International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

Significances of Smart Port, Smart Ship, and Smart Shipbuilding

Dr Hossain K A

Vice Chancellor, Bangladesh Maritime University, Dhaka, Bangladesh

***Abstract*--Ports are regarded as essential capital infrastructure, closely connected with a broad spectrum of economic activities and which manage maritime trade with ships and goods. Ports are vital economic hubs that drive global trade, local employment, and supply chain efficiency, yet they remain underrepresented in current academic literature. Future research should prioritize this critical infrastructure to better understand its multiplier effects on regional and national economies. Port handle more than 80% of global merchandise trade by volume. These ports play a critical role in regional economies and may face unique challenges and opportunities in adopting smart port solutions. Exploring the economic and environmental impacts of digitalization and smart port technology along with smart ship and shipbuilding practice, in these contexts will shed light on how localized socio-economic dynamics influence the success and sustainability of smart port, shipping and shipbuilding initiatives. This analytical study on smart ports, smart ship and smart shipbuilding will provide relevant insights for public policymakers, private companies, and port authorities interested in investing in digital port transformation. By considering the diverse realities and needs of different ports, shipping and their stakeholders, future studies can help build inclusive, adaptive, and sustainable pathways toward port digitalization and smart technology inclusion in ship and shipbuilding that align with global development goals and local priorities.**

***Keywords*-- Smart port, smart ship, smart shipbuilding, digitization, COTS, AI, ML, IoTs**

I. Introduction

The maritime sector plays a central role in international trade, accounting for more than 90% of global goods transport, yet it faces increasing environmental challenges. In this context, the development of smart ports, smart shipping, smart ship and smart shipbuilding has emerged as a strategic solution to enhance operational efficiency and promote sustainability (Li et al, 2025). In 21st century, due to inclusion of digitization and advance technology, smart ports are increasingly transitioning into automated fa cilities, leveraging advanced digital technologies to boost o perational efficiency, transparency, sustainability, and over all competitiveness.

These smart and automated ports integrate tools such as sensors, big data analytics, artificial intelligence (AI), mach ine learning (ML), deep learning (DL), augmented reality (AR), digital twins, and various automation systems to restr ucture cargo movement, minimize environmental impact, a nd offer improved services to relevant stakeholders including shipping companies, service providers, customs agencies, local communities, different service takers and other relevant parties (Hossain, 2024a). Furthermore, smart ports often incorporate ecofriendly feat ures such as renewable energy sources, electric vehicle char ging stations, onshore power supply, and smart logistics inf rastructure. These innovations significantly boost the functi onality and responsiveness of port operations, thereby playi ng a critical role in strengthening national competitiveness (Hossain, 2025a).

To confrontation the condition of cost competitiveness and transportation weakening due to major logistics competition, shipping agenesis or companies are reducing crew members or workforces. Furthermore, the publicity about efficiency improvement and carbon reduction in maritime industry has increased the attention to artificial intelligence (AI). Therefore, the demand for automation in navigation along with monitoring and control technology is highly upsurging to operate the ship and shipping smartly, safely, and economically. Additionally, the progress in intelligence information technology, as well known the 4th industrial revolution (4IR), is promoting the visualization of autonomous ships as well as shipbuilding. Countries such as the EU, US, China, Korea, Japan, etc. with the increased availability of these technologies are shaping the development of eco-friendly autonomous and smart ships in virtue of the private-public collaboration. Smart Ships, taking into account the applications of worldwide economic concepts and addressing the maritime sector regulations, aims to supply multi-layer optimization in fuel consumption, minimization of CO_2 and carbon emissions, and energy efficiency when full-fledged implementation is completed (Hossain, 2025c, d). As we know that, COTS technologies or Commercial Off-The-Shelf items that we buy ready-made, like standard software, computer hardware, and network tools.

Actually, they save time and money because we do not need to build them from scrape. Finally, this 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 (Marine, 2026).

In 21st century, ports are becoming increasingly intelligent, integrating smart technologies to improve shipping, customer service, and operations while maximising efficiency and profitability. Instead of hunting broad automation, the immediate priority for emerging shipbuilding nations should be Industrial IoT (IIoT) for Process Visibility. However, IIoT for process visibility over broad automation is a strategic and practical approach for emerging shipbuilding nations including India, Vietnam, or Bangladesh even, enabling them to focus on asset tracking, bottleneck identification, and workflow transparency. This semi-digital model manages capital exposure while delivering rapid efficiency gains before scaling up to complex robotics. Again, deploying low-cost wireless sensors to monitor critical welding parameters (current, voltage) in real time can meaningfully reduce defects and rework, addressing the quality consistency issues often encountered in manual welding. Furthermore, Computer vision technology can be applied to rigorously monitor worker safety compliance, such as PPE usage, a vital step in meeting international safety standards like the Hong Kong Convention (or HKC 2009). Again, automation streamlines management and operations, reducing environmental influence while confirming safety (Hossain, 2024b, d). Technologies such as AI, ML, Digital-twin, can optimise logistics by processing data from multiple sources, including shipping timing and agendas or cargo information. Innovative technologies also automate multiple tasks, suggestively decreasing manual labour requirements and boosting overall efficiency (Hossain, 2025b). Furthermore, these technologies ease and improved design and construction processes, identify anomalies, and forecast possible incidents, thereby enhancing safety, security, and compliance with international standards (Hossain, 2025a; Hossain, 2023b). By optimising operations and production costs, innovative technologies reduce resource consumption, minimise downtime, ensure safety, improve quality, and ultimately lower costs. Additionally, they contribute to sustainable shipbuilding by optimising energy use, waste management, and environmental monitoring.

Today, insufficient focus on the economic outcomes of port automation and digital tracking. Again, limited studies balancing economic gains with green shipping, ship, infrastructures and local carbon footprints. Despite growing research on green ports, ships,shipbuilding ,existing studies remain fragmented, with limited integratio n between technological, environmental, and governance pe rspectives within the blue economy framework (Noah, 2025). In 21st century, smart ship technology will increase the volume of data to optimize shipping operations and meet processing requirements. IMO's GNG strategy aims to reduce the shipping industry's total carbon emissions by 40% by 2030 (Hossain, 2018d; Marine, 2026). As a result in 21st smart port, ship, shipping and shipbuilding become a global phenomenon where digitization, IoTs, AI, ML, Digital twin, etc are playing a vital role. For improved efficiency, accountability, sustainability, competitiveness, customer satisfaction, and effective monitoring, the entire maritime sector, including port, ship and shipbuilding, must adopt smart, safe, and cost-effective practices. Smart port and shipyards employ digital solutions, including sensors, data analytics, augmented reality, big data, digital twins, blockchain, and automation, to shorten production timelines while ensuring quality, reducing waste and emissions, and providing better service to customers, local communities, and stakeholders (Hossain, 2025a). The economic gains are primarily derived from supply chain dynamics, timely delivery, and adherence to quality standards, rather than solely from internal activities. Thus, ensuring quality assurance, adhering to safety standards, meeting delivery deadlines, providing after-sales service, and maintaining goodwill are crucial to national competitiveness and the sustainable advancement of the shipbuilding industry (Hossain, 2025b). This is an analytical study to describe the significance of inclusion of digital and smart technology in port, ship and shipbuilding in the era of advance technology.

II. Literature Review

Maritime transport moves maximum global goods and is essential for trade, jobs, and economic growth. As climate change threatens ports and supply chains, countries need cleaner ships, resilient infrastructure, and smarter digital systems (Balcombe et al., 2019; Yang and Liu, 2022). The maritime sector is the backbone of global trade, commerce, driving economic growth, supply chains, and job creation. This dominance of maritime transport in the global flow of goods highlights its strategic importance for both economic growth and market integration. However, maritime transport is also associated with significant environmental pressures.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

It is estimated that the international shipping industry currently accounts for up to 5% of global carbon emissions, with some projections suggesting this share could rise to 25% by 2050. In this context, port digitalization and "smart port" initiatives have been increasingly proposed as potential pathways to improve logistics performance and support environmental objectives (Hossain, 2025e, f). However, the extent to which these initiatives deliver measurable economic and environmental gains—and under what conditions—remains uncertain. As hubs connecting maritime, land-based, and industrial activities, digital ports have significant potential to lead initiatives that balance economic development with environmental responsibility, particularly amid growing demands for cleaner, more efficient, and digitized operations (Molavi et al., 2020). At the same time, ports differ widely in governance, scale, hinterland connectivity, cargo mix, energy systems, and labor arrangements, which may lead to context-dependent outcomes from similar technologies. Several entities have already adopted port digitalization strategies. Examples include the Port of Rotterdam, Port of Hamburg, Port of Singapore, and Port of Shanghai, which have implemented smart port models through digital technologies (Niu et al., 2024).

The digital port is often described as a modern infrastructure model aimed at improving operational efficiency, sustainability, and safety. It is characterized by being a connected and automated system designed to meet the needs of various stakeholders. These ports implement smart and strategic management practices, rely on a highly skilled and creative workforce, and incorporate innovative solutions in infrastructure and technology to address the sector's challenges (Belmoukari et al., 2023; Molavi et al., 2020). The progression toward developing a smart port typically unfolds through successive stages of technological advancement. The first stage involves the adoption of digital systems aimed at reducing reliance on paper-based documents and minimizing manual processing. The second stage, referred to as the Automatic Port, features a semi-automated environment that implements electronic documentation and information systems to streamline operations. The third stage marks the transition to a Digital Port, characterized by higher levels of automation, interoperability through information sharing, and the provision of real-time services. Finally, the fourth stage is the Smart Port, in which full automation is achieved through the integration of emerging technologies, advanced automation solutions, and comprehensive digital transformation (Makkawan and Muangpan, 2021).

In the port context, Smartization describes the peak phase of port digital transformation, integrating IoT, AI, ML, and digital twins to optimize operations, boost sustainability, and connect supply chains. However, the term *smartization* is used in the literature to define an advanced stage in the digital transformation of modern ports. The concept refers to the evolution of traditional ports into more integrated, automated, and data-driven operational systems, supported by the coordinated adoption of digital technologies. Smartization involves the integration of sensors, communication infrastructures, data platforms, and analytical tools that enable the collection, processing, and sharing of information in real time, thereby supporting port operations management and decision-making (Hossain, 2025e, f). Among the objectives most frequently associated with this process are terminal automation, optimization of logistics chains, continuous monitoring of operations, and the strengthening of efficiency and resilience in port systems (Belmoukari et al., 2023; Molavi et al., 2020).

The progression toward developing a smart port typically unfolds through successive stages of technological advancement. The first stage involves the adoption of digital systems aimed at reducing reliance on paper-based documents and minimizing manual processing. The second stage, referred to as the Automatic Port, features a semi-automated environment that implements electronic documentation and information systems to streamline operations. The third stage marks the transition to a Digital Port, characterized by higher levels of automation, interoperability through information sharing, and the provision of real-time services. Finally, the fourth stage is the Smart Port, in which full automation is achieved through the integration of emerging technologies, advanced automation solutions, and comprehensive digital transformation (Makkawan and Muangpan, 2021). In this context, the term *Smartization* is used in the literature to describe an advanced stage in the digitalization or digital transformation of ports. The concept refers to the evolution of traditional ports into more integrated, automated, and data-driven operational systems, supported by the coordinated adoption of digital technologies. Smartization involves the integration of sensors, communication infrastructures, data platforms, and analytical tools that enable the collection, processing, and sharing of information in real time, thereby supporting port operations management and decision-making. Among the objectives most frequently associated with this process are terminal automation, optimization of logistics chains, continuous monitoring of operations, and the strengthening of efficiency and resilience in port systems (Belmoukari et al., 2023; Molavi et al., 2020).

Shipbuilding is a capital-intensive, global in nature, diversified, forward and backwards linkage-oriented, and technology-centred heavy industry, which needs huge capital investment (Hossain, 2015a, b; Hossain, 2018b). Export-oriented shipbuilding, particularly smart shipbuilding, is inherently a global industry (Stopford, M., 2009). Bangladesh has a distinguished shipbuilding history and a low-cost, abundant young workforce. Local shipyards have the capacity and capability to construct small and medium ships (10000 DWT) in accordance with international standards at approximately 10%-30% lower cost than similar ships built in Japan, Korea, China, and Western countries (Hossain, 2018a). However, in the era of intelligent, digitised technologies, the impact of the Fourth Industrial Revolution (4IR) has become a defining discourse and a challenge for the maritime and manufacturing sectors worldwide. 4IR combines digitisation with manufacturing using smart tech, such as AI, ML, DL, DS, IoT, blockchain, digital twin, big data, cloud, VR/AR, simulation, human-machine interaction, 3D printing, advanced materials, and automation (Hossain, 2025a, c; Hossain, 2024e). The main goal of 4IR in shipbuilding (shipbuilding 4.0) is to create intelligent shipyards that are not only flexible, resource-efficient, and profit-focused but also promote close collaboration among shipowners, shipbuilders, suppliers, and all other stakeholders across different business and value chains. (Hossain et al., 2017; Noordstrand A, 2018). Therefore, cheap labour and an abundance of young population are no longer sufficient drivers for industrial development in a developing nation in this century. Productivity and a technology-centred skilled workforce are paramount requirements. Suppose Bangladesh fails to develop its young population into a skilled workforce with a technology-friendly attitude. In that case, there is a high likelihood of missing this critical opportunity for economic advancement and sustainable growth, and of falling behind on the global development trajectory (Hossain, 2023a, b).

The global shipbuilding market is characterised by inflation, overcapacity, depressed prices, low profit margins, trade distortions, widespread subsidisation, financial and pandemic crises, volatile global politics, trade imbalances, and more. There are fluctuations in shipbuilding growth. The United Kingdom (UK) was the global market leader in shipbuilding before World War II. After that, Japan became the dominant shipbuilding nation in the 1960s and gradually lost its competitive advantage to the promising industrial nation, South Korea, which had lower wages, a more suitable shipbuilding strategy, strong government support, and a weaker currency. South Korean shipbuilding overtook Japan's in 2003 (Lixing Z, 2009).

From 2009 onward, during and after the global financial crisis, China became a global shipbuilding leader, surpassing South Korea and Japan by adopting the same strategies and techniques as those two shipbuilding giants (Hossain, 2018a, b). China uses the global financial crisis to develop its shipbuilding industry, initially targeting the medium- and small-sized global container, tanker, and cargo ship markets. High-labour-cost countries have consistently lost global shipbuilding market share following the removal of state subsidies; even with strong domestic policies, they have failed to provide sufficient support. Shipbuilding in the UK, the USA, and other European countries is a prime example of this (Stopford M, 2009, Hossain 2010). The market share of US and European shipbuilders began to decline in the 1960s, and their production is now primarily for military use, with few specialised ships such as cruise liners or pleasure Yachts. Today, China is the global leader in shipbuilding, with approximately 50% of the global market share. Their shipbuilding quality and technology have improved significantly, and they have earned the confidence of global customers. South Korea and Japan are following China, securing second and third positions in the global market with 19% and 15% shares, respectively (Hossain, 2021; UNCTAD, 2021a; Hellenic, 2024).

Middle-class societies in Asia and Africa are flourishing in the 21st century. At the same time, the price of shipbuilding labour in China has increased manifold in recent years. As a result, China will reduce its market share in the small and medium container, cargo, tanker, and multipurpose ship sectors over the next decade. Here, an opportunity has been created for small shipbuilding nations, including Vietnam, the Philippines, India, Bangladesh, Brazil, and Turkey. However, "indigenous shipbuilding in this region has a glorious history. Shipbuilding is considered an early industry developed in Bengal based on its traditional boat building" (Alam, 2004). Ibn Battuta visited Bengal in the 14th century and returned aboard a wooden ship built at the Sonargoan Shipyard in Dhaka. Interestingly, Ibn Battuta's ships have been conserved in European Museums. European traveller Mr Caesar Frederick noted that Chittagong was the centre of shipbuilding in the middle of the 15th century (Hossain et al., 2010a). In the 17th century, a fleet of ships was built for the Sultan of Turkey at Chittagong. During the Mughal period, Chittagong built numerous warships for its naval force. The British Navy used wooden-hulled warships built at Chittagong, which were successfully deployed at the Battle of Trafalgar in 1805. The wooden-hulled frigate Deutschland (1000 dwt) was built in Chittagong for the German Navy in 1818 (Hossain et al., 2017).

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

Alongside other criteria, the average operational lifespan of ships is a significant factor in vessel disposal decisions. Environmental rules, bunker fuel costs, technical obsolescence, freight rates, new-building pricing, EOL or used ship prices, and demolition prices are examples of policy-related factors (Hossain, 2018c, d). Typically, ships are scrapped after 25 to 30 years of service, with minor variations depending on ship type and region. For example, tankers typically have a disposal age of 25-30 years, whereas container ships have a shorter average lifespan of 17-26 years. Bulk carriers, however, exhibit a more variable age at disposal, ranging from 20 to 35 years. Between 2006 and 2012, the proportion of ships scrapped relative to the global fleet rose from 1% to 3.5%, before declining to 2% in 2014. These disposal rates vary significantly between countries (Hossain, 2026). Despite these fluctuations, overall disposal rates remained low, which is usually the case. However, due to inflation and the global economic crisis, the rise in the average age of scrapped vessels and anticipated trends in vessel demolition will be slowed. According to the research, tankers often have greater survival rates than container ships and bulk carriers. Notably, even after 40 years of service, double-hull tankers continue to have a survival rate of about 25%. On the other hand, because double-hull tankers are required to follow IMO standards to enhance safety, single-hull tankers are decommissioned early. New vessel needs are expected to total approximately 690 million GT, with 200 million GT for tankers, 315 million GT for bulk carriers, and 170 million GT for container ships. From 2030, disposal-related requirements will decline as activity returns to pre-crisis levels. Total new-building requirements from 2016 to 2035 have been estimated at 1,500 million GT, including 460 million GT for tankers, 710 million GT for bulk carriers, and 335 million GT for containers. Without capacity closures, excess capacity will likely persist for 15 years. The global population was 6.83 billion in 2010 and is expected to reach 9.08 billion by 2050. The urban population is growing faster than the overall population; approximately 50% of the global population lives in cities, and by 2030, about 70% will be urban (IHSSeaweb, 2016; OECD, 2011). A larger urban population creates a strong domestic market for goods and services, boosting economic growth and innovation, which should benefit seaborne trade. Urbanisation may also increase the middle class, enhancing the consumption of goods and services (Hossain, 2024a, 2025b). Finally, global shipping and shipbuilding will continue to grow.

III. Significance Of Smart Port And Smart Shipping

Todayports play an essential role in global trade but are also associated with significant environmental and social challenges. In 21st century, port 'smartization' is closely associated with the principles of Industry 4.0 and with broader processes of digital transformation in logistics infrastructures, which promote the integration of cyber-physical systems, interoperability among digital platforms, and the intensive use of data to improve operational performance (Behdani, 2023). In this context, several technologies play a central role in the development of so-called smart ports, including the IoTs, AI, big data and analytics, cloud and edge computing, artificial intelligence, digital twins, Artificial Intelligence, blockchain, and automation and robotics systems (Inkinen et al., 2021; Kuo and Chen, 2024; Q. Zhang et al., 2025). According to Sadiq et al. (2024), innovative technologies like All-Electric Ships, smart grids, and renewable energy systems are essential for modernizing port activities and reducing environmental impacts. Despite the rapid diffusion of these technologies and the frequent expectation of "win–win" outcomes, the evidence base on smart port impacts is dispersed across engineering, logistics, economics, and sustainability literatures, and varies substantially in methods, indicators, and system boundaries. As a result, findings are not always comparable and remain fragmented and sometimes inconclusive. While some studies suggest improvements in efficiency, trade capacity, and operational costs, others emphasize challenges such as labor displacement, high investment requirements, and financial risks (Kusumawati et al., 2023).

The effect of the ports on economic and environmental questions is studied and quantified where possible. However, digitalization may contribute to emission reductions, energy efficiency, and improved resource management, it may also generate new environmental concerns, including electronic waste and the growing energy demand of digital infrastructures (Z. Zhang et al., 2024). These tensions highlight the need to distinguish expected benefits from demonstrated outcomes, and to clarify the conditions under which impacts are positive, negative, or negligible. These developments have also been linked to broader sustainability agendas, particularly the United Nations Sustainable Development Goals (SDGs).

Smart ports may contribute to SDG 8 (Decent Work and Economic Growth) by fostering job creation and sustainable economic development; SDG 9 (Industry, Innovation, and Infrastructure) through the digitalization and modernization of port infrastructure; SDG 13 (Climate Action) by optimizing processes and reducing carbon emissions; and SDG 17 (Partnerships for the Goals) by encouraging collaboration among public, private, and international stakeholders to implement innovative and sustainable solutions (Almeida and Ocon, 2024; Khalifeh and Caliskan, 2025). However, the strength of these claimed contributions depends on how impacts are defined and measured, and on whether assessments account for trade-offs (e.g., energy use of ICT systems, rebound effects, distributional impacts on labor, or shifting emissions beyond port boundaries).

In 21st century, smart ports make a significant contribution to improving environmental performance, particularly through emissions reduction, increased energy efficiency, and enhanced ecological safety. Technologies such as IoT, automation, traffic management systems, and smart energy solutions demonstrate strong potential to reduce fuel consumption and greenhouse gas emissions while improving operational coordination. However, the effectiveness of these solutions varies depending on regional context and regulatory frameworks. While Europe adopts an integrated approach aligned with ambitious climate targets, Asia emphasizes carbon efficiency gains driven by state policies, and developing regions tend to focus on more immediate environmental challenges, such as local pollution and waste management. Additionally, relevant trade-offs emerge between sustainability and technological investment. Despite their environmental benefits, the implementation of digital infrastructures may entail high energy consumption and, if not supported by renewable energy sources, may even increase the carbon footprint. There is also a risk of negative externalities, such as water pollution or indirect increases in emissions due to intensified port activity. Therefore, the environmental impact of smart ports is not automatically positive, as it depends on the alignment between technological innovation, clean energy sources, and effective public policies. In this context, a differentiated assessment of technologies becomes essential, prioritizing solutions tailored to local conditions and capable of balancing operational gains with long-term environmental objectives.

There is growing interest in the concept of smart cities, driven by urban growth and rapid technological advancements.

In this context, smart ports are emerging as technologically advanced seaports that leverage data-driven technologies, automation, and digitalisation to improve operational efficiency, optimise logistics, enhance security, and reduce environmental impact (Chen, Jihong, 2019). Smart ports are essential for developing sustainable, integrated urban systems and facilitating global trade. To improve resource use, minimise ecological impacts, and simplify port operations, some ports implement sophisticated digital tools. Blockchain, AI, ML, DL, DS, IoT, and big-data sensors are among the advancements being incorporated into port operations (Hossain, 2025b, d). To enhance their infrastructure and daily operations, automated ports are increasingly implementing digital technologies, including data analytics and smart sensors. These encompass the coordination of vessel movements, the monitoring of port facilities, and the real-time tracking of cargo. Interoperability solutions, digital twin technology, predictive analytics, communication systems, cybersecurity tools, supply chain integration, and augmented and virtual reality applications are among the technologies that may be used in these endeavours (Hossain, 2024b, e). AI is a technological innovation that is both general-purpose and versatile in this digital transformation. It has a wide range of applications, including automation, robotics, language translation, image processing, decision-making, online banking, digital healthcare, credit evaluation, web-based commerce, Innovative farming, and many others (McCorduck Pamela, 2004). Artificial Intelligence and innovative technologies will be integral to the future of the ship, shipping, and shipbuilding industries and has been shown in figure 1 (Hossain, 2025a).

The use of technologies such as the Internet of Things, Artificial Intelligence, and big data in smart shipping provides a variety of benefits, including increased safety, regulatory compliance, environmental sustainability, and enhanced operational efficiency. These developments result in a more resilient and efficient supply chain, streamlined routes, and cost reductions (Lloydslist, 2024). Fleets can comply with evolving marine regulations and minimise their environmental impact by leveraging innovative shipping technologies to monitor and analyse pollutants. Smart containers and logistics solutions provide real-time visibility into the location and status of goods, thereby enhancing the efficiency of the entire supply chain, eliminating delays, and streamlining inventory management (Shipping technology, 2025).

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

A more sustainable marine business is enabled by optimised energy use and reduced emissions, consistent with global environmental objectives and standards. Smart shipping may enhance the profitability of shipping firms and enterprises in general by optimising routes, reducing delays, and enhancing cargo security.

The danger of human mistakes is minimised by the reduction of reliance on manual processes through the use of automation and sophisticated navigation technologies. LCs are issued by crediting parties, such as banks, as payment guarantees for businesses (buyers, sellers, and logistics providers).

Figure 1: Smart technology transforming the port operation and global shipping sector

Libelli's Blockchain (BCT) platform, built on Hyperledger, streamlines digital Letters of Credit by addressing issues such as slowness, cost, and the strictness of traditional processes. It speeds transactions, enhances security, and provides an efficient alternative to conventional methods (Bangzhang & Zirianov, 2021). Throughout the process, BCT ensures immutability and transparency, funds are deposited into Libelli's escrow account, and smart contracts are created. BCT's capacity to ensure the traceability, validity, and dependability of information, in conjunction with smart contracts, enhances supply chain management. The rules and regulations encoded in a smart contract govern the negotiation of conditions and actions between parties. Contractual terms and transactions are automatically verified. When the network receives a message from a member or another contract after the contractual conditions are met, the contract updates the ledgers accordingly. The crew's comprehension of the surrounding environment, including potential hazards and other vessels, is enhanced by real-time data from sensors and cameras (Chod et al., 2020). Innovative ships enhance overall operational efficiency, resulting in cost savings in different areas of maritime operations. Automation and optimised processes reduce reliance on manual labour, thereby lowering labour costs. Predictive maintenance helps prevent unexpected breakdowns and reduces costly repairs.

Optimised routing and improved engine performance reduce fuel use, leading to substantial cost savings. Automated ship systems or innovative ships are dedicated to specific tasks based on clear criteria and have a limited operational scope. Specific onboard systems, processes, or tasks may be automated, meaning they are performed without human input. Autonomous or self-sufficient ships, analogous to driverless cars, are entirely self-governed and require no human intervention. They are equipped with advanced systems, sensors, AI, ML, DL, and blockchain technologies and can learn, adapt, and respond to changing environmental conditions (Shipnerdnews, 2024).

IV. Significance Of Smart Ship

The typical lifespan of a ship is around 30 years. Currently, shipowners and operators are focused on ensuring that their fleets remain safe, efficient, and operational for as long as possible. This involves maintaining compliance with existing regulations and staying prepared for upcoming standards, both of which are crucial. Innovative ships offer a range of benefits, including enhanced operational efficiency, improved safety protocols, and greater environmental sustainability. Autonomous vessels constitute a distinct category within the broader classification of innovative ships; however, not every smart ship qualifies as autonomous.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

Innovative ships increasingly rely on digital technologies to enhance onboard and onshore operations, as systems such as alarm monitoring, power management, dynamic positioning, integrated navigation, and electronic engines become increasingly digitised. This transition results in a sustained increase in both the volume and frequency of generated data. Transforming data into actionable steps is essential for more innovative ships. Although smart shipping presents numerous opportunities, these only come to fruition when data is collected, processed, and delivered to the appropriate recipient at the right time.

This process includes gathering data, analysing it for patterns and trends, and providing context to support decision-making. Dashboards can display this data to generate insights, notifications, and alerts. Additionally, the data can be used to predict and simulate optimal scenarios, enhancing understanding of the ship's performance and supporting operational decisions (Marine-offshore, 2024). Smart Ship and its operation have been shown in figure 2 below.

Figure 2: Smart Ship and its smart operation

Retrofitting existing ships with modern technologies and converting them into 'smart' ships offers a means to address this challenge. By incorporating advanced systems and digital tools, shipowners can improve efficiency, reduce costs, meet regulatory standards, and enhance safety. As technology advances across industries, the maritime sector is embracing innovative ship technology. This breakthrough is transforming ship operations by enhancing efficiency, safety, and sustainability. Modern, intelligent shipyards provide sophisticated solutions that enable clients to leverage advanced technology and remain competitive. Innovative ship technology represents a significant leap forward, integrating IoT, AI, DL, ML, big data, and blockchain into ship systems. Through sensors, communication devices, and data analytics tools, innovative ships can monitor and improve operational processes in real time (Computer Weekly, 2025). This technology improves performance and enables predictive maintenance, reducing unexpected failures and costly repairs. A key advantage of innovative ship technology is its capacity to boost operational efficiency.

In 21st century, innovative ships leverage sophisticated algorithms and data analytics to enhance fuel efficiency, optimise route planning, and manage cargo effectively.

By analysing information from sources such as weather forecasts and traffic patterns, these vessels can make well-informed decisions that result in cost savings and reduced environmental impact (Port technology, 2024). They accomplish this using automation, advanced navigation systems, real-time monitoring, and predictive maintenance, all driven by digital technologies and AI. Equipped with advanced sensors, real-time AI-powered data, and predictive maintenance, these systems enhance situational awareness, minimise human error, and prevent equipment failures, thereby improving overall safety. Innovative ships use data analytics to improve fuel efficiency, route planning, and cargo management, resulting in substantial cost savings and a smaller environmental footprint. Automation, strategic route planning, and predictive maintenance reduce operational expenses for fuel, maintenance, and potential downtime. Additionally, innovative systems help reduce crew workload by simplifying reporting and providing improved navigational support, thereby enhancing crew safety and operational efficiency. AI-powered analysis can forecast equipment failures, enable timely maintenance, and prevent costly breakdowns. Intelligent systems can detect potential hazards and issue early warnings, enabling crews to take preventive action.

Additionally, innovative ships can implement robust cybersecurity measures to safeguard against cyber threats, ensuring operational safety (Ship-Technology, 2025). They also monitor and control emissions in real time, thereby aiding compliance with environmental standards. Increasingly, innovative ships are adopting sustainable energy solutions, such as hybrid propulsion and renewable energy sources. Through operational optimisation and emission reduction, these vessels promote a more sustainable maritime industry. They are designed to adapt to changing regulations and integrate new technologies to meet evolving needs and standards.

Innovative ships generate detailed performance and emissions reports, aiding regulatory compliance. They can precisely monitor and control emissions to comply with stringent regulations. Currently, innovative ship solutions aim to improve operational efficiency, boosting performance and competitiveness. Safety is critical in maritime operations; innovative ship technology significantly enhances safety through real-time monitoring and AI analytics that can identify hazards, predict equipment failures, and provide early warnings to crews. These systems enhance navigation safety and ensure compliance with international regulations. Smart shipbuilders provide technologies that help vessels meet safety standards while reducing operational risks. As the maritime industry evolves, innovative ship technology will continue to drive innovation. The integration of IoT, AI, ML, DL, Blockchain, and big data is expected to grow, offering new capabilities and opportunities for improvement (Jihong, 2019). They are committed to innovation, offering clients the latest innovative ship technology to prepare for the future. This technology revolutionises the maritime industry by improving efficiency, safety, performance, and sustainability. Smart shipyards provide advanced solutions to navigate modern maritime complexities. Embracing these technologies helps shipowners enhance efficiency, safety, and environmental sustainability.

Innovative ships will be built with digital evidence, supercomputer code, and advanced technological infrastructure, forming the core of modern maritime technology. These elements will drive innovation and promote a more sustainable and environmentally friendly supply chain. Many commercial contracts worldwide may evolve into smart contracts, coded and executed by computers. Collectively, all these innovations will be referred to as innovative systems shipping. The IMO's Maritime Safety Committee (MSC) agreed to revise its agenda following the 2017 proposal from several member states.

This update was a preliminary scoping exercise to explore how Marine Autonomous Surface Ships (MASS) could be safely, environmentally soundly, and securely integrated into IMO regulations (IMO, 2023). Shipping companies reduce crew sizes to remain cost-competitive amid intense competition in the logistics sector. Growing interest in efficiency and carbon reduction is boosting demand for AI, automation, and more intelligent navigation systems to enable safer, cheaper shipping. Progress in information technology, a key enabler of the fourth industrial revolution, drives the development of autonomous ships. Countries such as China, the EU, Korea, and Japan, where these technologies are more accessible, are leading the development of eco-friendly autonomous ships through public-private collaborations.

In 21st century, innovative Ships revolutionise ship design and operations, transforming the maritime sector and its core components. This affects shipbuilders, shipping companies, owners, system providers, and other firms in the manufacturing technology industry (Pinto, A.M., 2020). Real-time remote vessel monitoring worldwide will boost safety, efficiency, trust, and global supply chain integration, increasing revenue and savings. AI will enhance vessel autonomy and improve sailors' environmental awareness. Utilising AI applications on ships reduces human errors and helps prevent accidents. Innovative ships are expected to reduce human-error-caused marine accidents by mitigating risks through improved decision-making algorithms and effective decision-making management systems. Smart contracts, particularly when integrated with blockchain technology and IoT devices, enable transparent shipment tracking across the entire shipping value chain. They also greatly enhance the logistics system by automating procedures, improving security, and offering real-time visibility updates. Smart contracts enable transparent shipment tracking across the entire supply chain, improving logistics. A data-driven approach can expand the value chain and potentially reduce maintenance costs. Additionally, it can improve safety and operational efficiency (Sarkar, D., 2023). Smart contracts on a decentralised blockchain create an immutable, transparent record of all shipment details, from start to finish. This enables authorised stakeholders to monitor shipments in real time and improves transparency. Cryptography and consensus protocols safeguard data integrity and authenticity, preventing fraud and unauthorised access, thereby building trust among supply chain participants. However, addressing challenges such as scalability, system integration, and regulatory compliance is essential for broader adoption.

Augmented reality integrated with big data analytics provides an immersive, comprehensive experience for ship navigation. It provides a real-time representation of the physical environment, using computer-generated visuals, including graphics, videos, and GPS data, to enhance the visualisation of surrounding information. The innovative technology enhances the current perception of reality relative to the virtual perception. Sensors and connected systems will produce substantial data to enhance ship and fleet operations. Smart sensors and satellite communication facilitate an integrated network between onboard and onshore systems, enabling real-time analysis of extensive condition data. Various sensor data are available during ship and fleet operations, including position, speed over ground, wind speed, fuel flow, shaft torque, shaft RPM, and emissions data (Sezer, B.B. et al., 2023). Again, insights from big data enhance decision-making within ships, shipping, and ports. Currently, big data analytics can be used to address existing challenges, thereby improving safety, efficiency, and productivity. Over the next decade, mandatory ECDIS adoption, the upcoming EU MRV legislation, and the industry's drive for transparency and improved ship-shore connectivity will increasingly rely on data transmission and knowledge sharing. The innovative approach automates systems to increase productivity and reduce labour hours.

In 21st century, adopting cloud technology simplifies workforce management for both off-site and on-site teams, improving operations, communication, and collaboration. Cloud services provide users with access to IT resources at any time and from any location via wired and wireless devices connected to the internet. As a result, cloud computing has become a prominent industry within the fourth technological revolution 4IR (National Geographic, 2018). A cloud service is an on-demand platform that delivers internet-based resources, software, hardware, and expertise infrastructure. On the other hand, cloud technology allows ship owners and shipping companies to manage centralised data systems and enforce data policies across global locations. Cloud services are typically categorised as public, private, or hybrid. Public cloud services are operated by third-party providers for a broad user base and provide shared resources. These services impose restrictions by setting private policies for sensitive data that should not be shared, and by sharing only information deemed necessary by the policies' stakeholders (Khan, M.A. et al., 2018).

Connecting with IoT devices enables the collection of real-time data on shipment conditions and locations, which smart contracts can automatically process. This improves decision-making and helps optimise routing.

Blockchain transforms supply chain management by enabling real-time tracking, enhanced security, and automation through smart contracts. Stakeholders can monitor product movement from origin to destination, thereby reducing fraud and ensuring data integrity. It also simplifies compliance checks and streamlines workflows, thereby reducing delays and manual effort. Everyone involved- manufacturers, suppliers, retailers, and regulators-gains equal visibility into the supply chain operations. However, innovative ship technology will generate more data, improving shipping efficiency and meeting processing demands. The IMO has strengthened its initiatives by creating a legally binding framework to lower global greenhouse gas emissions from ships, aiming for net-zero emissions by approximately 2050 (AECO, 2024). IMO's GNG strategy aims to reduce the carbon intensity of international shipping by at least 40% by 2030 and to achieve net-zero GHG emissions around 2050. It emphasises reducing CO2 emissions per unit of transport work relative to 2008 levels (IMO, 2023).

In 21st century, the global economy relies heavily on maritime transport, with seaborne trade projected to increase by approximately 35% by 2050, driven by a growing and more prosperous global population. However, a shift towards a circular economy will affect maritime trade, reducing the transport of coal and oil. Conversely, container ships and gas carriers are expected to grow significantly, with the most rapid expansion seen in specialised vessels supporting offshore wind projects. The two major megatrends-Sustainability and Digitalisation will undoubtedly influence the maritime sector's future industry. Shipping is the most energy-efficient method for transporting large cargo over long distances, but its scale results in significant environmental impacts. International shipping accounts for about 3% of global greenhouse gas emissions, comparable to aviation, but it contributes more to global sulfur and particulate matter levels.

The shipping industry is undergoing a major technological revolution. As digital and advanced technologies transform ship capabilities and maritime connectivity, terms such as "smart ship," "autonomous ship," and "electric ship" are frequently used to highlight the significant progress made by ships equipped with modern digital tools relative to traditional vessels. However, these terms denote distinct concepts in maritime technology and may represent different stages of technological evolution. They hold great significance in today's maritime landscape. Following CSIC (China)'s launch of the uncrewed freighter, Japan also launched a Smart Ship Application Platform project (ICC-CCS, 2023).

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

Europe's Munin initiative aims to develop an uncrewed vehicle by 2035, with support from Rolls-Royce. Yara Birkeland and Kongsberg plan to replace 40,000 trucks via automated maritime deliveries. Hyundai advances ICT for maritime use. Finland is establishing AAWA in partnership with companies such as Inmarsat and DNV-GL. Major players like Maersk and IBM are investing (Navsea, 2020).

Since the IMO classifies this as Level 2 automation, fully automated ships could arrive in five years. The goal is Degree 4 automation, but a long path remains; estimates for fully autonomous shipping range from 10 to 30 years. The situation will be challenging when Smart Ships navigate alongside traditional analogue shipping routes. While Smart Ships remain distant, they are not far off. Smart shipyards are using innovative and advanced technology in shipbuilding and that shown in figure 3 below.

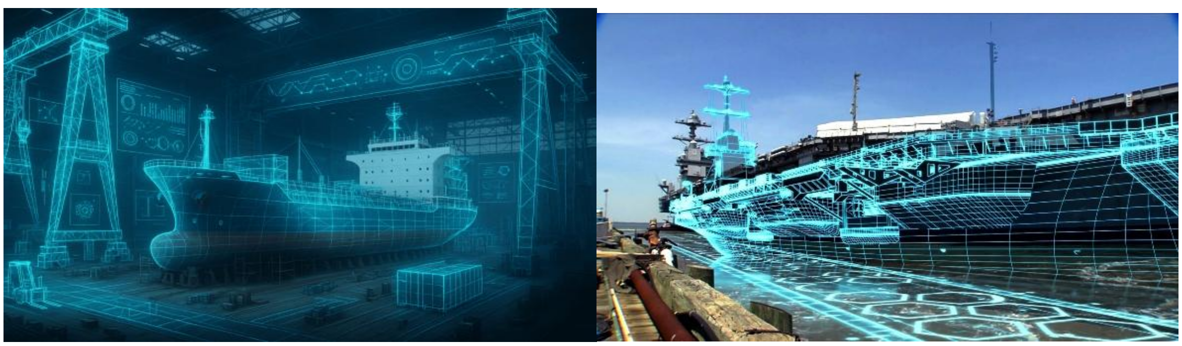

Figure 3: Smart shipyards are using innovative and advanced technology in shipbuilding.

V. Significance Of Smart Shipbuilding

Innovative ships incorporate advanced digital technologies, such as AI, ML, DL, Blockchain, and big data, into their design, propulsion, systems, and manufacturing processes to enhance efficiency, safety, and operational performance. They utilise advanced materials, such as glass fibre, carbon fibre, and reinforced polymers (GFRP), in hull plating. Additionally, they develop innovative structures, including adaptive damping systems for thrusters and composite sandwich panels incorporating Phase Change Materials (PCMs) to improve insulation in refrigerated cargo ships (Thermtest, 2024). Phase change materials (PCMs) are substances that absorb or release thermal energy as they transition between solid and liquid states. This characteristic enables them to store and release significant amounts of energy at specific temperatures, making them well-suited for thermal energy management and temperature regulation applications. Key aspects include digital twins, advanced materials, and automated monitoring and control systems. Digital replicas of ships and their components enable concurrent development alongside the physical product, supporting detailed analysis and continuous optimisation throughout the lifecycle (Safewise, 2023). Using automation in shipbuilding, including robot work for welding and assembly, as well as integrated systems for power management, navigation, and alarm monitoring, all help generate more data and improve operational efficiency (MDPI, 2024).

Innovative technologies optimise performance across varying conditions, including changing cargo loads, shallow waters, and waves. They also lower maintenance costs by using corrosion-resistant materials and increase cargo capacity by employing lightweight composites. However, not all innovative ships are fully autonomous. The development of autonomous vessels is a key aspect of the "smart ship" concept, which utilises advanced digital systems for autonomous operation.

In 21st century, smart shipbuilding offers numerous benefits, including increased efficiency, cost savings, improved safety, and enhanced environmental sustainability. Incorporating technologies such as AI, automation, and data analytics enhances multiple stages of the process, from design and engineering to construction and maintenance. This results in quicker production, lower operational costs, fewer human errors, and a reduced ecological impact. Additionally, digital twins and simulation tools are used to refine designs, minimise errors, and accelerate development. Robotics and automation enhance manufacturing efficiency, resulting in faster production and lower labour costs. Intelligent systems optimise material flow and inventory control, decreasing delays and waste. Smart shipyards employ prefabricated sections and modular construction methods to significantly reduce assembly time. Automation and robotics can reduce reliance on manual labour, particularly for repetitive or hazardous tasks. Data-driven predictive maintenance helps detect potential problems early, lowering repair costs and reducing downtime.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

Clever shipbuilding techniques reduce material waste and improve resource efficiency. Automated systems and AI-based navigation can reduce human error, a key factor in accidents in traditional shipbuilding. Additionally, intelligent systems can detect early signs of equipment failure, prevent accidents and promote safer operations (Thinaer, 2024). AI-powered systems enhance emergency response by analysing situations and automating safety protocols. Innovative shipbuilding practices reduce material waste and improve resource utilisation. Automation and robotics enhance precision and accuracy in manufacturing and assembly processes. Intelligent systems can detect and fix defects early, enhancing the overall quality of the ship. They continuously monitor the quality of materials and processes throughout the shipbuilding lifecycle, ensuring high standards. Considering the large pool of young, unskilled workforce in Bangladesh, Augmented Reality (AR) and Virtual Reality (VR) based training systems are more effective than traditional methods. These digital tools can accelerate skill acquisition for complex tasks such as precision welding and fitting, without the safety risks and material waste associated with physical training. Additionally, adopting a 'Digital Twin' approach for ship repair and retrofitting, creating 3D digital replicas of existing vessels, will allow local yards to precisely engineer modifications, giving them a competitive edge in the high-value retrofitting market.

Smart shipbuilding represents a significant shift in the industry, offering a more efficient, cost-effective, safer, and sustainable approach to ship construction (Duarte, S. et al., 2017). Smart shipyards can incorporate green technologies, such as alternative fuels and energy-efficient systems, thereby reducing emissions and supporting environmental sustainability. Today, in the production sector, shipyard management, materials, and machinery are highly integrated with advanced technology. Like steam engines, internal combustion engines, electricity, and computers, AI is now widely used in both industry and academia. Currently, ML, DL, ANN, and DS are employed in ship and port operations and in the shipbuilding industry to enhance efficiency, reduce costs, and improve overall performance. These technologies support data-driven decision-making, predictive analytics, and automation, leading to significant progress in port management. In modern shipbuilding, AI and related innovations are used to develop intelligent, automated shipyard infrastructure that addresses current challenges. In addition to construction and maintenance, smart shipyards also place a strong emphasis on security enhancements. Digitalisation is transforming shipyard facility management through collaborative platforms and advanced technologies, thereby ensuring safety, profitability, and timely delivery. To optimise shipbuilding processes and profits, smart shipyards utilise digital tools such as automation, sensors, data analytics, the IoT, AI, and DL. Smart Shipyards and their activities have been shown in figure 4 below.

Smart asset and logistics management systems enhance this transformation by tracking the location, condition, and performance of key shipyard assets such as cranes, vehicles, machinery, and infrastructure (Hossain K A, 2024e). These intelligent systems contribute to extending equipment lifespans, enabling proactive maintenance, and increasing overall asset utilisation. The adoption of predictive maintenance techniques, in which algorithms analyse sensor data, maintenance records, and operational performance, facilitates early detection of potential failures and the scheduling of repairs. This strategy improves the reliability and safety of shipyard operations, while also reducing downtime and maintenance costs. Today, real-time monitoring and assessment of infrastructure and equipment are enabled by big data analytics, AI, and IoT sensors. Furthermore, ML and DL algorithms can analyse historical data to forecast future ship demand, informing better decisions regarding inventory, workforce, logistics, work scheduling, and resource allocation (Hossain, 2024d).

In 21st century, digital technologies and IoT are poised to play a key role in the future of AI integration within the shipping sector. IoT and AI devices will deliver real-time information and market data. AI algorithms can be used to optimise production, operations, and management (Hossain K A, 2025b). AI will also support the maritime industry's sustainability efforts by optimising fuel consumption, minimising emissions, and improving supply chain efficiency. AI-driven solutions will enable shipping companies and shipowners to comply with environmental regulations and advance their sustainability objectives. Looking ahead, AI is expected to fuel the development of more sophisticated predictive analytics tools. These tools will provide valuable insights into market dynamics, empowering industry stakeholders to make informed, data-driven decisions and maintain a competitive edge. However, adopting AI, ML, DL, data science, and other innovative technologies demand substantial investment in hardware, software, and skilled human resources. These high initial costs may pose challenges for the small and medium-sized shipping and shipbuilding industry. Additionally, integrating such technologies entails collecting and processing large volumes of data, raising concerns about data privacy, cybersecurity, and overall safety. Images of two very large shipbuilding industry has been shown in figure 4 below.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

Figure 4: Smart Shipyards and their activities (Samsung Heavy Industry and Hyundai Heavy Industries)

The shipbuilding industry stands on the brink of a technological revolution, spearheaded by groundbreaking research and development initiatives. Leading companies are advancing fuel-efficient engines and innovative ship technologies, paving the way for faster, more sustainable maritime solutions. This surge in innovation is not only redefining efficiency but also transforming eco-friendly practices into a standard for modern shipbuilding. Eco-friendly shipbuilding practices are crucial for mitigating the maritime industry's environmental impact. The adoption of sustainable design principles, innovative materials, green construction methods, and digitalisation alongside green technologies enables the industry to reduce its ecological footprint. Implementing sustainable practices necessitates a holistic approach that engages all stakeholders, including designers and shipyard operators (Lloyd's Lloyds-register, 2023).

Now, Hyundai Heavy Industries (HHI) is a leading innovator in the maritime industry, transitioning from a traditional shipbuilder to a "future builder" focused on decarbonization and digitalisation. HHI is doing this by developing intelligent and secure engine control systems, eco-friendly technologies, and innovative ship solutions, and by being a global leader in shipbuilding that invests heavily in R&D to push the boundaries of maritime innovation. Their key focus areas include autonomous shipping, green energy solutions, and digitalisation. HHI has been developing innovative ships equipped with AI-driven navigation systems to enhance safety and efficiency. They are also investing in alternative fuels such as ammonia and hydrogen to reduce carbon emissions in line with IMO regulations. HHI collaborates with other companies to develop innovative solutions, such as blockchain-enabled class registers with Lloyd's Register. Their research into blockchain-based logistics is improving transparency and security in global shipping operations. With a strong technological foundation and world-class production facilities, HHI is a global leader in shipbuilding, delivering thousands of vessels to clients worldwide. Today, shipbuilding companies are focusing on making their ships more fuel-efficient. They are researching ways to reduce engine fuel consumption. This helps reduce harmful gases released into the atmosphere. By improving fuel efficiency, ships can also save on fuel costs. Embracing these methods can lead to cleaner oceans. Encourage shipbuilders to prioritise fuel-efficient technologies. HHI is actively developing eco-friendly technologies such as LNG- and ammonia-fuelled vessels, as well as next-generation propulsion systems, to reduce carbon emissions.

In the era of advance technology, many shipbuilders are turning to advanced materials for their ships. These materials are lightweight yet highly strong. Using lighter materials helps ships move faster and use less fuel. This can reduce the wear and tear on the ship. It also reduces maintenance costs. Advise shipbuilders to explore the possibilities of advanced materials. HHI is investing in advanced materials and propulsion systems to build faster, more efficient ships. Now, innovative technologies are becoming a key area of focus in shipbuilding. These include systems that enable ships to operate autonomously. Research is being done to improve these intelligent systems. This can make ships safer and more reliable. It can also reduce the need for large crews, saving costs. Advocate for greater investment in innovative ship technologies. HHI is involved in developing autonomous shipping technologies and digital tools to improve shipbuilding efficiency. They have even conducted autonomous ship demonstrations. Artificial intelligence can enhance ship design and production methodologies, leading to increased efficiency and minimised waste. Blockchain technology enhances supply chain transparency and mitigates potential environmental impacts. The Internet of Things (IoT) enhances the monitoring and control of ship systems, thereby reducing energy consumption and increasing efficiency.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

In this era, digitalisation is significantly transforming the shipbuilding process. With digital tools, the design and production of ships have become more efficient. These tools can catch mistakes early, saving time and money. Digitalisation helps streamline the supply chain as well. It supports better communication among different teams. Promote the benefits of digitalisation in shipbuilding. Digital tools can optimise ship design to improve energy efficiency and reduce environmental impact. Digital planning tools enhance production efficiency and cut waste. Supply chain management improves transparency and reduces environmental risk. Today, sustainable practices are critical in modern shipbuilding. Companies are using eco-friendly materials to build ships. They are also adopting methods that cause less environmental harm. This trend is important for preserving marine life. Sustainable practices can lead to long-term savings and regulatory compliance. Urge shipbuilding companies to invest in sustainable practices. The shipbuilding industry is being transformed by digitalisation and green technologies. These technologies offer substantial opportunities to enhance efficiency, minimise waste, and advance sustainability. Electric and hybrid propulsion systems have the potential to substantially reduce greenhouse gas emissions. Energy-efficient systems, such as LED lighting and HVAC systems, can reduce energy consumption. Technologies like recycling systems and waste-to-energy converters effectively reduce waste.

Modern shipbuilding is implementing lean manufacturing principles. It minimises waste and optimises production processes. Green shipyard practices, such as the use of renewable energy and the minimisation of water consumption, can substantially reduce a shipyard's environmental footprint. Damen Shipyards has adopted various sustainable practices, such as modular construction and the use of energy-efficient facilities. Fincantieri has made investments in green technologies, including solar power and energy-efficient lighting, to mitigate its environmental impact (Ship-technology, 2021). Three-dimensional printing has the potential to decrease material waste and enhance manufacturing efficiency. Digital twin technology enables virtual testing and simulation, reducing reliance on physical prototypes. Automation has the potential to improve production efficiency and reduce labour costs. Today we need to adopt green and sustainable practices. It often involves higher costs than traditional methods, and regulatory barriers can hinder their implementation. A lack of awareness about green technologies also presents challenges. Hyundai Heavy Industries has invested in renewable solutions like solar power and energy-efficient lighting to lower its environmental footprint.

Adopting sustainable practices is essential for minimising the environmental footprint of shipbuilding. This effort requires a comprehensive strategy that engages all stakeholders, from designers to shipyard workers. Setting clear sustainability objectives and targets can foster meaningful change. Offering training and education on sustainable methods helps cultivate a culture of sustainability. Working together with suppliers, clients, and other partners can reveal areas for enhancement. Mitsubishi Heavy Industries has adopted various eco-friendly initiatives, including energy-efficient facilities and waste-reduction programs.

VI. Future Outlook

In many ports cities worldwide the relation between ports and their cities is a complex and evolving one: ports need less labour but have become more capital and space intensive, which naturally conflicts with space constraints in growing metropolitan regions. Various developments have also strengthened a global-local mismatch connected to ports, with positive spillovers across the metropolitan boundaries, but with negative impacts that are highly localised. In the era of advance technology, transitioning to “smart ports”, which rely on the use of advance/smart technologies and digitalization, to rationalize, reorganize and streamline port activities, has proven to be a viable strategy to address both economic efficiency and environmental performance, at normal times and at times of great disruptions. Major ports around the world, such as Rotterdam, Hamburg, Singapore, Los Angeles, Qingdao and Busan, are deepening digitalization in port development and operation in order to improve port productivity and strengthen cooperation among stakeholders. Automated container handling and digital customs clear goods faster, reducing ship waiting times. IoT sensors and radar systems track real-time vessel movement and infrastructure health. Smart energy grids and optimized traffic flow cut local emissions and resource waste. On the other hand, smart ships revolutionize vital aspects like ship designing, construction, quality control assurance and operations, redefining the global maritime industry and the roles of primordial elements in it, along with implications for shipbuilders, shipping companies, ship owners, maritime systems providers, and other relevant sectors which producing the technology. The real-time constant remote monitoring and decision making of ships, globally will see ships become safer, more efficient, more trustworthy, and more closely integrated into the worldwide supply chains management and which generating revenue aid with a higher bonus of cost-savings.

Marine data analytics monitor speed, load, and trim to optimize fuel burn. Predictive maintenance uses AI and ML to spot engine and sensor faults before failures happen. Vision analysis and self-mooring tools minimize human error during complex manoeuvres. Again, the shipbuilding sector stimulates heavy backward and forward linkages, creates massive employment, generates foreign income, and functions as a strategic anchor for national manufacturing. Virtual twins and digital modelling test ship durability before physical construction begins. Automated robotic welding and modular assembly speed up production timelines (Hossain, 2025b). Yards are optimized to construct dual-fuel and LNG-ready eco-vessels meeting global green rules.

A crucial characteristic of smart ports and smart shipbuilding lies not in the complete removal of human involvement, but in the effective integration of AI-assisted decision support and human-in-the-loop operational control. Rather than fully autonomous operations, contemporary smart shipyards rely on digital systems to augment human judgment in areas such as production planning, safety monitoring, quality assurance, and environmental management. This hybrid operational model enhances efficiency and consistency while remaining realistic for developing and emerging shipbuilding economies, where workforce availability and skill transition remain critical factors (Hossain K A, 2025b; Hossain, 2024c). This significantly boosts efficiency while reducing labour costs with perfect security (Hossain K A, 2024e). These dynamics optimise production costs, improve operational efficiency, and ensure optimal resource use, with timely, accurate data playing a vital role in the maritime industry. Additionally, innovative shipbuilding practices are more environmentally friendly, focusing on reducing carbon emissions and protecting marine ecosystems. Modern shipyards increasingly adopt renewable energy, sustainable practices, and innovative technologies to minimise environmental impacts while ensuring sustainable growth and maximising profitability. Smart shipbuilding and port systems are also designed for greater integration with logistics and industrial networks. By employing advanced technologies, they enhance the movement of goods, streamline production processes, and improve information flow and workforce coordination within the broader supply chain. Furthermore, these industries adopt an open innovation approach, enabling continuous improvements in design, operations, construction, production, safety, and efficiency by incorporating new technologies and ideas. However, even minor disruptions to production processes or workflows in large shipyards can have serious consequences.

For ports, disruptions could empty grocery store shelves and gas station tanks within days, due to the breakdown of the zero-inventory, just-in-time delivery systems that underpin global trade (Hossain K A, 2024e). Similarly, cyber-attacks targeting energy supplies or automated systems could severely impact the global economy, and such risks also apply to the shipbuilding industry to a considerable extent (Hossain K A, 2025a). There are few challenges for inclusion of smart technology. Initial setup and ongoing maintenance, software updates, and staff training create financial burdens. Again, sensor inaccuracy in harsh marine conditions and poor real-time data transfer disrupt operations. Finally, greater reliance on connected digital platforms increases exposure to cyber threats (Nicoleta, 2025)

VII. CONCLUSION

Today ports support millions of direct and indirect jobs in logistics, manufacturing, and transport. They serve as critical nodes that stabilize the flow of goods and raw materials and massive transportation done by ships. Smart ports enable the port industry to interact with external businesses with higher accuracy, openness and transparency, improved relationships and business efficiency. They provide a comprehensive solution that - through the convergence of advanced information technology - addresses sustainability, efficiency, productivity, communication and transparency, and the evolution of equipment or facilities. Smart ports also have the potential to contribute to port accident prevention and port security. However, the smart port serves as a core base for the establishment of an eco-friendly, low-carbon shipping system and the development of intermodal transport system, and is expected to serve as a communications hub for all stakeholders, including the port and shipping industry and the global supply chain. Digitization and smart technology inclusion in major ports is progressing through connectivity between individual systems operated independently, advancement and expansion of existing information systems and establishment of a community of different stakeholders. Advanced technologies like robots, AI and digital twins, applied to port, shipping and shipbuilding facilities or equipment, minimize human-to-human contact. Port and shipyard operation, monitoring, automation can be realized through the acceleration of digital transformation, establishment of a smart shipping and logistics system using a digital platform, as well as construction of eco-friendly ports and shipping industry that are aimed at achieving sustainable shipping and shipbuilding with low-carbon, effective, and the development of a non-contact port and maritime trade and business.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 08, August 2026)

Today's shipbuilding industry increasingly leverages smart technologies, including advanced fifth and sixth-generation ports and smart shipping systems, to ensure effective, sustainable, and market-driven shipbuilding that optimizes profits and supports long-term growth. Considering the current opportunities, future challenges, and the suggested measures highlighted in this research, Bangladesh's shipbuilding sector should formulate viable policies (the means) and develop effective strategies (the ways) to capture suitable market segments while optimizing production capacity. This approach could sustainably revitalize the nation's lost glory in shipbuilding. Advanced technologies such as digitization, robotics, IoT, AI, machine learning, deep learning, and data science have significantly transformed the global shipbuilding landscape. Therefore, enhancing labour productivity and developing a skilled workforce is essential to sustaining growth in this sector. Simultaneously, ensuring safety and adherence to global standards is paramount to remain competitive in the international market. For substantial growth, the sector requires a balanced approach that includes strategic investments, sustained government support, and focused human resource development to effectively meet future challenges. By addressing critical issues such as productivity, technological adoption, and safety standards, Bangladesh's shipbuilding industry can enhance its global competitiveness and contribute meaningfully to national development and economic growth. To implement smart technology in ports, ship and shipyards, there must balance automation goals with labour workforce adjustments and legacy system integration. They may face larger hurdles with high entry costs and complex data integration compared to major global terminals. They need to set interoperable data standards to ensure smaller players are not left behind.

This study analyses offer valuable insights for stakeholders and policymakers aiming to promote the digitalization and smart technology inclusion in ports, shipping, ship and shipbuilding. The evidence suggests that the implementation of smart port, smart shipping, smart ship, and smart shipbuilding technologies generates tangible benefits across different dimensions, economic, environmental, and operational, providing shared value for all parties involved in the entire maritime ecosystem. These analyses reinforce the strategic importance of fostering digital and smart transformation in maritime infrastructure, particularly in the face of global pressures for sustainability and efficiency. However, to advance the current understanding of this topic, future research should delve deeper into the specific effects of digitalization and effective use of smart technology on the various stakeholders associated with different arm of maritime sectors.

Since the costs and benefits of digital and smart technologies vary depending on the nature of port and shipping activities, demand, cost-effectiveness and the roles of different actors, a more nuanced analysis is essential to tailor digital and smart strategies effectively. So, smart cranes, smart gates, digitization, AI scheduling speed up cargo clearance and vessel turnarounds in a modern port. On the other hand, predictive maintenance, optimized routing and smart ship cut fuel consumption and operational downtime. Additionally, real-time energy control and green shipbuilding lower carbon emissions and improve resource management and efficiency.

REFERENCES

[1] Alam, Commodore M. K. (2004), Bangladesh Maritime Challenges in the 21st Century. Dhaka: Pathak Shamabesh Publication.

[2] Almeida and E. Ocon, (2024), Achieving sustainable development goals through digitalization in ports, Bus. Strat. Environ. (2024), 10.1002/bse.3842, accessed on 09 Jun 2026

[3] Argyriou, O. Nisiforou, T. Tsoutsos, (2025), Setting sail for a sustainable growth in small/medium ports, Sustainability (Switzerland), 17 (8) (2025), 10.3390/su17083330, accessed on 13 May 2026

[4] Balcombe et al., (2019). Impact of government-owned banks on the restructuring of marginal large enterprises, Korea Development Institute, Jun 2019, accessed on 13 May 2026

[5] Bangzhang and Zirianov (2021). Report from the commission to the council on the situation in world shipbuilding, COM-474 final, Dec 2009, accessed on 09 Jun 2026

[6] B. Behdani, (2023), Port 4.0: a conceptual model for smart port digitalization, Transp. Res. Procedia, 74 (1) (2023), pp. 346-353, 10.1016/j.trpro.2023.11.154, accessed on 13 May 2026

[7] B. Belmoukari, J.F. Audy, P. Forget, (2023), Smart port: a systematic literature review, European Transport Research Review, 15 (1) (2023), 10.1186/s12544-023-00581-6, accessed on 09 Jun 2026

[8] Computer Weekly (2025). Transforming SME Lending Landscape in Bangladesh. Retrieved from https://futurestartup.com/2022/01/17/transforming-sme-lending-landscape-in-bangladesh/, accessed on 16 May 2026

[9] Chen and Jihong (2019), Trade in transition, Global Report, Economist Intelligence Unit, DP World, Dec 2021, available at: https://www.dpworld.com, accessed on 16 May 2026

[10] Chod et al., (2020). Transforming SME Lending Landscape in Bangladesh. Retrieved from https://futurestartup.com/2022/01/17/transforming-sme-lending-landscape-in-bangladesh/, accessed on 16 May 2026

[11] Duarte S. et al., (2017). Deep sea port in smart technology: Technological trajectories and scenarios in seaport digitalization, Research in Transportation Business and Management, 41 (2021), 10.1016/j.rtbm.2021.100633, accessed on 16 May 2026

[12] Hossain K A, Zakaria M N G and Islam M S (2010). SWOT analysis of shipbuilding industries in Bangladesh and its challenges to become a potential ship exporting nation, Journal of Ship Technology India, Volume 6, Issue 2, July 2010, accessed on 19 May 2026

[13] Hossain K A, (2010), Evaluation of potential prospects and challenges of Bangladeshi shipbuilding in light of global contest by Khandakar Akhter Hossain, Dept of NAME, BUET, 10 Jan 2010, available at: https://docplayer.net/64761793-Khandakar-akhter-hossain.html, accessed on 09 Jun 2026

[14] Hossain K A (2015). Future of energy resources, International Journal of Renewable Energy Technology Research (IJRETR), Volume 4, Issue 5, Nov 2015, accessed on 09 Jun 2026

[15] Hossain K A (2017), Ship recycling status of Bangladesh and annual reusable material output, Journal of Toxicology, Volume 2, Issue 2, 12 Oct 2017, available at: https://juniperpublishers.com/oajt/pdf/OAJT.MS.ID.555582.pdf, accessed on 19 May 2026

[16] Hossain K A (2018a). SWOT analysis of China shipbuilding industry in the third eyes, Journal of Recent Advancement of Petrochemical Science, Volume 4, Issue 2, 22 Jan 2018, available at: https://juniperpublishers.com/rapsci/pdf/RAPSCI.MS.ID.555632.pdf , accessed on 19 May 2026

[17] Hossain K A (2018b) Analysis of important steering factors which give success to global shipbuilding leaders, Journal of Recent Advancement of Petrochemical Science, Volume 4, Issue 5, 10 Apr 2018, available at: https://juniperpublishers.com/rapsci/pdf, accessed on 19 May 2026

[18] Hossain K A (2018c) Proposed viable ship recycling process for South East Asian recycling yards specially for Bangladesh, Procedia Engineering, Elsevier, published on 27-07-2018, available at: https://www.mtc-utm.my/wp-content/uploads/MARTEC_2018_Paper/I2.pdf, accessed on 19 May 2026

[19] Hossain K A (2018d) Sustainable ship recycling methods and process for global major ship recycling players, Open Access Journal of Toxicology, published on 15-01-2018, available at: https://juniperpublishers.com/oajt/OAJT.MS.ID.555622.php, accessed on 19 May 2026

[20] Hossain K A (2018e). Material Flow Analysis (MFA) is a better tool to calculating reusable material for ship recycling, 11th International Conference of Marine Technology, MARTEC 2018, Malaysia, published on 19 Jul 2018, accessed on 19 May 2026

[21] Hossain K A, (2018b), Analysis of important steering factors which give success to global shipbuilding leaders, Journal of Recent Advancement of Petrochemical Science, Volume 4, Issue 5, 10 Apr 2018, available at: https://juniperpublishers.com/rapsci/pdf, accessed on 06 Jul 2026

[22] Hossain K A, (2021), Strength Weakness Opportunity, Threat (SWOT) analysis of Bangladesh shipbuilding industry, Technical Paper: NAME, MIST, 16 Dec 2021, available at: https://www.mist.ac.bd/storage/files/name/TECHNICAL, accessed on 06 Jul 2026

[23] Hossain K A, (2023a), Challenges of development and operation of port in 21st century, IJNRD (www.ijnrd.org) ISSN 2456-4184, Volume 8 Issue 5, 23 May 2023, accessed on 06 Jul 2026

[24] Hossain K A, (2023b), Evaluation of global and local shipbuilding market, SciencePG, Science, Technology & Public Policy, US, 2023; 7(2): 52-68, doi: 10.11648/j.stpp.20230702.12, ISSN: 2640-4613, ISSN: 2640-4621, accessed on 09 Jun 2026

[25] Hossain K A, (2024a), An Overview of Merchant Ships, ISBN-13, 979-8324932374, May 2024, Amazon, US.

[26] Hossain K A, (2024b), Warship Construction Idea, ISBN-13, 979-8327525443, June 2024, Amazon, US.

[27] Hossain K A, (2024c), Analysis of ship recycling, ISBN-13, 979-8343259971, Oct 2024, Amazon, US.

[28] Hossain K A, (2024d), Artificial Intelligence and Robot, ISBN-13, 979-8332453625, Sep 2024, Amazon, US.

[29] Hossain K A, (2024e), AI is the smart solution for ocean resources preservation and maritime industry operation in modern era, Scientific Research Journal (SCIRJ), Volume XII, Issue X, October 2024 ISSN 2201-2796, available at: https://www.scirj.org/papers-1024/scirj-P10241001.pdf, accessed on 09 Jun 2026

[30] Hossain K A, (2025a), Analytical Study of Efficiency of Smart Ports, American Journal of Traffic and Transportation Engineering, Volume 11, Issue 2, April 2026, DOI: 10.11648/ j.ajtte, accessed on 09 Jun 2026

[31] Hossain K A, (2025b), Evaluation of Bangladesh Shipbuilding State and Major Challenges, Automation, Control and Intelligent Systems, Issue: Volume 13, Issue 3, September 2025, DOI: 10.11648/j.acis.20251303.13, accessed on 09 Jun 2026

[32] Hossain K A, (2025c), Artificial Intelligence (AI), ISBN-13, 979-8328010290, 2025, Amazon, US.

[33] Hossain K A, (2025d), Evaluation of Internet of Things, ISBN-13, 979-8306216980, Jan 2025, Amazon, US

[34] Hossain, K. A., (2025e), Smart 6th Generation Port (6GP): A Futuristic Perception Proceedings of the 8th IEOM Bangladesh International Conference on Industrial Engineering and Operations Management, Dhaka, Bangladesh, December 20-21, 2025, Vol:8, Issues:1, page: 18-24; IEOM Society International, USA; Dec, 2025; accessed on 07 May 2026

[35] Hossain, K. A., (2025f), Future Employment Opportunity, e-book, Amazon, available at: https://www.amazon.com/Future-Employment-Opportunity-Hossain-KA-ebook/dp/B0FNK6LS6H, accessed on 07 May 2026

[36] Hossain K A, (2026b), Bangladesh's Ship Recycling Industry in the Global South: Readiness, Regional Competition, and Reform Imperatives, MDPI, Sustainability 2025, 17(24), 10998; Volume 17, Issue 24, pp1-33; Available from: https://doi.org/10.3390/su172410998; accessed on 16 Apr 2026

[37] Hellenic Shipping News, (2024), 24 Global shipbuilding review: Largest order intake for 17 years, available from: https://www.hellenicshippingnews.com/2024-global-shipbuilding-review-largest-order-intake-for-17-years/, accessed on 09 Jun 2026

[38] T. Inkinen, R. Helminen, J. Saarikoski, (2021), Technological trajectories and scenarios in seaport digitalization, Research in Transportation Business and Management, 41 (2021), 10.1016/j.rtbm.2021.100633, accessed on 09 Jun 2026

[39] IMO (2023) Reduced limit on sulphur in marine fuel oil implemented smoothly through, 28 January 2021, available at: https://www.imo.org/en/MediaCentre/PressBriefings/Pages/02-IMO-2020.aspx, accessed on 09 Jun 2026

[40] IHS Seaweb (2016) The world's largest maritime ships database, Jul 2016, available at: https://onlinebilgi.com.tr/ihs-sea-web, accessed on 17 Jun 2026

[41] Jihong (2019), shipbuilding market, ID: MRFR/AD/8836-HCR, 168 Pages, May 13, 2026; available from: https://www.marketresearchfuture.com/reports/shipbuilding-market-10314, (Accessed on 01 Jan 2026).

[42] M. Khalifeh, A. Caliskan, (2025), The role of port smartness in achieving sustainable development goals, Marit. Pol. Manag., 52 (1) (2025), 10.1080/03088839.2023.2273349, accessed on 17 Jun 2026

[43] Khan, M. A. et al., (2018). Applications of Complex Adaptive Systems Approaches to Coastal Systems, PhD Thesis, University of Plymouth, accessed on 03 May 2026

[44] Kuo, L.-B. Chen, (2024), Utilizing emotional intelligence and artificial intelligence to improve safety behavior in smart port operations, IEEE Transactions on Technology and Society (2024), pp. 1-12, 10.1109/tts.2024.3513775, accessed on 17 Jun 2026

[45] E. D. Kusumawati, K. Karjono, K. Karmanis, (20230, Review of port management integrated digitization system: a pathway to efficient and sustainable port operations, Maritime Park Journal of Maritime Technology and Society (2023), pp. 52-57, 10.62012/mp. v2i2.26531, accessed on 17 Jun 2026

[46] C. Lazaroiu, M. Roscia, (2017), Sustainable port through sea wave energy converter, accessed on 17 Jun 2026

[47] 2017 6th International Conference on Renewable Energy Research and Applications, ICRERA 2017, 2017-January (2017), pp. 462-467, 10.1109/ICRERA.2017.8191103, accessed on 17 Jun 2026

[48] Li, L. Wang, A. Gharehgozli, S.J. Joo, J.Y. Lee, (2025), Resilience analysis of maritime silk road shipping network structure under disruption simulation, J. Mar. Sci. Eng., 10 (5) (2022), 10.3390/jmse10050617, accessed on 17 Jun 2026

[49] Lixing Z (2009). Development-oriented finance and economy in China: A historical review and prognostic assessment, printed in Bloomington, Indiana, USA, July 2009, accessed on 17 Jun 2026

[50] Lloyds Register of Ships (2022) World ships statistics, Archive and library, available at: https://hec.lrfoundation.org.uk/archive-library/lloyds-register-of-ships-online, accessed on 17 Jun 2026

[51] Marine-Offshore (2024). Trade in transition, Global Report, Economist Intelligence Unit, DP World, Dec 2021, available at: https://www.dpworld.com, accessed on 17 Jun 2026

[52] Marine Digital, (2026), Smart Ship as one of the Trends in Maritime, available at: https://marine-digital.com/article_smartship, accessed on 17 Jun 2026

[53] Makkawan, T. Muangpan, (2021), A conceptual model of smart port performance and smart port indicators in Thailand, Journal of International Logistics and Trade, 19 (3) (2021), pp. 133-146, 10.24006/JILT.2021.19.3.133, accessed on 17 Jun 2026

[54] Molavi, G.J. Lim, B. Race, (2020), A framework for building a smart port and smart port index, Int. J. Sustain. Transp., 14 (9) (2020), pp. 686-700, 10.1080/15568318.2019.1610919, accessed on 11 Jul 2026

[55] National Geographic (2018), "Huge defaulted loans an acute risk for Bangladesh's banking sector: IMF". The Business Standard. 30 October 2018, available from: https://www.trade.gov/country-commercial-guides/bangladesh-market-overview, accessed on 11 Jul 2026

[56] Nicoleta Acomi, (2025), The impact of digital technologies on the efficiency and sustainability of maritime transport, December 2025, Scientific Bulletin of Naval Academy, XXVIII (1):141-150; DOI: 10.21279/1454-864X-25-I1-013, accessed on 11 Jul 2026

[57] Noah Ugur Kilinc, (2025), Digital Transformation at Smart Ports: Artificial Intelligence Integration for Operational Excellence, Sustainability, and Strategic Transformation in Global and Turkish Maritime Logistics, November 2025; DOI: 10.13140/RG.2.2.33280.29441, accessed on 11 Jul 2026

[58] Navsea (2020), Retrieved from, The World's Biggest Shipping Hubs (marine-digital.com), https://marine-digital.com/article_eeoi_biggest_shipping_hubs, accessed on 11 Jul 2026

[59] B. Niu, J. Dong, H. Wang, (2024), Smart port vs. port integration to mitigate congestion: ESG performance and data validation, Transport. Res. E Logist. Transport. Rev., 191 (2024), 10.1016/j.tre.2024.103741, accessed on 11 Jul 2026

[60] Noordstrand A (2018) Experience with robotic underwater hull cleaning in Dutch Ports, Hull PIC 18 (pp 4-9), Redworth, 3rd Hull Performance and Insight Conference, Jun 2018, accessed on 11 Jul 2026

[61] Pinto, A. M., (2020) Disruptions and resilience in global container, Apr 2021, accessed on 11 Jul 2026

[62] OECD (2011) International trade and capital movements in OECD, 11 Mar 2011, available at: http://www.theworldeconomy.org/advances, accessed on 11 Jul 2026

[63] Port Technology (2024). The Suez Canal accident and the state of global shipping, Port News, 19 Jun 2021, accessed on 27 Jul 2026

[64] Sadiq, C.L. Su, G. Parise, K. Sayler, (2024), A comprehensive review on roadmap to seaports: methodologies, area of use, and purposes, Conference Record - Industrial and Commercial Power Systems Technical Conference (2024), 10.1109/ICPS60943.2024.10563883, accessed on 27 Jul 2026

[65] Sarkar, D., (2023). Trade patterns in the 2060 world economy, OECD Economics Department Working Papers, No. 1142, OECD Publishing, Dec 2014, accessed on 27 Jul 2026

[66] Safewise (2023), "Transport and Development", in D. Richardson, N. Castree, M.F. Goodchild, A. Kobayashi, W. Liu, and R.A. Marston (eds) The International Encyclopedia of Geography, New York: John Wiley & Sons, accessed on 27 Jul 2026

[67] Sezer, B. B. et al., (31 January 2023), "Infrastructure and logistics sectors of Bangladesh: Neglected issues (Part 1)". *Textile Today*. Amin & Jahan Corporation Ltd, accessed on 27 Jul 2026

[68] Shipping Technology and Ports (2021) The COVID-19 pandemic vs the 2008-2009 financial crisis, Maritime Economics and Logistics, volume 23, issue 2, No 1, Nov 2021, available at: https://link.springer.com/article, accessed on 27 Jul 2026

[69] Shipnerdnews (2024). Shipping Review Outlook, June 2024, accessed on 27 Jul 2026

[70] S. Y. Kuo, L.-B. Chen, (2024), Utilizing emotional intelligence and artificial intelligence to improve safety behavior in smart port operations, IEEE Transactions on Technology and Society (2024), pp. 1-12, 10.1109/tts.2024.3513775, accessed on 27 Jul 2026

[71] Shipping Technology (2025) Container shipping: continued disruption will ensure carrier profitability well into 2021, BIMCO, 25 February 2021, accessed on 27 Jul 2026

[72] Stopford M (2009). Maritime Economics. Routledge, New York, USA, Nov 2009.

[73] Thermstest (2024). "AIOps: Predictive Analytics & Machine Learning in Operations", Cognitive Computing Recipes: Artificial Intelligence Solutions Using Microsoft, accessed on 23 Jul 2026

[74] Thinaer, (2024), Retrieved from, "Smart Ports of the Future: A Digital Tomorrow". Port Technology International. 2019-09-17, Archived from the original on 2019-10-11, accessed on 11 Mar 2026.

[75] Cognitive Services and TensorFlow, Apress, pp. 359–382, doi:10.1007/978-1-4842-4106-6_7, ISBN 978-1-4842-4106-6, accessed on 11 May 2026

[76] UNCTAD (2021a) Global Trade Update. World trade rebounds to record high in Q1 2021, May 2021, available at: https://unctad.org/system/files/official-document/ditcinf2021d2_en.pdf, accessed on 27 Jul 2026

[77] Y. Yang and Liu, (2022), Resilience analysis of maritime silk road shipping network structure under disruption simulation, J. Mar. Sci. Eng., 10 (5) (2022), 10.3390/jmse10050617, accessed on 27 Jul 2026

[78] C. Zhang, Y. Yang, N. Wang, (2024), Port governance and sustainable development: the impact of port smartization on port carbon emission efficiency, Ocean Coastal Manage., 259 (2024), 10.1016/j.ocecoaman.2024.107485, accessed on 27 Jul 2026

[79] Q. Zhang, W. Li, L. Cai, L. Guo, X. Qi, (2025), A rigid body consensus-based collaborative control framework for dual AGVs in smart port, IEEE Internet Things J. (2025), 10.1109/JIOT.2025.3557952, accessed on 27 Jul 2026