objectively trained in port operations, with algorithms able to determine what makes a good response given a customized dataset and well-defined criteria. Realistic checks, which compare the algorithms' timetables and predictions to actual durations, are an essential component of the training process to do this.[235]These aids in the algorithm's ability to adapt its responses for subsequent programs by learning from the unique actions and limitations of a port. But in recent years, the amount of cargo that container ships have carried around the world has steadily increased. These days, there is a huge growth in demand for container ships across the board. The Hong Kong Marine Department's data indicates that Asian ports, distinctly those in China are becoming more and more dominant in this sector. Two ports in Europe and one in North America remained among the world's largest maritime hubs in 2005. But in 2021, only Rotterdam Port was still in the top 10 in the lowest ranking.[236] In the recent past, China has had significant success using AI and digital technologies in the port operation and administration system.

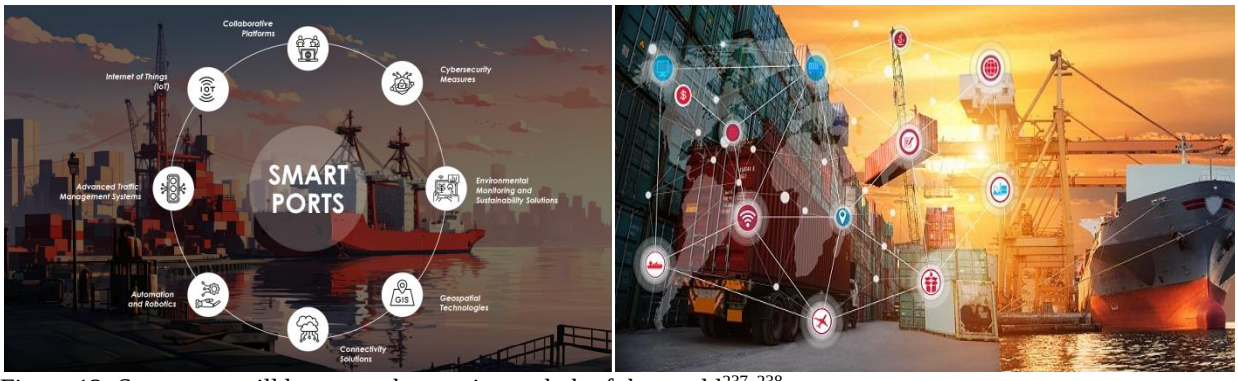

Figure 12: Smart port will be game changer in any hub of the world[237, 238]

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

The safety and efficiency of vessel traffic are paramount and act as the heart of modern maritime operations. NeuralBoost is an AI based vessel traffic system invented by MakarenaLabs.[239] 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. [240] Integrating NeuralBoost advanced tools into any vessel traffic services is necessary and useful to oversee and manage the complexities of modern maritime traffic.[241] 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 provides the clarity, but more foresight needed to navigate the future of maritime operations confidently. However, few benefits of NeuralBoost for vessel traffic services has been given below.

- It can help to identify 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 vessels by make sure comprehensive insights to navigate away from hazards and ensure vessels operation in safe waters.
- It can help to optimize traffic flow and use as aids in maintaining a smooth and efficient movement of vessels and minimize delays and improve operational timelines.



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Figure 13: AI transforming shipping sector[242]and future of shipping traffic system[243]

**AI and Smart Ship**

The term smart ship is applied to ships on which many sensors are installed to collect all possible information about the state of the vessel, various indicators, etc. A new era is calling us. Smart ships will comprise of digital information, computer coding, and new technology infrastructure which is also the driver of the modern world. These drivers will inevitably innovate and push the supply chain on a sustainable and greener side. Many of the commercial contracts within the world may become smart contracts coded by computers. Everything will be jointly known as smart shipping. In contrast to Digital Twin, all information collected from the vessel is aggregated in one place, in the office on the shore or, for example, on the captain's bridge and the decision is made based on the current readings, without additional simulation of the situation. But for this concept to work, an Internet of Things (IoT) platform is needed that streamlines this process. Smart ship relies more on various sensors installed on the ship, almost does not require many different algorithms and other systems. It displays various indicators on a special dashboard, for obtaining data about the ship in real time, analyzing them and making decisions. The data is stored in a centralized cloud database providing dashboards for the ship-owner and managers to use and analyze the data, before making a decision. IoT adoption in the maritime industry is growing with the emergence of many new innovative enterprises. Aggregates all data on servers and provides great opportunities for their further analysis or use in other systems/other companies. To tackle the situation of cost competitiveness and transportation decline due to major logistics competition, shipping companies are reducing crew members. Moreover, the hype about efficiency improvement and carbon reduction in maritime industry has increased the attention to artificial intelligence.

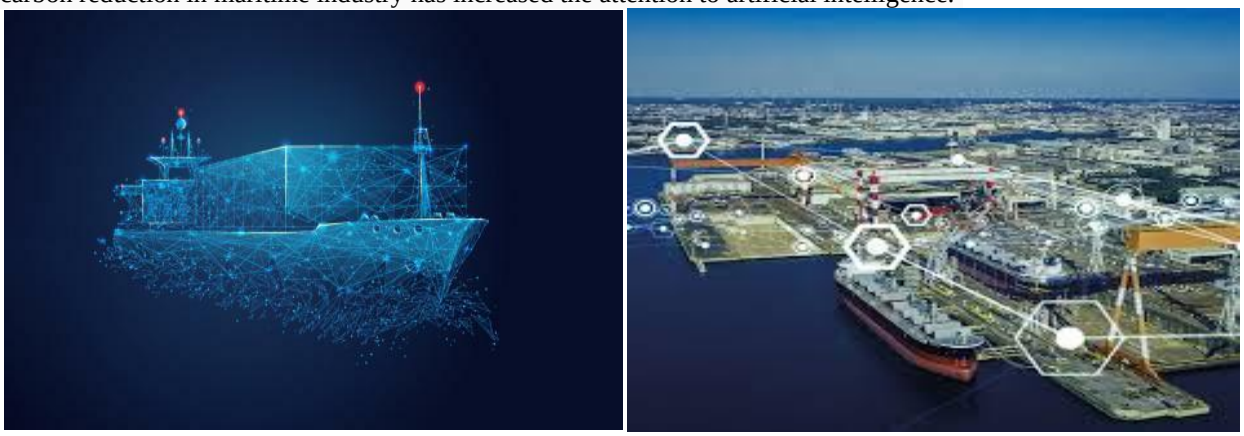
Figure 14: Smart ship and future shipping industry[244,245]

The demand for automation in navigation and control technology is highly up-surging to operate the shipping smartly, safely, and economically. Furthermore, the progress in intelligence information technology, known as the core of the 4th industrial revolution, is promoting the visualization of autonomous ships. Countries such as China, the EU, Korea, Japan, etc. with the increased availability of these technologies are shaping the development of eco-friendly autonomous ships in virtue of the private-public collaboration. Smart Ships revolutionize vital aspects: ship designing and operations, redefining the global maritime industry and the roles of primordial elements in it; with implications for shipbuilders, shipping companies, ship owners, and maritime systems providers, as well as the other sector companies producing the technology. The real-time constant remote monitoring of vessels globally will see ships become safer, more efficient, more trustworthy, and more closely integrated into the worldwide supply chains generating revenue aid with a higher bonus of cost-savings. Smart Ships, considering the applications of worldwide economic concepts and



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addressing the maritime sector regulations, aims to supply multi-layer optimization in fuel consumption, CO2 and carbon emissions control, and energy efficiency when full-fledged implementation is completed. It will capitalize on available COTS technologies and can deliver an ICT and IoT enabled holistic cloud-based maritime performance and monitoring system, for the whole lifecycle of a vessel**,** aimed to fully optimize the energy efficiency, emissions reduction, and fuel consumption, with regards to introducing circular economy concepts within the maritime field. However, despite the hopeful prospect of AI, ML and other smart technology in the shipping and maritime industry, several barriers obstruct extensive acceptance and widespread implementation of those technologies. Such as: Cybersecurity, data Privacy and Integration, shortage of talent manpower, skill on smart technology, reduce acting employment regulatory compliance, fear of job replacement, time and energy limitations, etc.

**AI Use Effectively in Shipping Industry**

Shipping companies have now found that investing of any marine incident or issue as well as faster communication for their ships offers many benefits not only to captains and engineers but also to the shipping companies themselves and that is possible by utilize AI or other smart technology. Most vessels have evolved into remote offices at sea that can offer reliable internet access, virtual networks, email, route planners and many other systems and applications to the captain and crew. However, it is time for shipping companies to think about long-term growth and better business solution. So, to invest in new technologies that can improve standard vessel operations, to reduce company's costs and optimize business processes. That is why AI and ML come on the stage and solving all shipping problem and better management effectively. Computers can process enormous amounts of data and that is faster than humans can ever accomplish.[246] The high intelligence of AI and ML algorithms along with industry experience will create a great advantage for ship owners and stakeholders who first implement them in their business. So, the higher the investment in AI or ML or other smart technology will ensure the greater the benefit of its big data analysis capabilities. AI, ML and DL algorithms are able to handle data throughout the history of vessel operation.[247]

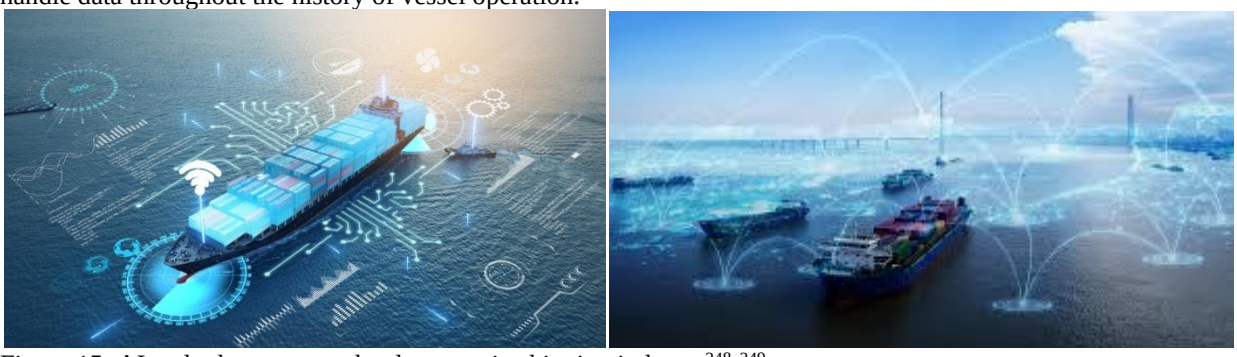

Figure 15: AI and other smart technology use in shipping industry[248, 249]

Today, many shipping companies by using AI, ML, DL solution have successfully reduce the amount of crew and passenger accidents, minimize fuel consumption, better shipping management, crew management, and many more problems. The port of Rotterdam uses an ML based system to determine vessels' time of arrival.[250] As we know that data is a major element for abolishing uncertainty, adapting AI and ML algorithms and that can help to increase a typical data that can be crucial for ship owners. So far, data mining in the maritime industry is very limited. Consequently, the application of AI and ML techniques in maritime transport is limited compared to other industries. AI or ML allows users to apply intelligent algorithms and to evaluate data that helps to guide the logic of possible problems in maritime transport. Such methods can be used in marine network planning, voyage planning, cargo optimization, maintenance process etc. Advanced AI and ML algorithms will be capable of improving voyage optimization, like fuel efficiency, minimizing crew performance, improving voyage costs estimates, calculating the optimal route in a minute, give recommendations on speed, course, route, etc.

**AI Use Successfully in Maritime Trade and Commerce**

AI or ML has remarkable potential in maritime business field, as like in manufacturing industry. AI-based solutions will not only improve terrestrial transportation but will also greatly benefit the maritime industry. The shipment of goods is a crucial component of the global economy, and the increasing opportunities for customers around the world necessitates that the field be constantly optimized. Actually, AI is changing the landscape of the current maritime business in a variety of ways. Automated units get some autonomy via AI. It also examines and optimizes procedures. It forecasts the future trends and patterns of marine business. It is entirely possible to achieve sustainable goods and outperform the competition by taking use of all of these unique chances.[251] It has been noticed that container fires cause numerous deaths each year. A survey found that many containers did not pass inspection due to one or more faults. For example, wrongly stowed or declared freight. AI can assist in identifying and monitoring containers prior to loading, hence it is improving overall safety. As we know that, any advancement replaced its predecessor because it was safer, less



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expensive, and more efficient. AI optimization follows this tendency. AI and ML technology improve maintenance, operations, fuel, trip planning, logistics, port calls, paperwork, management, and surveillance.

According to a joint report in 2023[252] by Lloyd's Register and maritime innovation consultancy,[253] Thetius, the AI-driven systems and vessel autonomy markets will be worth a combined US$ 5.01 billion by 2028.[254] However, besides focusing on financial survival in the future market there is also innovations which can have a favorable effect on globe. However, the maritime industry is one of the most dangerous and complex work environments on the planet. As a result, mariners have greater death rates than laborers ashore. Seafarers and other marine personnel face a variety of high-risk duties, including tank inspections, oil spill cleaning, firefighting, search and rescue (SAR) operations, and operating in high winds and waves. AI-powered robotics can now do high-risk activities like underwater hull inspection, tank entrance, and machinery operation at sea. AI and ML-powered automation can help to reduce the crew's exposure to such working environmental threats. Again, in the near future, unmanned MASS may completely eliminate all risks at sea and adverse conditions. However, Maritime Autonomous Surface Ships (MASS) is a short form used by the International Maritime Organization (IMO) to explain commercial vessels that operate with little or no human intervention, using sensors, software, and communication systems to navigate, avoid collisions and perform the tasks and functions of the vessel.[255] Now, AI drones are already being utilized to inspect tanks, hulls, and holds, thereby saving money and time. Passenger tracking and monitoring during emergencies, bridge alerts when someone falls overboard, detection of illegal fishing or drug trafficking, recognition of fatigued and stressed crew members, early detection of fires, and pinpointing vessels and pirates in distress are just a few of the current AI surveillance and tracking tools used in the maritime industry successfully. [256]

**AI and Future Shipping Business**

The future of AI and other smart technology in the shipping industry has become visible and increasingly promising and revalorizing. Developments in AI, ML, IoT, natural language processing, and computer vision will drive innovation and advancement, from smart ship to autonomous shipping to smart ports to smart supply chain optimization. Smart and autonomous ship equipped with AI-driven navigation and surveillance systems will revolutionize and promising maritime transport, offering absolute efficiency, safety, security, reliability and flexibility. Again, by using ML, DL and ML algorithms, AI can help predict fuel and machinery spare need and adjust inventory levels, accordingly, ensuring timely and efficient fuel delivery and on-board maintenance.[257] On the other hand, in supply chain management, AI and smart technology can analyze huge amounts of data to optimize fuel delivery, mapping routes, minimize fuel waste and reduce transportation costs. With the help of AI, refueling companies can also design, control and plan their fleet models.[258] Additionally, AI and ML driven maritime digitalization and blockchain-based solutions will improve and promote transparency, accountability, track-ability, confident and trust across the maritime supply chain and entire industry, to constrain operational excellence and wonderful management.[259] However, the integration of AI and other smart technologies provides versatile and distinct advantages for the shipping industry. Such as:

- AI, Ml and other smart technology are capable to work out speed and power for propulsion machinery and merchant ships itself to forecast performance changes due to underwater fouling or abnormal weather pattern. Smart technology helps shippers to understand, calculate and forecast the rate of the degradation of ships and remaining useful life by analyzing and processing historical data.
- AI and ML will help to build perfect and useful models to resolve the most efficient voyage routes and passage planning and that is the best path for minimum fuel consumption and solving weather-related slowdowns and offering technical reports for best management.
- The primary benefit of AI, ML, DL, Big data, etc. are ensure operational efficiency through optimized route planning, condition-based monitoring, electronic generated reports, useful robotics, Big Data analytics, fuel consumption reduction, optimized cargo handling processes, management excellences.
- AI, ML or automation play a noteworthy role in the shipping industry. Automating processes can help to recognize problems before they happen, leading to proactive asset management, minimizing downtime, remote monitoring and tracking, helping proper decision-making, extending machinery and equipment lifetime by proper diagnosis and in time measures and predictive maintenances. As a result, smart and autonomous vessels minimize costs and maximize safety.
- Maritime industry is achieving success by using AI and ML for autonomous navigation, weather routing, and safety and security measures from accidents bypassing human errors. Those smart technologies are effectively used to detect threats and malicious or nasty activities of online arena.
- AI or ML assures to boost environmental sustainability by enabling fuel monitoring, emission reduction, risk mitigation strategies, better management and which may be considered as beyond operational gains.
- AI or ML powered analytics allow shipping companies and related stakeholders to make data-driven decisions, improve resource allocation, quickly adapt to dynamic market conditions, etc. Those will help to analyze historical data by considering related things like weather patterns, shipping seasons, cargo movement history, etc.



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Today, ship owners, shippers, operators, charter or other stakeholder can achieve advantage by using cutting-edge technologies like AI, ML or other smart technology to optimize their operations and stay ahead of the competitors.[260] Mr Vikram Roopchand, CTO of Smart Ship © Hub, is capable to deliver high quality software in very diverse and complex technical domains of shipping and maritime industry. He said, 'AI has the enough potential and prospect to revolutionize the maritime industry, in a way the steam or internal combustion engines did for the automobile industry. Today, we talk about AI use cases for the industry, but in the future the machines will be built AI enabled. The integration of technology will be much simpler as all machineries will inter-operate seamlessly with each other.'[261] Actually, he perfectly understands and evaluates the capability of smart technology for shipping industry. Again, Smart Ship(c) Hub is a remote vessel and voyage management platform that offers real-time, high-frequency data, vessel reporting systems, predictive analysis, voyage optimization, cost saving, and more through smart alerts and Vessel Information Reports (VIR).[262] It ensures EU ETS (European Union Emissions Trading System), EU MRV (European Union Monitoring, Reporting, and Verification), IMO DCS (International Maritime Organization Data Collection System) and CII (Carbon Intensity Indicator) compliance for favourable environmental impact towards decarburization. With timely SSH audits and monthly inspections there is an added advantage to collaborating with SSH. Inclusion of smart technology and digitalization is enabling operational profitability, lower down time, lesser break down maintenance and up to 35% high efficiencies for the global maritime industry. AI is playing a more prominent role in shipping operations as companies try to stay competitive and ahead of the curve. In fact, according to a 2023 joint report by Lloyd's Register and maritime innovation consultancy, Thetius, the AI-driven systems and vessel autonomy markets will be worth a combined USD 5.01 billion by 2028.[263] Besides focusing on financial survival in the future market, there are also innovations which can have a favorable effect on our planet. The latest findings in a McKinsey Global Survey report a nearly 25% year-over-year increase in the use of AI in standard business processes, with a sizable jump from the past year in companies using AI across multiple areas of their business.[264]

Presently, most ocean tankers, bulk, cargo, cruise and container ships rely on diesel engines to generate power and electricity as propulsion plant. The maritime industry is accountable for 90% of trade for transporting around globe. Those sea-going ships discharge 3% of the world's greenhouse gas (GHG).[265] With growing concerns about the effects of climate change, there is more pressure on industries to limit their GHG gas or carbon footprint. The IMO has set lofty ambitions for 2030 and 2050.[266] The United Nations Agency wants to reduce carbon emissions by 40% from 2008 levels by 2030. They want to reduce at least halve all the industry's emissions by 2050. To implementing AI and ML algorithms which recommend a few logical solutions like least energy-intensive routes, the most efficient use of resources, automated container configuration, optimum space management for passenger and cargo, etc. Introducing AI processes into shipping operations and management has much prosperity and benefit.[267] Now, data analysis and system monitoring are made possible by fusing the virtual and real worlds in simulations. This prevents unnecessary outcomes, eases the operation, cuts downtime, finds new opportunities, plans for future and manages effectively.

Figure 16: AI will dictate future shipping[268] and AI solution will grow exponentially[269]

The first zero-emission, fully autonomous container ship set for sail in Norway, after a two-year extensive trial in 2022. This was an interesting story. Yara and technology company Kongsberg of Norway have grouped up to build the planet's first autonomous and zero-emission container vessel. The vessel boasts Yara Birkeland has a 7 MWH battery, equivalent to 1000 times the capacity of a typical electric car battery. The ship is able to accommodate 120 containers at an average speed of 10 knots. On the other hand, the largest container ships in operation at present can carry 24,000 with more than 20 knots speed. After introducing vessel Yara, which has removed 40,000 diesel-powered trucks journeys every year, and reduce NOx (Nitrogen oxide) and CO2 emissions, improve road safety, reduce road dust formation, traffic noise, and other environment friendly achievement. This vessel is transporting mineral fertilizer from Yara's production plant in Porsgrunn, Norway to the regional export port in Brevik successfully.[270]

The idea of the digital twin can help the maritime industry by utilize digitalization and AI or other smart technology in a way that is more effective and guide in a new age. Operation, monitoring and management of the shipping fleet, port effectiveness and improvement of the end-to-end supply chain and are other elements that are greatly enhanced by digital twin technology.[271] It includes both the hardware to acquire and process data and the software to represent and maneuver these data, to making them more powerful than models and simulations because they leverage digital data streams to link the fence between the physical entity and its



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illustration. So, digital twin analytics relies on historical data or data-lake and real-time digital data streams or IoT generated data, to analyze possible outcomes or solution.[272] Digital twin technology can be used for monitoring, diagnostics and prediction to optimize asset performance and their utilization. Digital twin offer shipping companies, port operators, businesspeople and other stake-holders specific and accurate virtual environments to test innovative ideas and nurturing innovation across the marine sector. Digital twin also helps to providing important insights and input in ship designing, software operation, optimum machinery systems. Such helps to cut extra costs, enhance ship performance, effective operations, make easy systems, prevent damages, reduce risks and accidents. [273] So, there is no doubt that blockchain, digital-twin, big data, IoT, AI and other smart technology are vital factor to driving the next wave of smart transformation, and there is no exception in the ship and shipping industry.

**AI and Future Shipbuilding**

Shipbuilding is a complex and most innovative primitive engineering which meets the hugeness of the open seas. It integrates the cutting-edge technologies and that has always been influential in approaching the boundaries of anything that is possible. In the Ship manufacturing sector, there will be many changes to control environmental pollution. In near future, we can see smart ships and also, we can see several vessels which are really economical. We all know that Industry 4.0 has made several changes in the manufacturing sector. Based on the commercial market requirements Shipbuilding is evolving to meet these requirements. Almost the entire industrial sector is being digitalized, so in the near future we can see the shipbuilding industry as a totally digitized manufacturing sector. Right now, Ship manufacturing is on the path of a technological revolution. Advanced materials are utilized to manufacture ships or vessels. Augmented reality and Robotics is utilized to manufacture different kinds of ships or vessels. All these technological revolutions in the Ship manufacturing sector will be useful to control environmental changes. Several technologies would be utilized in the maritime sector to handle several problems in the marine sector. There would be economical and autonomous vessels due to the technological advancement in the maritime sector. We can make sure that while digitalizing the Shipbuilding sector we can improve the quality, reliability, efficiency, and productivity of the vessel.[274]The evolution of AI in the shipbuilding industry has brought significant benefits in terms of efficiency, accuracy, and safety. AI has been applied in various aspects of the industry, from the design and construction of ships to their operation.

Now, as the world stands on the very changeable situation of technological revolution, we are on the rock face of harnessing the potential of AI, ML and other smart technology to revolutionize shipbuilding. The shipbuilding landscape is evolving quickly, driven by new rules and regulations to clean up our seas and embrace greener, more efficient technologies. New fuels, digital solutions and artificial intelligence are helping shipbuilders embark on a journey to future-proof their business operations over the lifecycle of a vessel.[275] In the design process, AI algorithms have been used to analyze large amounts of data and identify patterns and trends that can inform the design of more efficient and effective ships. This has allowed shipbuilders to optimize the design of vessels for specific purposes, such as cargo shipping or oil transportation. AI has also been used to improve the construction process, with AI-powered robots being used for tasks such as welding and painting. This has not only improved safety on the construction site, but it has also increased efficiency and reduced costs.[276] In the operation of ships, AI-powered systems can be used to monitor and optimize performance, identifying potential issues before they become problems and suggesting corrective actions. This can help reduce fuel consumption, improve safety, and increase the lifespan of the vessel. As AI continues to evolve and become more sophisticated, it is expected to play an increasingly important role in the shipbuilding industry. It will drive innovation and help shipbuilders meet the growing demand for shipping and transportation. However, it is important to consider the ethical and societal implications of AI, such as the potential for job displacement and the risk of bias in decision-making. It is crucial that we ensure that AI is developed and used responsibly to benefit all members of society.[277]

Figure 17: AI and other smart technology will transform future shipbuilding[278,279]

One area where AI is making significant strides is in design optimization and simulation. By leveraging AI algorithms, naval architects and engineers can explore countless design variations and evaluate their performance in real-time. AI-powered simulation



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tools can accurately predict a vessel's behavior under various conditions, enabling the optimization of key parameters such as hull shape, propulsion systems, and structural integrity. This empowers shipbuilders to develop more efficient and environmentally friendly vessels, minimizing energy consumption and reducing carbon footprints. Another critical application of AI in shipbuilding is predictive maintenance and condition monitoring. By leveraging machine learning algorithms, sensors, and data analytics, ships can be equipped with intelligent monitoring systems that detect anomalies, predict potential failures, and recommend maintenance actions. This proactive approach to maintenance helps prevent costly breakdowns, optimizes operational efficiency, and enhances the lifespan of critical components.[280]

The advent of AI is also propelling the development of autonomous and smart shipping. AI-powered navigation systems, integrated with advanced sensors and real-time data, can assist in autonomous vessel operations, improving safety and efficiency. Furthermore, AI-enabled decision support systems can optimize route planning, fuel consumption, and cargo distribution, leading to more sustainable and cost-effective shipping operations. As shipbuilders and engineers, we find ourselves at the forefront of a new era where AI opens doors to unprecedented possibilities in shipbuilding. By embracing AI technologies, collaborating across disciplines, and nurturing a culture of innovation, we can pioneer the future of shipbuilding that is smarter, safer, and more sustainable. With AI as our compass, we embark on a transformative journey that holds the potential to reshape the shipbuilding industry. Let us harness the power of AI to navigate the challenges ahead, unlocking new frontiers of efficiency, advancing maritime safety, and shaping a greener and more connected future for ships and those who sail them.

As with any transformative technology, AI in shipbuilding brings its own set of challenges and ethical considerations. Ensuring data privacy, addressing algorithm bias, and establishing regulatory frameworks are among the key concerns that need to be carefully addressed. Additionally, striking the right balance between human expertise and AI automation is essential to maintain the human element and decision-making capabilities crucial in critical situations. Today, the digital life of a vessel is born before its physical life – and buried after recycling has occurred. Those players best able to adapt and offer effective solutions over the digital lifecycle of their vessels will outperform the others. The biggest obstacle is to get everyone involved. The technology is available. Implementing a Digital Twin is not such a big task if the company is already doing 3D modeling. Digital lifecycle thinking bridges the communications gap between the different stakeholders in the shipbuilding cycle – between the designer, yard and owner – by using a 3D model with colors and interactions. It also helps departments communicate better internally. As a result, by using Digital Twins is an opportunity to enhance collaboration among all stakeholders and helps create new designs and solve engineering problems.

AI or ML has the potential to revolutionize the shipbuilding industry by improving efficiency, cost-effectiveness and safety measures by predictive maintenance, automation, data analysis, better management and effective monitoring. There are many advantages of digitalizing and smart technology in the shipbuilding sector. Data plays an important role in many industries so several important decisions can be taken based on the collected and historical data by utilizing smart technology. The emission of carbon and other GHG can be controlled and reduce as well as environmental pollution can be optimized by using smart technologies. Ship designing, building and operational costs can be reduced by implementing advanced technology like AI, ML or big data. Smart technologies in shipbuilding can easily improve safety and security of shipping sector. By using smart technology in shipbuilding sector profit can be optimized due to the reduction of operational costs. [281] Advantage and related statistics related to use of AI in shipbuilding industry has been described in few paragraphs below.

AI can be utilized to carry out several tasks in this industrial sector. In the manufacturing sector, Automation plays a great role, and AI can be utilized in this to carry out several operations securely.[282] AI can also be utilized to control cargo ships there are several cargo ships all around the globe. Cargo ships are the major means of transporting goods, so these goods must be transported properly at the required time and AI can be utilized to transport cargo in an efficient manner by classifying and organizing the goods which are going to be transported. there will be less terminal traffic by implementing AI in the cargo section. Again, sensors play an important part in the industrial revolution. Sensors can be utilized to determine the ship's operations and thus we can ensure the safety of the vessel. Naval architects can reduce several manual tasks by utilizing sensors. Different equipment in the ship can be connected by utilizing sensors and also, we can analyze the quality of the devices with the help of sensors driven by AI. Remote monitoring is possible with the help of sensors. Maintenance can be carried out in proper time and also preventive maintenance can be done. Faults can be detected before they can happen and thereby reducing the cost of maintenance. Communication can be easily carried out because of these sensors. Ships can be controlled by fleet members on land by utilizing these sensors powered by AI. On the other hand, 3D printing technology is utilized to create the virtual image of several objects. It would be useful to develop several pieces of equipment and also it can reduce the manufacturing cost. The virtual image would be really useful to reduce manufacturing costs in shipbuilding



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industry. The major advantage of utilizing the 3D printing feature is that we can reduce the development cost. So, it can be utilized to create a virtual ship model and also this feature can be utilized to carry out maintenance.

Robotics plays a key role in most industrial processes like manufacturing, and it can be utilized to do dangerous tasks. There are several dangerous tasks in shipbuilding and one of them is welding we can utilize robots to do these works. Robots will be useful to uphold the security of the ships, and they can also inspect the vessel and can prevent faults. Engineer can utilize robots to work in hazardous environments where human life could be in danger. Robots can do several tasks in shipbuilding like blasting, cutting, welding, painting, lifting huge weights, assembling, etc.[283] Again, IoT is utilized to create smart homes. We can remotely control several household devices by connecting these devices to the internet. We can utilize this technology in the shipping industry successfully. We can control several pieces of equipment or devices in a ship remotely by utilizing this technology. All the devices in the manufacturing sector can be connected to each other via a wireless network. Communication can be easily carried out by utilizing this technology as well as the data from sensors and other equipment can be easily transmitted to the control system. Today, propeller system for ships has designed by utilizing smart technology. The propulsion system would be controlled by advanced technology and due to this the chances of human error are reduced. So, the captain of the ship doesn't have to monitor the vessel frequently. The ship engine can be controlled by utilizing the AI power software so the captain and the engineers on the ship can monitor the status of the ship with the help of that software. 1 in every 3 vessels sailing the oceans of the world has Wärtsilä solutions on board. These include Guinness record holding engines, Hybrid propulsion solutions, ground-breaking, award winning VOC recovery systems, the latest environmentally sustainable processing and voyage AI solutions. Wärtsilä declared that they are able to deliver the future marine ecosystem that will lead the transformation towards a new era of efficiency and sustainability.[284]

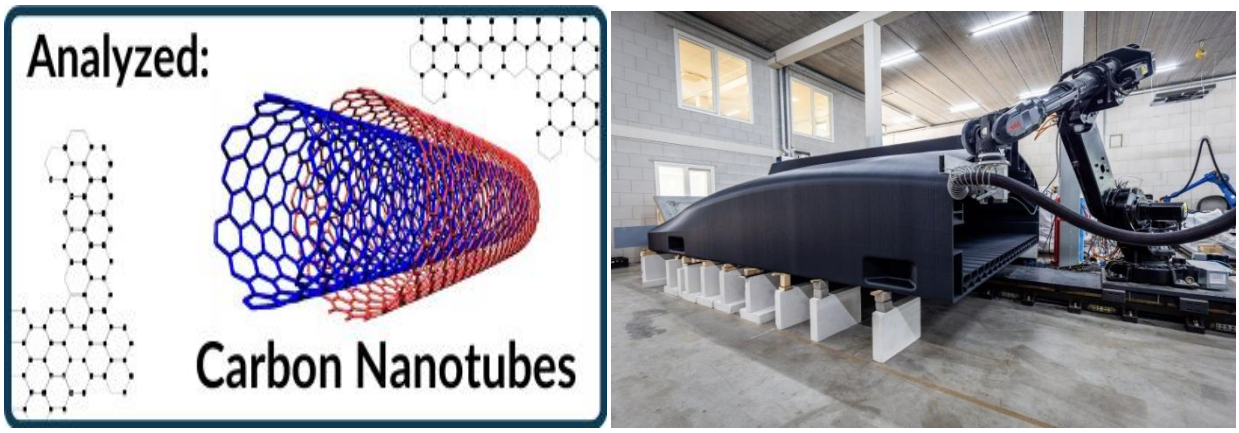


Figure 18: Future shipbuilding material (carbon nanotubes buckypaper)[285] and smart technology (3D printing)[286]

Carbon nanotubes are utilized to create Buckypaper, basically, it is a thin sheet. Conventional shipbuilding material was steel but now in the future, this Buckypaper would be utilized to create ships.[287] The weight of Buckypaper is less when compared to steel and it is twice stronger as steel. So, if a ship is constructed by utilizing Buckypaper then the weight of the ship can be easily reduced and hence less fuel would be required. There could be a time when ships are not constructed using cables, but with structures that are conductive, yet stronger and lighter than steel. Cabling could be made redundant if ships were constructed with composites of buckypaper and carbon-fibre instead.[288] LNG fuels are eco-friendly and can be used as fuel in ships. The carbon emission from LNG machines is low when compared to diesel engines. So, in the future, ship builders can expect a lot of LNG ship engines with AI-driven, instead of diesel engines in near future.[289] Major ship manufacturing organizations are planning to create LNG machines. Another advantage of utilizing LNG in ships is that LNG is cheaper when compared to diesel. Again, the shipping industry is planning to utilize renewable energy like wind and solar energy as the energy source. This would be helpful to reduce fuel consumption. Many ship manufacturers are doing a lot of research based on this. As an example, Turanor is a solar-powered ship, and it has traveled all around the world without using any fuel.[290] Augmented Reality **(**AR) and Virtual Reality (VR) are advanced and smart technology which can create digital environment based on the user's environment in real-time. AR or VR would be really useful for shipbuilding and design, and it can be utilized to inspect the ship. Maintenance can be easily carried out by utilizing this feature. During the development process, such smart feature can be utilized, and thus ship designers and builders can create digital or smart model by utilizing this and can find out if there are any faults in it. So, by utilizing such smart technology in shipbuilding we can save money and time.



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Figure 19: AI-based engine automation system[291] and use of VR in shipbuilding[292]

**Future of AI Market in Shipping, Shipbuilding and Maritime Industry**

The shipment of commodities is a vital part of the global economy, and the growing demands of customers around the world necessitate ongoing optimization. Again, AI and other smart technologies are altering the face of the current maritime business in three ways. For example, AI enables partial autonomy to fully autonomous units, assesses and optimizes processes, and forecasts future trends. AI is anticipated to become a reality by 2060. Then, AI will be able to learn how to complete new jobs that have nothing to do with what it already knows. Stability is critical for ships, commerce, and the maritime economy. In fact, the marine industry may still confront some challenges to the application of AI and smart technology. It is expected to become an important part of maritime operations in the long run, improving ease of use and safety. The maritime industry is an important part of today's global economy. It transports materials and goods to and from all over the world. This is a demanding and complex setting; even slight adjustments can result in significant benefits and changes. To remain competitive and ahead of the game, maritime enterprises must invest in the best AI technologies available. AI and other smart technology can assist marine organizations in making better decisions, optimizing operations, implementing sustainable management practices through work automation, and maintaining accountability. [293] Based on product and service, the AI market is divided into four groups. Examples include specialized AI applications, AI consulting services, AI hardware, and AI platforms. The specialized AI applications segment will have the highest revenue opportunity among the AI product and service divisions between 2021 and 2026. The widespread integration and use of AI in specialized software applications and platforms, such as image recognition, speech recognition, computer vision applications, natural language processing, sentiment analysis, risk management, content workflow management, context awareness, and so on, will drive revenue growth in the specialized AI applications segment. Again, the AI market size has been divided into BFSI, communication, construction, consumer goods, education, energy, government, healthcare, information technology, manufacturing, media, medical devices, mining, pharmaceuticals, retail, transportation and logistics, and others. Among these, BFSI, healthcare, retail, government, and information technology are the top 5 verticals and contributing major share and that has been shown in figure 20.

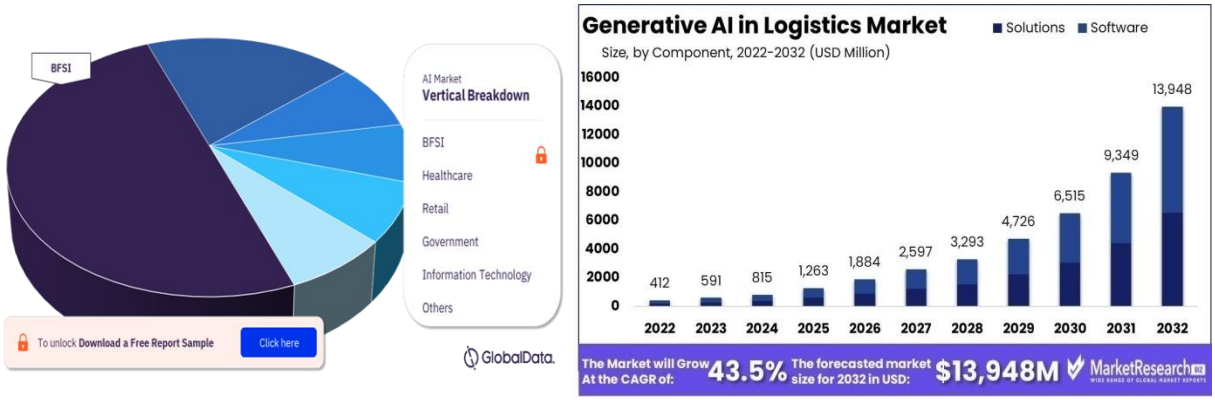


Figure 20: AI segment-wise market analysis and[294] along with forecast of AI software and solution in global market[295]

Ship and shipping usually operates in a traditional, as age-old industry model, new paces as part of this automation or AI-driven industrial revolution have created new patterns of innovation and change and that is well-known as Shipping 4.0.[296] However, maritime companies are adopting new technology like AI and that will sweep away the need for schedule and repeated tasks carried out by ship officer and crew, like navigation, loading-unloading of cargo or passenger or containers, sorting of events, monitoring for routine maintenance, and other delivering real-time reports. This increased efficiency has the potential to dramatically reshape the entire supply chain, not just on the industry or company level, adding USD 15 trillion to the global economy by 2030.[297] AI can



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streamline operations in shipping, with significant applications including automated processing and real-time analytics. ML uses an organization's historical and real-time data to help mitigate risks and serves as a helpful tool that aids in decision-making processes. As the use of AI in logistics grows, it becomes more imperative than ever before that organizations adopt these tools to optimize their operations to keep a competitive edge. AI is a valuable tool in maritime industries and no way to ignore. As shipping becomes more digital and smarter; so the volume of data in future will become enormous. AI will shape the future of global shipping. In future, smart navigation, route optimization, collision avoidance, predictive maintenance, smart management, etc will be helped by AI or smart solutions.[298] Technological trends promise to showcase the positive impact of AI in the shipping industry in the long run, even if the majority of immediate integrations appear to be small-scale.[299] Today, more than 250 million companies are either using or are exploring AI in their business operations. So, around 77% of companies are either already using or in the process of planning their AI integration, where China has the highest rate of AI adoption. The global AI market is expected to reach USD 1.85 trillion by 2030. [300]

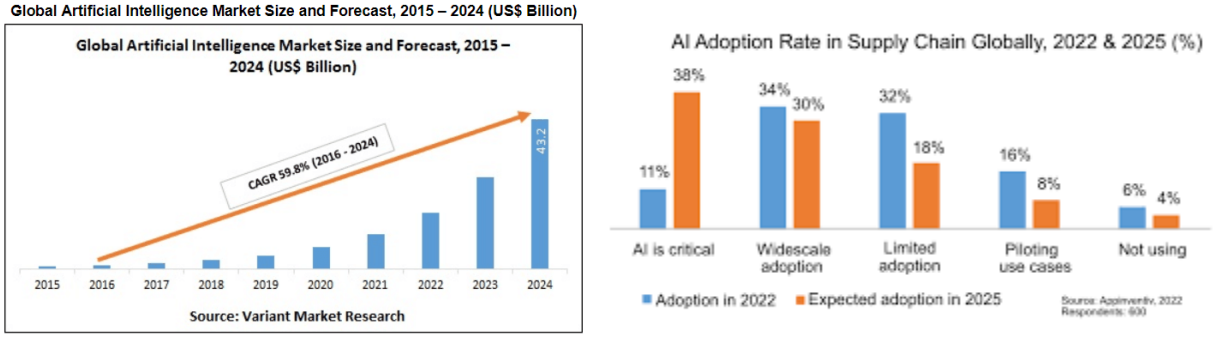


Figure 21: Growth in AI global market [301] and AI adoption in manufacturing market[302]

AI is growing at a breakneck speed. Its applications are being increasingly used across various industries including healthcare, media and advertising, retail, and automotive. Researchers from 'Variant Market Research' recently predicted the future of artificial intelligence, and reported that it might reach USD 43.2 billion by 2024; exhibiting a CAGR of 59.8% during 2016-2024.[303] AI can add $957 billion to Indian economy by 2035.[304] The global AI was in 2019 in manufacturing market size was USD was 8.14 billion and is projected to reach USD 695.16 billion by 2032, exhibiting a CAGR of 37.3% during the forecast period.[305] This indicates that, the growth of adoption of AI is very fast. The Global Generative AI in Logistics Market size is expected to be worth around USD 13,948 million by 2032 from USD 412 million in 2022, with the growing at a CAGR of 43.5% during the forecast period from 2023 to 2032.[306] Again, the global AI in logistics market size is expected to be worth around USD 549 billion by 2033, from USD 12 billion in 2023, growing at a CAGR of 46.7% during the forecast period from 2024 to 2033.[307]

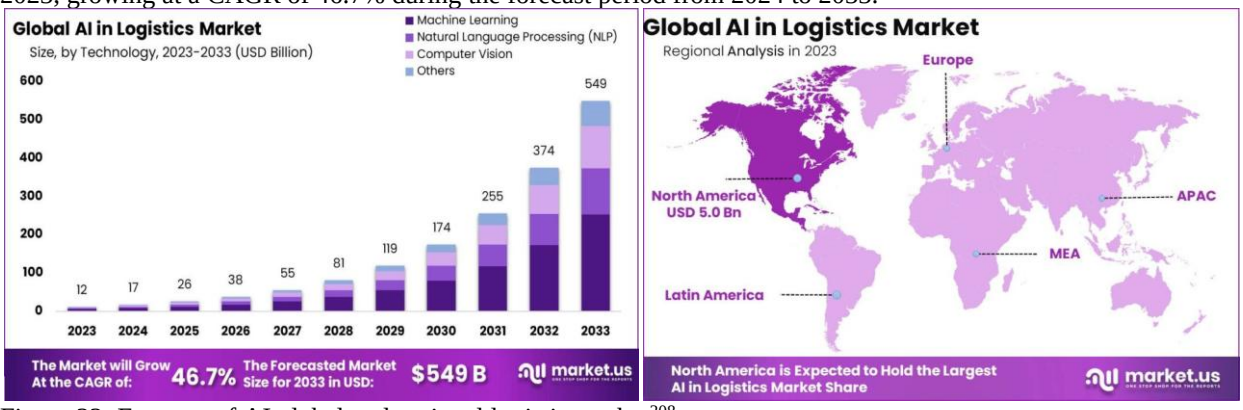


Figure 22: Forecast of AI global and regional logistic market[308]

In the another report state that, AI and robotics in the global shipbuilding market is expected to reach USD 2.8 billion by 2033 published by Spherical Insight and Consulting.[309] This statistic indicates the projected value for the global AI market specifically within the shipbuilding industry by the year 2033, estimated to be USD 2.8 billion.[310] This figure represents the anticipated total spending on AI technologies and services within the shipbuilding sector, reflecting the increasing adoption of AI tools and solutions in ship design, manufacturing, operation, and maintenance processes. [311] The growth forecast suggests a growing recognition of the benefits AI can bring to the shipbuilding industry, such as improving efficiency, safety, and overall productivity. This statistic highlights the significant potential for AI technologies to transform and enhance operations in the shipbuilding sector in the near future. AI in shipbuilding is projected to grow at 13.6% CAGR from 2019 to 2024. This statistic indicates that the use of AI in the shipbuilding industry is expected to experience a Compound Annual Growth Rate CAGR of 13.6% from 2019 to 2024.[312] This projection suggests a significant increase in the adoption and integration of AI technologies within the shipbuilding sector over the



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specified period. The growth rate of 13.6% per year signifies a rapid expansion of AI applications in various aspects of shipbuilding processes, such as design, manufacturing, maintenance, and operations.[313] This trend underscores the industry's recognition of the potential benefits and efficiencies that AI can offer, including improved operational performance, cost savings, enhanced safety, and competitiveness in the global market.


Figure 23: AI global market size in percentage region-wise in 2022 and forecast of AI global market size in billion USD[314]

On the other hand, another market survey state that, the global AI market size was valued at USD 454.12 billion in 2022 and is expected to hit around USD 2,575.16 billion by 2032, progressing with a compound annual growth rate (CAGR) of 19% from 2023 to 2032. The North America artificial intelligence market was valued at USD 167.30 billion in 2022. In U. S. the AI market size accounted for USD 103.7 billion in 2022 and is estimated to reach around USD 594 billion by 2032, growing at a CAGR of 19.1% from 2023 to 2032. Whereas, in Canada AI market was valued at USD 43.7 billion in 2022 and it is expected to reach at 251.3 billion in 2032, at a CAGR of 19.2% from 2023 to 2032. Again, in Germany, AI market was valued at USD 25.7 billion in 2022, and it is projected to grow at a CAGR of 20.6% from 2023 to 2032. Again, in Japan, AI market was valued at USD 20.2 billion in 2022 and will reach at CAGR of 21.0% from 2023 to 2032. [315] AI projects are usually complex and those they require multidisciplinary expertise in areas including computer vision, natural language processing and machine learning. Services are being utilized widely to bring together a diverse set of skills and resources to tackle such complex projects effectively. As per Precedence-research statistics and market survey, the global market revenue trend by smart technology in 2022-2032 in billion USD has been found upward in nature and very fast growing. Again, global AI market revenue trend, by solution in 2022-2032 in billion US$ is also growing very fast.

| Smart Technology | 2022 | 2023 | 2027 | 2032 |
|---|---|---|---|---|
| **DL[316]** | 165.98 | 196.83 | 392.57 | 948.24 |
| **ML[317]** | 122.59 | 145.43 | 290.57 | 703.50 |
| **NLP[318]** | 91.33 | 108.31 | 215.94 | 521.48 |
| **Machine Vision[319]** | 74.22 | 87.57 | 171.01 | 401.95 |
| **Total value of AI market in billion USD** | **454.12** | **538.14** | **1070.09** | **2575.17** |

Table 1: Global market revenue trend by smart technology in 2022-2032 in billion USD [320]

| Smart Solution | 2022 | 2023 | 2027 | 2032 |
|---|---|---|---|---|
| **Hardware** | 109.20 | 129.66 | 260.25 | 633.13 |
| **Software** | 168.85 | 200.24 | 399.66 | 966.09 |
| **Services** | 176.08 | 208.23 | 410.19 | 975.94 |
| **Total Value of AI market in billion USD** | **454,12** | **538.14** | **1070.09** | **2575.17** |

Table 2: Global market revenue trend by solution in 2022-2032 in billion USD

Recent statistic indicates that incorporating AI technologies into shipbuilding processes has the potential to enhance performance levels by up to 20%. This suggests that utilizing AI algorithms, ML, DS and other smart technologies in ship designing, building, and operation can lead to significant efficiency improvements, cost savings, and operational enhancements within the shipbuilding industry.[321] By leveraging AI capabilities like predictive maintenance, autonomous operations, and data analytics, shipbuilders can optimize ship performance, increase safety, and reduce downtime, and ultimately driving a more competitive and innovative



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shipbuilding sector.[322] The AI and robotics in global shipbuilding market size was valued at USD 1.26 billion in 2022 and is projected to grow from USD 1.32 billion in 2023 to USD 1.85 billion by 2030.[323] The statistic suggests that by 2030, approximately half of the tasks involved in shipbuilding could be automated through the use of AI and robotics technology. This implies that advancements in technology are likely to significantly change the shipbuilding industry by allowing greater level of automation and efficiency in various processes involved in shipbuilding. The automation of tasks like welding, painting, and assembly could lead to increased productivity, reduced costs, and improved safety in shipyards and shipbuilding operation.[324] However, it also raises questions about the impact on the workforce, as automation may lead to changes in job roles and the need for up-skilling of workers to adapt these technological developments.

Another important statistic suggests that 30% of companies within the shipbuilding industry are projected to incorporate AI into their design and production processes by 2025. This integration of AI technology is likely to revolutionize the shipbuilding as how ships are designed, manufactured and maintained, and that potentially leading to increased efficiency, cost savings, and innovation within the industry. By leveraging AI's capabilities, like data analysis, predictive modeling, and automation, shipbuilders can streamline their operations, optimize decision-making processes, and enhance overall competitiveness in the marketplace. This trend indicates a growing recognition among industry players of the benefits and potential of AI technology. This will transform traditional practices in shipbuilding towards smart industry. One interesting statistic state that the use of AI in shipbuilding can reduce production time considerably (around 20%). It implies that implementing AI technologies in the shipbuilding industry can significantly improve efficiency and streamline various processes. By leveraging AI and ML algorithms or automation, tasks like design optimization, production planning, and quality control can be performed more quickly and accurately, leading to faster manufacturing cycles and ultimately accelerating the delivery of ships.[325] This statistic highlights the potential benefits of integrating AI into shipbuilding operations, ultimately enabling cost savings and enhancing competitiveness in the maritime industry.

In another study it has found that AI can increased efficiency in shipbuilding operation by 10% in South Korea in 2019 and which indicates that the implementation of AI technology led to a significant improvement in the productivity and effectiveness of ship construction processes in South Korea during that year. This advancement suggests that AI systems were able to optimize various aspects of the shipbuilding operation, like design processes, material selection, manufacturing techniques, and quality control, and that resulting in a notable 10% increase in efficiency. Such a positive impact highlights the potential benefits of integrating AI technologies into shipbuilding sector, paving the way for improved operational outcomes and cost savings in the industry. Another renowned statistic states that, incorporating AI in shipbuilding processes has the potential to lead to a significant reduction in labor costs, and that estimates up to 50%. This means that by automating certain tasks and utilizing AI technology in shipbuilding, there is opportunity for substantial savings due to the reduced need for human labor.[326] AI can streamline operations, increase efficiency, and perform tasks that would traditionally require manual labor, and ultimately driving down costs associated with workforce salaries and expenses. Additionally, AI can also enhance precision and accuracy in shipbuilding processes, contributing further to cost savings by reducing errors and misuse.

One of the statistics suggests that implementing AI technology in the shipbuilding industry has the potential to prevent a significant proportion of data breaches dramatically (up to 80%). By utilizing AI tools for data security measures like real-time monitoring, anomaly detection, threat prediction, and incident response, shipbuilding sector can enhance their cyber-security posture and reduce the likelihood of falling victim to cyber-attacks.[327] Such statistic emphasizes the effectiveness and importance of leveraging AI solutions to safeguard sensitive information and mitigate risks associated with data breaches in the shipbuilding industry. Other statistics described that AI technology can reduce maintenance costs in shipbuilding significantly (around 18%) and this prove the financial potential of integrating AI solutions into the maintenance processes in shipbuilding operations and management. This statistic suggests that leveraging AI technology can lead to significant cost savings by improving maintenance efficiency, enhancing predictive maintenance capabilities, optimizing resource utilization and minimizing downtime due to equipment failures.[328] By harnessing the power of AI and ML algorithms and predictive analytics, shipbuilding companies can make data-driven decisions, proactively address maintenance issues, and ultimately reduce operational costs and which showcase the substantial financial gains and improved overall performance in the shipbuilding industry.

One recent statistic suggests that ML algorithms have been successfully utilized to forecast the likelihood of maritime equipment failure few days in advance with a certain level of accuracy. By analyzing historical data on equipment malfunctions and potential contributing factors, these algorithms can identify patterns and indicators that precede failures, enabling proactive maintenance or interference to prevent accidents as well as downtime.[329] The ability to predict equipment failure in advance allows ship crew and machine operators to plan for necessary repairs or replacements, optimize maintenance schedules, and ultimately contribute to improved safety, cost-effectiveness, and operational efficiency in the maritime industry.[330] Another statistic stating that around 40% of shipbuilding companies plan to significantly increase their investments in AI by 2025 and that indicates a growing trend within the industry towards adopting AI or other smart technology. Now, most of the shipbuilding companies recognize the potential benefits and competitive advantages that AI can offer by enhancing efficiency, productivity, innovation and profit optimization.[331] Today, AI



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investment in maritime industry is increasing to achieve streamline in operations, optimize in decision-making and gain in competitive advantages.[332] This statistic reflects a strategic shift among shipbuilding companies to enhance their capabilities and remain competitive in the developing market landscape. Another statistic describe that, AI in shipbuilding promises to reduce manufacturing defects by more than 90% and AI technology can significantly improve the quality control process in ship construction.[333] By utilizing AI algorithms and ML techniques, shipbuilders can analyze vast amounts of data to identify potential defects at an early stage, and allowing for timely interventions and preventing the occurrence of issues that could lead to defects.[334] By considerable decrease in manufacturing defects, AI is improving efficiency and quality assurance in the shipbuilding industry.[335]

One of the recent statistics suggests that implementing AI in maritime platform and shipbuilding industry could potentially extend their operational lifetime significantly (more than 25%).[336] By utilizing AI for predictive maintenance, real-time monitoring of equipment, and advanced decision-making processes, maritime ships can reduced breakdowns, improved efficiency in operations, and reduced risks of accidents at sea.[337] Such achievement will benefit both vessel owners and operators by reducing maintenance costs and downtime along with enhance overall safety and sustainability within the industry. Another statistic states that the implementation of AI technology can enhance the effectiveness of cargo management systems distinctly (more than 40% by 2035).[338] This projection suggests that by incorporating AI techniques like ML, DL and data analytics,[339] companies can significantly streamline and optimize their cargo operations, with greater efficiencies in many areas like route planning, inventory management, resource allocation and better navigation.[340] Leveraging AI in cargo management systems can help to identify trends, predict demand, and make real-time adjustments, and that may result in cost savings, faster delivery times, and improved overall performance in the logistics industry. Another statistic suggests that AI systems will have a significant impact on improving logistics and supply chain efficiencies within the shipbuilding industry by the year 2030.[341] The projected 80% boost in efficiencies indicates a substantial increase in productivity, cost-effectiveness, and operational effectiveness within the industry. AI technologies like ML algorithms, predictive analytics, and automation tools are likely to revolutionize[342] how logistics and supply chain processes are managed in shipbuilding, leading to streamlined operations, faster decision-making, reduced errors, and enhanced overall performance.[343] This statistic underscores the transformative potential of AI in optimizing processes and driving growth in the shipbuilding sector over the next decade.

**Case Study of Effective AI Power Maritime Industry Solution**

Today, AI power platform or set-up showcased and determined on maritime analytics, asset monitoring, process automation, marine surveillance, operational guidance, autonomous shipping and helping managing and strategic decision making. There are many AI driven maritime solutions invented and advanced solution for maritime analytics, asset monitoring, process automation, autonomous shipping and other business decisions. Those AI operated set-up or platform develop by innovated and advanced software, system architect, devices like dashboard or monitor and provide a complete matching set of tools for evaluating and managing maritime risks and help maritime related decision making process.[344] Those AI power maritime industry solution or platforms leveraging data-driven insights collected from various sources and predictive analytics, they are enables maritime stake-holders and companies to stay ahead of probable threats, optimize operational spirit, assess course of action, navigate oceanic challenges and helps to take strategic decision with confidence. A few examples of AI In maritime industry has given below. However, below mention case studies demonstrate the various and forceful ways AI, ML and other smart technologies are leveraged within the maritime and shipping industry to drive innovation, improve efficiency, promote sustainability, optimize operational activities, environmentally friendly approach and business benefits.[345] As these technologies continue to evolve, the potential for further advancements in the maritime sector remains useful, vast, promising and eye-casing a future where maritime sector and shipping business is safer, more efficient, environmentally pleasant and useful.[346]

**Scoot Science**, It is a revolutionary set-up invented by US researchers, which provided developed progressive solutions for ocean risk assessment by its innovative ocean risk analytics platform. It has designed to deal with the growing need for inclusive risk evaluation in maritime operations, mostly in response to growing oceanic conditions as well as environmental and ecological challenges. US researchers developed advanced software that leverages complicated algorithms to identify and analyze abnormal oceanic dealings. This platform is capable for and by continuously monitoring and processing data from various sources, like satellites, sensors, and oceanographic models, can detect irregularities and trends that may create risks to marine assets, activities and entire system.[347] Scoot Science's has a distinct standout features named SeaState, by which maritime companies, ships and even any stakeholders can visualize, imagine and appraise marine threats in real time, receiving valuable situational awareness of probable risks or accident or abnormalities. Its solution may go ahead of traditional risk assessment by contributing predictive analytics and situation modeling and many more maritime problems. It is useful for practical risk management and strategic decision-making process.

**Orca AI**. It is a ground-breaking AI-based collision avoidance customize platform to improved, specialized and developed the maritime industry of Israel. This platform harnesses the power of AI to enhance safety and mitigate the risk of collisions in maritime operations. This is a collision avoidance platform operates by leveraging data from various sources, like smart alarms or cameras, to create real-time alertness of nearby hazards. By continuously analyzing those data, the system can accurately detect possible collision



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risks and provide timely alerts to crew members and operators. This real-time awareness significantly reduces the chances of collisions as well as improving safety at sea effectively.[348] So, Orca AI's platform can efficiently monitor and manage entire fleets of vessels, allowing fleet managers to conduct complete risk assessments across their operations and ensures maritime organization to implement proactive measures, prevent accidents and progress operational safety. It also enables its user to reduce human error during maritime emergencies. So, it is a good example of AI adoption for noteworthy development in maritime safety technology.[349]

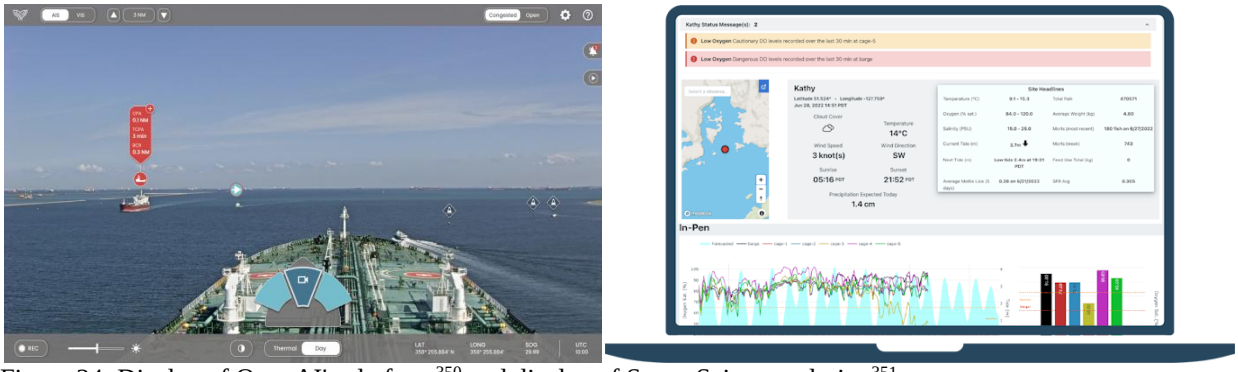

Figure 24: Display of Orca AI's platform[350] and display of Scoot-Science solution[351]

**Canscan.** It is an AI power set-up invented and developed by Canadian researchers and use as innovative solution for automating the inspection of shipping containers. It has revolutionized and provided wonderful solution to increase the competence and correctness of container management in the maritime industry and business. Its solution plays a vital role in optimizing costs by efficient and useful asset maintenance and management. Canscan use AI-driven software system flawlessly which incorporates with existing infrastructure cameras or alert system, enabling real-time monitoring, tracking, recognition and reporting of incident, accident, and issues on containers by leveraging advanced AI and ML technology. It has one unique feature to accurately identify containers that are non-compliant with safety standards. Its software contributes extensively to humanizing and improving overall employee safety within container inspection processes and simplifies compliance efforts by swiftly sensing any safety matters or abnormalities. Its software set-up incorporates complicated AI, ML and DL algorithms that enable predictive maintenance of shipping containers needs by analyzing historical data, information and patterns as well as allow shipping companies and stake-holders to deal with matters proactively and keep away from costly interruptions in operations by reducing downtime.[352] Canscan also software provides accurate insights into container conditions by automatic inspection process and enables companies to make AI and data-driven decisions regarding maintenance schedules, repairs, and replacements of containers. [353] So, it's an effective solution for employee safety, optimize asset maintenance, reduce costs and get better operational efficiency in container management and useful for maritime stake-holders.

**Captain AI**. Dutch researchers invented AI driven solution for shipping system and given the name as Captain AI. It revolutionized smart ship operations in high seas successfully. Captain AI is a cutting-edge set-up which utilizes AI-driven simulations to showcase and accustomed to changes in ocean conditions. It solves the way for safer and more efficient maritime operations.[354] The key strength of this set-up is its rigorous and continuous training of AI models within the system. This model helps to accomplish optimal performance by reducing fuel consumption and emissions. By leveraging AI algorithms, it can analyze vast amounts of data like ocean conditions, weather patterns; vessel activities to make real-time decisions which successfully minimize environmental impact operational costs along with optimize performance. Captain AI is using neural networks and enable the platform to accurately predict vessel behavior under various scenarios as well as enhancing situational awareness for ship operators. So, AI power platform provides shipping companies many valuable insights into potential risks and opportunities by integrating neural networks into its simulations. AI driven platform is also allowing shipping company to make informed decisions which helps to prioritize crew safety, operational efficiency and improve performance. The impact of Captain AI's technology is significant for the maritime industry. AI-driven simulations by enabling smart ship operations, such platform can helps shipping companies to lower their operational and energy costs by reducing emissions. AI power solution is also contributing to attain sustainable and environmentally friendly maritime industry. So, such AI-power simulations and neural network capabilities represent a game-changing advancement in autonomous or smart ship operations. Finally, by using Captain AI platform, we can optimize performance, enhance situational awareness, and prioritize asset of shipping companies sustainably to navigate high seas environments professionally and sensibly.



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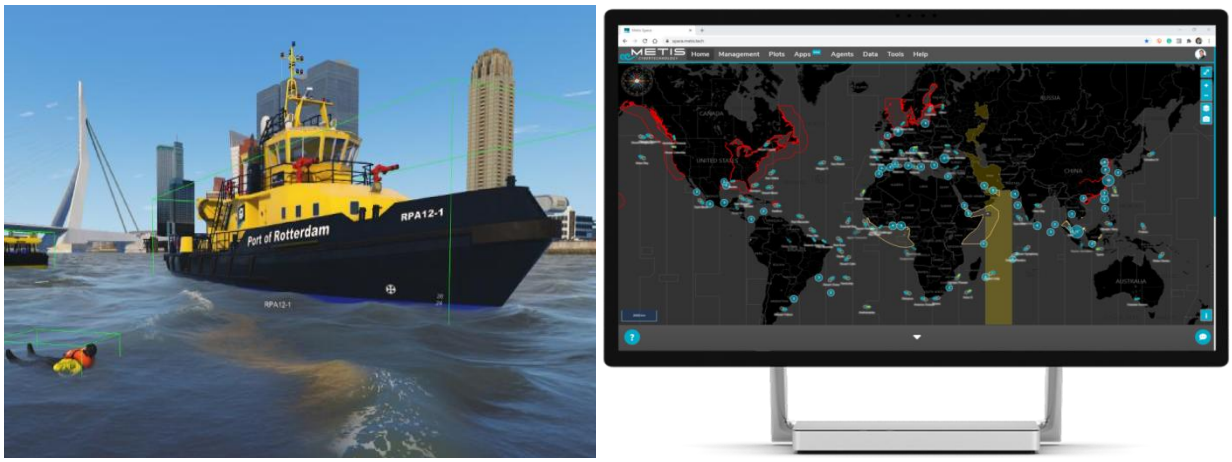

Figure 25: Captain-AI Nautis-simulator[355] and display of Metis Cyberspace solution[356]

**Metis Cyberspace Technology**. It's a Greek set-up, to develop an innovative solution by centering on integrated and historical data collection and analysis for shipping industry. Its software has designed to extract data from various ship systems, leveraging AI and ML algorithms to gain insights into critical aspects of vessel operations. This Ai-driven set-up can help shipping companies to track their environmental footprint and identify prospect to reduce emissions by analyzing data on carbon emissions across different operational scenarios. It allows maritime shipping companies and stakeholders to achieve sustainability and regulatory compliance by enabling them to make data-driven decisions to minimize their environmental impact. The important feature of such solution is its ability to analyze fuel consumption patterns, and which is prime requirement for shipping companies for reduce operational costs and decrease environmental impact by optimizing fuel efficiency and reduce GHG emissions. This set-up can identify trends, irregularities, and possible areas for optimization by gathering and analyzing data related to fuel usage.[357] This capability is crucial for shipping companies seeking to reduce operational costs and minimize environmental impact by optimizing fuel efficiency.[358] So, this solution helps shipping companies to keep up and operate their vessels in optimal conditions and help decision-making by maintaining smooth operations as well as reducing downtime.

**CMA CGM's AI-driven Shipping Route Planning.** Today, by optimizing delivery routes and logistics with AI is revolutionizing delivery routes and logistics as well as transforming an ancient shipping industry tradition. CMA CGM is a well-known leading global shipping group, and they have utilized AI to optimize the routing of their ships. This AI-driven system investigates, analyses, and estimates the most efficient ocean routes using historical data and real-time environmental variables. This AI setup collects and analyzes massive amounts of data, such as weather forecasts, current maritime traffic, port conditions, and so on, to identify the most fuel-efficient routes and achieve efficiency. This AI-powered solution also tracks and reports on each ship's individual characteristics, such as size, tonnage, speed capabilities, fuel usage, and other metrics.[359] The implementation of AI for route optimization by CMA CGM has led to significant fuel savings and reduced GHG emissions for the shipping company.[360] They reports such transformation has enhanced regularity and reliability of their services and achieving customer satisfaction. Few recent studies by some researchers anticipated that by 2030, the global market for route optimization software will be worth US$ 21.7 billion, and AI-powered solutions leading this industry. [361]So, it demonstrates AI's environmental benefits for shipping companies. It also showcases operational, economic, social and business benefits.

Figure 26: AI-driven shipping route planning[362] and AI-driven predictive maintenance[363]

**Maersk Line's AI-driven Maintenance Forecast.** Maersk Line is a globally recognized container logistics leader. They have built a sophisticated AI-powered predictive maintenance system across their fleet. This AI power model uses AI and ML



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algorithms and has a large number of onboard sensors that continuously monitor the health of ship's engines, major machinery, and their systems.[364] This predictive maintenance system gathers real-time data from several engine and key equipment sensors. However, these data include temperature, pressure, vibration levels, and so on, which are then investigated and analyzed using AI or ML algorithms to find and recognize patterns or irregularities suggesting possible breakdowns and provide the best solutions.[365] Maersk Line has found that by using this AI-driven solution, a significant reduction in unscheduled downtime has achieved and which leading to increased operational efficiency and reduced maintenance costs significantly. This AI-power system's is capable to predict failures before they occur and which allows for timely interventions, avoiding costly repairs and delays ships operations. [366] They estimate 20% reduction in maintenance costs and an improvement in machinery lifetime. So, such AI-driven platform is showcasing the substantial benefits of maritime operations successfully.[367]

Figure 27: Yara Birkeland's AI-driven smart container ship[368] and smart container port[369]

**Yara Birkeland's AI-driven Smart Container Ship.** The One Sea ecosystem intends to achieve commercial autonomous or smart maritime traffic by introducing AI-driven smart container ship within 2025.[370] Yara Birkeland is a smart zero-emission container vessel and that has co-developed by Kongsberg and Yara. The Yara Birkeland project marked a watershed moment in the growth of sustainable, autonomous, or smart maritime transportation.[371] Yara International and Kongsberg Technology have created a smart vessel that is designed to run totally without a crew and is powered entirely by electricity, eliminating emissions or achieving GHG free operation. A smart ship uses a mix of GPS, radar, cameras, sensors, and other equipment to sail between ports in a safe and effective manner without human interaction.[372] AI and ML algorithms assess input and previous data to make real-time navigation judgments, changing the vessel's direction to minimize collisions and maximize route operational efficiency.[373]The Yara Birkeland is planned to replace 40,000 truck rides per year, greatly lowering $NO_X$ and $CO_2$ emissions while enhancing road safety. The project emphasizes the potential of AI and smart technology to alter shipping with environmental, safety, and efficiency benefits; nevertheless, it is still in its early phases and a long way from full operational exploitation.

**Port of Rotterdam's AI-driven Smart Container Management.** The Rotterdam port has received recognition for its excellent physical infrastructure and automation. To maintain its strong competitive position in the region and maximize the impact of its actions, this port authority is continually developing its digital component and smart assets. [374] Smart vehicles to container management and predictive maintenance, AI and ML are driving efficiency and improving significantly productivity in many ports around the world. The Port of Rotterdam is considered as Europeans largest port. [375] They have innovated and implemented an AI-based set-up for optimizing cargo handling and stowage planning.[376] However, such initiative is a part of the ambitious and motivated digitization strategy of port to improve competence and throughput for port operation. This AI-driven platform uses data analytics to forecast the best loading and unloading sequences and plans for containers.[377] This system is considering the ship's arrival and departure schedules, container size, weights, and other information.[378]This AI-driven optimization plans reduces the time ships spend in port as well as improves the utilization of cranes, straddle-carrier and other port handling appliances. So, such AI-power smart container management system has significantly increased the port's operational efficiency, reduced ship turnaround times, and improved overall logistics management. The Port of Rotterdam has observed and reported a smoother flow of goods, reducing container congestion and improves environmental impact by reducing idling ship time at port.



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Figure 28: NYK Group's AI-driven green shipping[379] and smart ship[380]

**NYK Group's AI-driven Green Shipping.** NYK Group is a well-known global shipping and logistics corporation. They developed and implemented an AI-based application to improve fuel efficiency and ensure compliance with environmental standards, and this project reflects the company's dedication to sustainable shipping operations. This AI-powered system monitors and collects real-time data about the ship's operations, such as speed, fuel consumption, engine performance, and so on.[381] Then, AI and ML algorithms examine and analyze this data to recommend operational adjustments which can reduce fuel consumption and GHG emissions, by optimizing speed, changing the engine settings and other adjustments. Interestingly, they have found and reported noteworthy improvements in fuel efficiency and reduction in GHG emissions across their fleet.[382] Finally, they are contributing to environmental sustainability goals and are achieving efficiency.[383] So, this AI-driven system helps to achieve compliance with the IMO regulations on GHG and sulfur emissions along with improve operational performance and business benefits.

**AI Use Effectively to Develop Effective Surveillance Tools**

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 comes 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.[384] 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 solution[385] to enhance maritime surveillance capabilities. By analyzing large volumes of diverse data from various sources, AI 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.[386] 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.[387] 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.[388]



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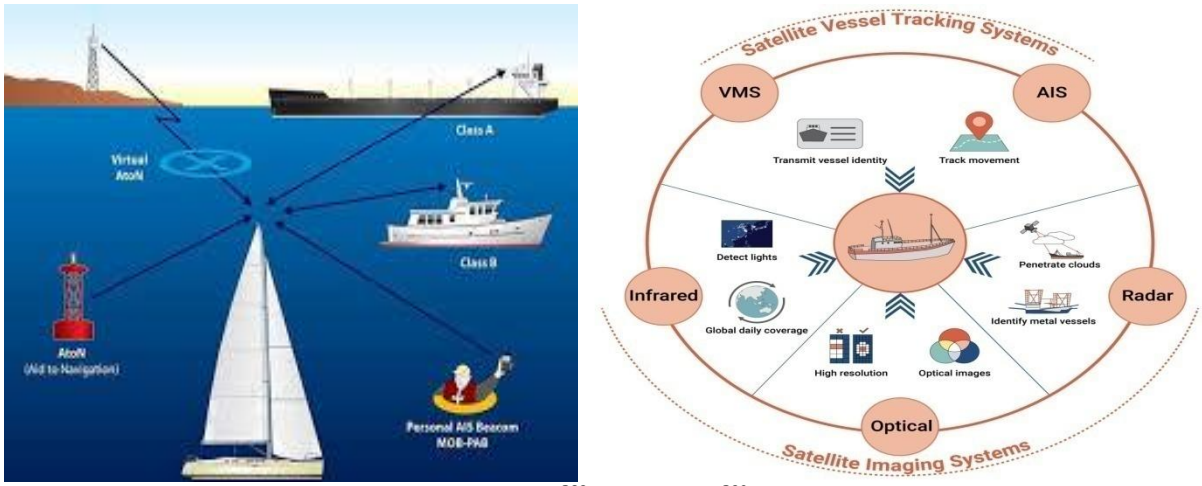


Figure 29: AI and other smart technology for NATO[389] and satellite[390] vessel tracking system

b. **Anomaly Detection**. The surveillance of large sea areas normally requires the analysis of large volumes of heterogeneous, multidimensional and dynamic sensor data, to improve vessel traffic safety, maritime security and to protect the environment.[391] AI algorithms can analyze patterns in maritime data to identify anomalies that may indicate security threats,[392] 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.[393]

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.[394] On the other hand, Nowadays, the shipbuilding industry has become more technologically advanced, and competition in this field has prompted the adoption of automatic control systems on ships, in which various data is collected, analyzed, and processed to create more efficient ships, optimized workflow, and environmentally friendly engines and vessels.[395] Again, with the growing interconnection of marine logistics, information exchange across diverse stakeholders is important to ensure efficient supply chain processes and management.[396]

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.[397] 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, from shipping to offshore installations, pose a risk to the environment and have the potential to cause accidents.[398] ML, specifically automated machine learning or Auto-ML, provides a variety of options for analyzing vast amounts of historical marine accident data using advanced algorithms to integrate predictive analytics into operational and policy decision-making to improve maritime safety.[399] 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.[400] This holistic approach enables authorities to prioritize resources and develop strategic plans to mitigate potential threats effectively.

f. **Response Optimization**. Today, Big data is an enormous amount of data that is difficult to collect, store, analyze, and process using legacy application software. Big data technology is showing efficiency by processing big data into a form that users can understand and utilize.[401] 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 decision support systems can provide real-time situational awareness 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.[402] Now, AI is being applied in almost every field of different sciences and engineering matters. The involvement of AI not only automates a meticulous task but also improves efficiency by many folds.[403] AI-



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driven cybersecurity solutions can detect anomalous network behavior, prevent cyber-attacks, and safeguard critical maritime assets.[404]

Figure 30: Cyber threat and Cybersecurity in maritime sector[405, 406]

h. **Geospatial AI Solutions**. AI is radically transforming the way IT solutions are designed and operated in all application areas, including geospatial. This paper discusses AI-based solutions for 3D point clouds and geospatial digital twins as generic components of geospatial intelligence.[407] Now, AI technology can be used to simplify and accelerate workflows for geo-data processing and geo-information systems.[408] 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.

**Example of Benefits of AI in Maritime Security**

Maritime Security is a wide and vital as well as unformulated concept. However, it has become a large task linking many entities from global, local, public and private sectors.[409] 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.[410] 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. AI driven surveillance systems provide real-time insights and alerts, enabling maritime authorities to make informed decisions and respond promptly to security incidents.[411] 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**. For the past two centuries, the United States (US) Coast Guard has protected their country's maritime interests in the heartland, ports, at sea, and around the world, as well as serving global maritime interests. They are attempting to defend the marine economy and the ecosystem of the ocean. They also guard their marine borders and rescue anyone in danger.[412] 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.[413]

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.[414] EU Utilizes AI for environmental monitoring, vessel tracking, and search and rescue operations.[415] 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 sectors.[416] Such as: 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.[417]



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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.[418] 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.[419]

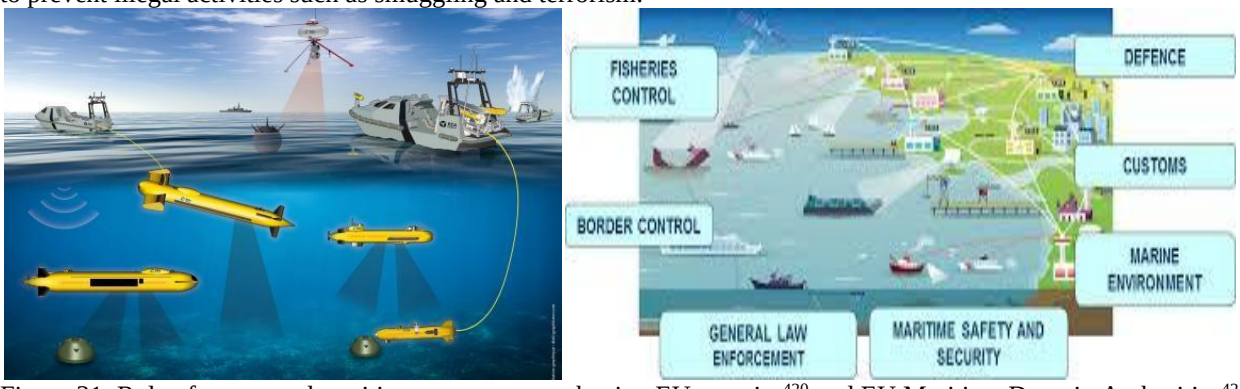


Figure 31: Role of unmanned maritime system strengthening EU security[420] and EU Maritime Domain Authorities[421]

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.[422] AI algorithms analyze data in real-time to identify suspicious behavior, such as unauthorized incursions into restricted areas or deviations from regular shipping routes.[423] These insights enable authorities to respond quickly to security incidents and maintain the safety and security of the strait.

e. **European Maritime Safety Agency (EMSA)**. The EMSA is a European Union agency assigned with reducing the risk of maritime accidents, marine pollution from ships and loss of human lives at sea by serving to enforce the pertinent EU legislation.[424] 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.[425] AI algorithms analyze data from these sensors to detect anomalies, identify potential risks, and provide decision support to maritime authorities.[426] EMSA's AI-based systems help improve situational awareness, enhance response capabilities, and ensure the safety and security of European maritime regions.

**f. MARSUR: Enhancing Maritime Surveillance Cooperation**. The European Defence Agency (EDA) and the European Union Satellite Centre (SatCen) have launched a new phase of collaboration under the Maritime Surveillance Information Exchange System (MARSUR). MARSUR, has debuted in 2005, and has grown into a multifaceted information exchange network for 22 European navies. Under MARSUR III, 16 EU fleets are developing capabilities for the automatic exchange of maritime surveillance data and decision-making assistance. 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.

**g. European Union Maritime Security Strategy (EUMSS).** EU Maritime Security Strategy or EUMSS is a maritime security strategy of the European Union.[427] It was widely accepted by EU member states in June 2014. The EUMSS establishes a framework for the EU's maritime security initiatives, encouraging larger and more rational approaches to identified genuine maritime security concerns.[428] Maritime security strategies have been adopted by a many countries such as France, India, United Kingdom, United States of America and many more.[429] Now, the EU has revised its strategy for maritime security. A key focus is increasing the resilience and protection of critical maritime infrastructure, including gas pipelines, undersea cables, ports, offshore energy facilities, and LNG terminals. Cooperation on developing a regional surveillance plan for underwater and offshore infrastructure is essential. In March 2023, the European Commission and the high representative of the union for foreign affairs and security policy adopted a joint communication on "an enhanced EU Maritime Security Strategy for evolving maritime threats" and it hope that, maritime sector will be benefitted further.[430]

**h. Maritime Safety & Security Information System (MSSIS).** It is an open, unclassified network for collecting and distributing data and maritime information in near-real time. Its member countries contribute, share, and distribute data from the Automatic Identification System (AIS), coastal radar, and other maritime systems.[431] It aggregates information from participating countries into a single data stream using secure internet-based servers. MSSIS allows share and participating governments to examine real-time AIS information around the world in a variety of geographic presentation options, such as text, photo overlays, electronic maps, and even Google Earth.[432] So, those displays can incorporate additional features such as user-provided radar overlays. MSSIS, on the other



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hand, has developed by the Volpe National Transportation Systems Center at the US Department of Transportation's Research and Innovative Technology Administration and is now available to governments and organizations worldwide to promote global maritime safety, security, trade, and environmental stewardship.[433]Today, global sharing of AIS information among countries through a standard and open exchange serves as a solid foundation for increased global trust, cooperation, and open dialogue.[434] As a result, it enhanced stability, security, commerce, and environmental stewardship.

**i. Satellite Imagery and Remote Sensing**. Remote sensing is a method of acquiring information about the earth's surface without coming into contact with it. The remote sensing procedure involves a light or energy source that travels through the atmosphere and interacts with the target.[435] Again, the satellite sensors gather the electromagnetic energy generated by the target and communicate it in electronic form to a receiving and processing station, resulting in an image.[436] The processed image is interpreted electronically or digitally to extract the information about the illuminated target. By this why, satellite imagery and remote sensing have revolutionized maritime surveillance system.[437] These technologies provide unparalleled insights into our vast oceans. By harnessing their power, we can enhance maritime domain awareness, protect marine ecosystems, and ensure safety and security at sea.

**j. NATO's Maritime Surveillance Enhancement Initiative**. The Digital Ocean initiative, initiated in 2023, aims to improve NATO's maritime situational awareness from seabed to space. It seeks to improve coordination between national and Allied maritime surveillance capabilities.[438] This includes satellites and autonomous systems that operate below on, and above the sea. They focused on how to increase NATO's ability to see, sense and act to better protect sea lines of communication, which are vital for the security of the Euro-Atlantic area.[439] NATO has begun an initiative to enhance maritime domain awareness. 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.[440]

**k. AI and Smart Conservation.** Climate change poses an increasingly serious threat to global biodiversity. Animal populations in the fast-changing Arctic are sometimes viewed as a litmus test for wildlife's response to climate change, particularly those whose lives are closely linked to sea ice, such as polar bears, walruses, and certain caribou populations. As Arctic species traverse their increasingly uncertain and rapidly dwindling sea ice habitat, they are also under pressure from shipping, fishing, mining, and tourism sectors driven to the open ocean. Conservation practitioners must create adaptive management plans that are effective in these quickly changing contexts.[441] In recent years, breakthroughs in AI-based sea ice forecasting have allowed for more accurate predictions of sea ice conditions. IceNet, an in-development operational AI model, predicts daily pan-Arctic sea ice concentration (SIC) up to three months in advance at a 25 km2 grid-cell resolution.[442] IceNet forecast maps have the potential to inform dynamic conservation and management plans, by providing early-warning of ice-dependent species seasonal movement patterns.[443] By linking satellite observations of sea ice concentration (SIC) with GPS movement records, the team were 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. Following the success of the caribou migration case study, the team is working with stakeholders to explore applications for other Arctic species.

**l. AI based Maritime Security Solution in India**. AI algorithms can forecast possible marine incidents by examining historical data, weather patterns, and vessel movements. The ability to anticipate future events enables the Coast Guard to strategically allocate 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-based solutions to enhance maritime security. Their initiative in this regard is remarkable. The Indian Coast Guard has been deploying AI and ML algorithms to bolster its surveillance capabilities along the country's vast coastline and Exclusive Economic Zone (EEZ). 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, and illegal fishing. India's state-run defence technology behemoth Bharat Electronics Limited (BEL) newly did a deal to strengthen the Indian Navy's maritime domain awareness. The electronic tool dubbed "TRIDENT" is made by the private-sector firm Blurgs Innovations Private Limited, use AI technology in the field of security in ocean successfully. This partnership is a key step forward in India's plans to secure its vast coastline with the help of AI to face newer challenges in the Indian Ocean Region (IOR).[444] AI algorithms enable the Coast Guard to sift through large volumes of maritime data, identify patterns, and generate actionable insights to support decision-making and response operations. India has implemented the National Automatic Identification System (NAIS) to enhance maritime domain awareness (MDA) and security.[445] 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.[446]

Project Seabird, located in Karwar, Karnataka, is a strategic naval base under development by the Indian Navy. The project aims to enhance India's naval capabilities and infrastructure along the western coast. AI technologies are being integrated into the surveillance



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and security systems of Project Seabird to ensure comprehensive protection of naval assets and infrastructure. This includes AI-driven surveillance cameras, intelligent sensors, and predictive analytics tools to detect and deter security threats in real-time.[447] 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.[448] 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 smart port initiatives leverage AI to automate security processes, minimize human error, and respond swiftly to security incidents, thereby ensuring the uninterrupted flow of maritime trade. 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.[449] As AI continues to evolve, further integration and optimization of these technologies are expected to enhance India's maritime security posture and contribute to regional stability.


Figure 32: AI has both opportunity and challenge in maritime industry[450, 451]

**AI Future Prospect and Challenges**

The marine industry is increasingly interested in applying advanced AI and ML technologies to solve sustainability, efficiency, and regulatory compliance issues. The maritime industry has come a long way since the days of oars and sail. History says, old-age clipper ships' sleek hulls have replaced caravels and galleons; then windjammers, with their labour-saving brace-winches and smaller crews, have replaced clippers. Steam has replaced sail, propellers have replaced paddle wheels, and diesel has replaced coal. Cranes have replaced union purchase, and containers have replaced boxes, bags, barrels and loose cargos. 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 21st century. 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 is among the most dangerous work environments on the planet. Seafarers and other maritime workers face high-risk tasks, from oil-spill cleanup and search-and-rescue (SAR) operations to firefighting and tank inspections. AI-driven robotics and ML, DL, etc can take over high-risk tasks, from tank entry to underwater hull inspection to deep ocean activities. In 21st century, 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. Even now, AI drones are being used for hold, hull and tank inspections, saving time safety and money. After many container fires led to several deaths, a National Cargo Bureau survey found 55% of containers failed inspection with one or more deficiencies, including mis-declared or improperly stowed cargo.[452] AI can help to identify these containers before loading, and hence improving safety. In future, entire 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.[453] By accepting AI and other smart technologies, maritime organizations like shipping, shipbuilding, port, coast guard, navy, solution provider can improve operational efficiency, reduce costs, optimize benefits and enhance safety as well as minimize their environmental impact and become 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 becoming a fastener in healthcare, from medical chatbots to cancer diagnosis or education or industrial field in 21st century. But despite these, it's still unused in maritime medical care. But with the financial and regulatory pressure, it will just become a matter of time before telemedicine supported by AI will also come to use at Deep Ocean. The captain of the ship is considered the master under God by custom and law, with the legal responsibility to comply with the ever-growing body of laws, rules, conventions, regulations,



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and recommendations. However, they're not lawyers. Again, lawyers ashore are already using AI. Simple chatbots can assist public with their legal decisions. Even if maritime is still lagging 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. Commercial pressure, miscalculated stability, and inappropriately declared weights can all result in dangerous marine accidents at any time at high sea. Modern AI 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.

AI, ML or big data are crucial components of data-driven decision-making in most industries.[454] The maritime industry is one of the oldest and traditional industries to still rely more on intuition than on data, due to the vast size of network and planning problems.[455] Now, AI is capable of doing things that were impossible a decade ago. Despite its potential benefits, the adoption of AI in maritime surveillance also presents various challenges and limitations. AI algorithms rely on high-quality, labeled data for training and validation, which may be limited or incomplete in maritime environments. 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.[456] AI power system is need ethical and legal considerations. AI-driven surveillance raises concerns about privacy, data protection, and the potential misuse of surveillance, monitoring and execution capabilities for authoritarian purposes.[457] AI should complement human decision-making rather than replace it. So, it requires collaboration between AI systems and human operators to ensure effective integration and user acceptance otherwise some unwanted disaster may happen in future.

The future of AI in maritime surveillance holds several promising directions. Advancements in AI algorithms, including DL, reinforcement learning, and explainable AI, will address complex maritime surveillance challenges in future. Integration of AI with other emerging technologies, like UAVs, satellite imaging, and distributed sensor networks, to create comprehensive and interoperable surveillance platforms. International collaboration and information sharing to address transnational maritime threats, like illegal trafficking, terrorism, and environmental crimes. Again, ethical and regulatory frameworks will govern the responsible development and deployment of AI-driven surveillance systems, by ensuring transparency, accountability, and human rights. However, future smart technology development need balanced with a more robust research emphasis on social, financial, legal and environmental matters in 21st century.[458] There should be more attention on socio-cultural and commercial research perspectives which will identifying and addressing the drivers and barriers on increasing transparency and trust in the maritime sector, including few legal issues like cybersecurity and data ownership within own network by remain connected with global network or online. As digitalization is a key supporting technology for AI, data silos are a key barrier of it. Data silos result from the lack of interoperability between systems. The differing formats of data make it difficult to work together or use the data without first spending resources converting it to a compatible format. Solving data silos will take a complete rethink of the culture of competition.[459] In the short term, maritime organizations can try to break down the silos within their organization. Looking to the future, alliances like the Open Industry 4.0 Alliance aim to ensure operators and OEMs collaborate, to establish a common platform and semantics, and to ensure interoperability with no vendor enclose.[460]

At present world of advanced technology, AI is important to research to harvest its potential and advantage, whereas avoiding possible drawback. In 21st century, 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.[461] 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. [462] Great scientist Stephen Hawking,[463] Microsoft founder Bill Gates,[464] and SpaceX founder Elon Musk[465] 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.[466] In 2014 Stephen Hawking expressed that, 'Success in creating AI would be the biggest event in human history. Unfortunately, it might also be the last, unless we learn how to avoid the risks.' [467] Again, Hawking believed and explained that in the coming decades, AI could offer 'incalculable benefits and risks like technology outsmarting financial markets, out-inventing human researchers, out-manipulating human leaders, and developing weapons we cannot even understand.'[468] Again, the law is another key barrier to widespread AI. There's no relationship between AI and maritime law. Yet, the law needs to regulate AI. The Comite Maritime International (CMI)[469] and the IMO, along with many governments, are working on regulatory scoping for autonomous or unmanned vessels.[470] But there's more to maritime AI than autonomous vessels, and in an international industry the legal grey areas can curtail its use. As a result, the absence of international agreements makes companies truly wary of relying on AI.

Nick Bostrom defines superintelligence as 'any intellect that greatly exceeds the cognitive performance of humans in virtually all domains of interest.'[471] Existential risk from artificial general intelligence (AGI) is the idea that substantial progress in AGI could result in human extinction or an irreversible global catastrophe.[472] If AI were to exceed humanity in general intelligence and become superintelligent, then it could become difficult or impossible to control. Just as the fate of the mountain gorilla depends on human goodwill, so might the fate of humanity depend on the actions of future machine superintelligence.[473,474] In 2015, Baidu Vice



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President Andrew Ng once said that 'AI existential risk is like worrying about overpopulation on Mars when we have not even set foot on the planet yet.'[475] So, stories of AI takeovers remain popular throughout science fiction, but recent advancements have made the threat more real. possible scenarios include replacement of the entire human workforce due to automation, takeover by a superintelligent AI (ASI), and the notion of a robot uprising.[476] Many scholars concerned about the AGI existential risk believe that the best approach is to conduct substantial research into solving the difficult 'control problem': what types of safeguards, algorithms, or architectures can programmers implement to maximize the probability that their recursively as 'improving AI would continue to behave in a friendly manner after it reaches superintelligence.'[477] 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.[478,479] Again, in October 2023, US President Joe Biden has issued an executive order on the 'Safe, Secure, and Trustworthy Development and Use of AI.'[480] Most of the related scholars and technologists surveyed and believed that, we will be capable to develop AGI by 2060. When we get there, AI will be capable of independently learning to carry out new tasks that aren't related to what it already knows how to do.[481] However, if human-machine interfaces or other human-augmentation technologies like nanotech end up being a bottleneck, it might not be possible to have a singularity until the end of the century. The singularity would occur in the far future once we have the ability to deconstruct the human brain, scan every neuron, and then recreate it and run it on a computer. Few expertise explains that the brain emulation scenario wouldn't happen until the 22nd century.

In general, regulations and procedures have come a long way in improving safety. They will never solve every problem. However, maritime industry problem like, tracking passengers in emergencies, identifying illegal fishing, pirates, vessels in distress, stopping fires as soon as they start, recognizing stressed or fatigued staff and many more such simple but critical difficulty and crisis can be solved by AI tracking and surveillance tools effectively and successfully. Here, AI is really a smart solution.[482] The maritime industries come a long way, but we could go so much 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.[483] 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 can expect to see AI become as familiar as smart phones. Mainly at sea and harbor, the major obstacle and challenge to adopt AI are not technical or legal; main barrier is human and our attitude. So, unless we address the maritime industry's resistance to change, those traditions will become an anchor holding us back. So, let's change our attitude and accept AI and other smart technology spontaneously in maritime sector.

**Conclusion**

AI, ML, DL, ANN, DM, DS and other smart technology can transform data, image and patterns into algorithms to automate functions and suggest more effective strategies, decision-making ideas and techniques based on past, present and forecasted conditions. In the event of an oil spill, plastic dumping and other pollution incident AI-powered robotic systems, ML, DL, DM or other smart technology can be deployed to clean up the spill, reduce the environmental impact and protect marine life and resources effectively. AI and other smart technology can also assist to design more resilient coastal infrastructure, vessels tracking system, optimum route planning, better navigation system, minimizing the damage caused by natural disasters and managing different maritime issues, etc. 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 ocean 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. 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 companies efficiently. In 21st century, we live in such a fertile and confuse globe, 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 needs to be conduct among scientists, researchers, engineers, programmers, companies, businessman, stakeholders, sea fearers and the members of shipping and maritime community who are affected by the technological developments and introduction of smart technology. We need to create education and skill development programs and smart infrastructure mainly for underdeveloped countries for sea fearer and maritime community as they will remain as competitive in shipping and maritime business world with new standards in 21st century.

In 21st century, there is a greater risk of cyber threats due to digitalization and inclusion of smart technology in shipping 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 ships and companies' external communications, or even confusion with the navigation, tracking and surveillance systems, and such incident potentially causing harm to the crew, ship, as well as the company. There are few common cyber threats that can be posed to ship, system, shipping company or maritime industry. Such as: hackers can change ships data, may send false weather information to



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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), many more misinformation, false data, etc. There are few more common challenges may arise due to huge automation or introduction of smart technology. As a result, crews, sea-fearers, semi-skilled workers, port service providers and traditional maritime workforces, 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. However, 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 address these concerns through open dialogue, essential training and logical motivation.

All parties involved in initiatives involving numerous service providers and supply chains must be willing to offer data and interfaces. Even though these cooperative projects frequently have the highest potential for optimization for all parties involved, persuading outside parties to provide their data can be challenging. It's not hard to see that AI is already having a positive impact on ships and shipping operations, and that it can provide a variety of benefits to the maritime industry. AI systems make tasks and processes more convenient for humans, and this will be priceless as the world continues to develop new, effective and smart technology. If we can successfully navigate the challenges involved with integrating AI into ship, shipping, shipbuilding, port and other maritime sector in 21st century, and then it is sure to be a successful attempt for all maritime industry to adopt to reduce costs, improve efficiency and achieve targets set by the IMO. There are lots of innovations that have been implemented already, and with exciting prospects like autonomous ships and shipping on the prospect, we can expect that AI, and other smart technology will continue to make waves in the maritime industry. On the other hand, concept of creating AGI and destroy of human civilization may not be happen. Again, singularity will never happen. However, machines will get more and more intelligent but, in the direction, orthogonal to that of humans. So, human will remain, and we are irreplaceable forever as Almighty desired. With the progresses of smart technology, AI approaches will be progressively applied to maritime research and development, complementing traditional marine and maritime forecasting models and observation techniques to further elaboration and enhancement.

In 21st century, integrating AI into the shipping industry marks a central shift and transform towards more efficient, safe, sustainable operations and business benefits. From the case studies and analysis shown in this paper, it has been proved that miscellaneous applications of AI, ML, DL, ML and other smart technology can ensure and achieve effective and optimize predictive maintenance, route mapping, better navigation, smart shipping, cargo handling, effective port equipment uses, operational efficiency, environmental conformity and safer 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 along by addressing climate change issues, 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, businesspeople, government and whole community and society around the globe. However, respectable maritime technology manufacturers and their projections regarding the future of the shipping need to be analyzed and potential threats of such developments should be determined and solved. 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 issues as we don't know but which may rise in future. Conservationists are harnessing the power of AI to observe ocean dynamics and restore it. Obviously, AI and other smart technology are helping and will continue to assist us to save and preserve ocean and it's contained. We need to train our workforce and future generation with the knowledge and skill of AI and other smart technology in 21st century to prepare them to utilize and deploy its power to flourish the maritime industry by preserving our earth.

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