

Analysis of Local Shipbuilding to Evaluate Sustainable Option

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ABSTRACT

Generally traditional shipbuilding is a low-tech, rudimentary and personnel-reliant industry which plays a key role for enhancing forward and backward economic linkages. Shipbuilding is a strategic keystone for many developing countries striving to replicate the economic trajectories of the present dominating industrial leaders like Japan, South Korea, and China. Historically, this sector has suffered from weak global regulations and often faced problems of systemic over-investment for the technological diversity and vast supply chain networks. Regardless of these difficulties, shipbuilding is still a lucrative avenue as it creates significant employment opportunities and thereby contributes substantially to national economic growth. Bangladesh is struggling to maintain sustained progress and global competitiveness despite having a rich maritime heritage and inherent shipbuilding expertise. The country significantly lags behind the leading market players in terms of workforce productivity, technological integration and a coordinated policy framework, although the labor costs are comparatively lower than those in other countries. Nevertheless, the market analysis reflects that, due to the strategic position, Bangladesh can capture the niche markets targeting small- and medium-sized vessels (1,000–20,000 DWT), which are currently underserved globally. In the near future, the global shipbuilding industry is expected to reach approximately USD 500 billion within 2035, and Bangladesh has the potential to contribute up to 2 to 5% of this market by improving workforce productivity, integrating advanced technologies and enhancing safety standards, which would ultimately contribute to national economic growth. This research study will investigate the prospects and challenges of domestic shipbuilding by examining the shipbuilding history, technological advancement, projected global market dynamics, future growth trajectory, and environmental sustainability.

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Introduction

Shipbuilding defines the industry that focuses on the design and construction of ocean-going and inland ships, along with various floating structures [1]. These complex operations are executed in shipyards or dockyards with the facilities of heavy machineries. This sector used to face challenges for weak global regulations and inclination towards over- investment as the shipbuilding yards normally uses diversified technologies, and substantial workforce to contribute to national and global economy. However, considering its scale and strategic importance, this high-level-state- backed sector is always a lucrative domain for many developing countries [2]. After the Second World War, between the decades of 1950 and 1960, Japan heavily concentrated on shipbuilding to rebuild its industrial foundation. Following the same model, South Korea reached the peak of shipbuilding in the 1970s. Later, China adopted the same strategic concept, utilizing huge state -backed investment along with favorable government policies and became the global leader in the shipbuilding sector [3,4]. Since the post-world era, shipbuilding has developed as a crucial strategic industry, with specific growth in the parts of South Asia [3]. Currently, the market is facing the challenges of inflation, geopolitical tensions, excess capacity, low profit margins, market distortions, and persistent subsidization.

In the twenty-first century, the quick growth of middle class across Asia and Africa, coupled with ascending labor costs in China's

shipbuilding industry, is changing the industries landscape. This has created opportunities for developing nations with emerging shipbuilding industries including Bangladesh, Brazil, India, Vietnam, Philippines, and Turkey to capture the larger portion of the market [4]. Notably, in the indigenous shipbuilding history of this region, Bengal is recognized as an early hub of maritime craftsmanship [6]. History says that in the 14th century, on his return trip from Bengal, the famous traveler Ibn Battuta, took along a wooden ship constructed at a shipyard in Sonargaon, Dhaka. European visitor Mr. Caesar Frederick documented that, Chattogram was a prominent hub for ocean-going ship buildings in the middle of the 15th century [7]. Its maritime significance continued through the construction of a fleet of ships for the Sultan of Turkey, in the 17th century, and a large number of vessels for the Mughal naval forces during the Mughal era too. Additionally, in 1805, in the Battle of Trafalgar, Chattogram-built wooden-hulled battleships were effectively used by the Royal Navy. Furthermore, The German Navy's wooden-hulled frigate Deutschland (1000 dwt) was built in Chattogram in 1818 [3,8-9].

Today, modern ports are highly advanced. They are using digital, computerized, and cutting-edge tools such as artificial intelligence (AI), machine learning (ML), deep learning (DL), the Internet of Things (IoT), artificial neural networks (ANN), data science (DS), big data, blockchain, and automation to facilitate management processes and reduce environmental footprint [10]. Smart technologies can optimize logistics, automate numerous tasks, significantly decrease the workforce demands and boost the overall efficiency of the port operations [11]. Moreover, these

technologies can assist in design and construction processes, detect anomalies, predict potential incidents, thereby enhances safety, security, and compliance with global standards [12,33]. They can contribute to reduce resource consumption, minimize downtime, ensure safety, improve quality, and lower the overall expenses. Additionally, sustainable shipbuilding can be practiced by advanced technologies. Moreover, the supply chain dynamics, on-time delivery, and quality control, play a significant role to increase profitability. Therefore, the crucial factors such as quality assurance, safety standards, timely delivery, customer support, and goodwill are essentials for national competitiveness and the sustainable advancement of the shipbuilding industry.

Smart ports and smart shipbuilding are characterized by uninterrupted operations with significantly limited human involvement through the adoption of Artificial Intelligence (AI), automation and digitization [11,14]. This boosts operational efficiency, reduces labor costs and overall ensures the optimal use of resources through data driven precision [15]. Additionally, environment-friendly smart shipbuilding practices focus on reducing carbon emission and protecting marine ecosystem [16]. The incorporation of renewable energy systems and smart technologies in modern shipyards is gradually reducing the environmental impact. Smart shipbuilding and port systems are also designed to accelerate the movement of goods, enhance productivity, maintain uninterrupted information flow and smooth workforce coordination within the broader supply chain networks [17]. Furthermore, following the “open innovation” model, these industries are incorporating new technologies and ideas for continuous improvements in design, operations, construction, production, safety, and efficiency. However, any minor disruption in the production processes in shipyards or workflow in ports might have negative consequences on global trade [15]. Likewise, the global economy may face severe consequences if cyber-attacks penetrate the energy supplies or automated systems. Such risk factors are also substantially applicable to the shipbuilding industry [12].

After the downturn of Europe and America in this sector, Asia continues to dominate the market, despite of various difficulties such as inflation, a critical geopolitical environment, overcapacity, low-profit margins, trade distortions, extensive subsidization, war related crises, etc. Since the post-Second World War era, due to some inherent advantages such as healthy economic conditions, favorable political environment, stable regulations, robust government support, comparatively low labor costs, a wide range of forward and backward linkage industries; few Asian countries - mainly China, South Korea, and Japan have maintained their dominance in the global shipbuilding market. This industry manufactures costly customized vessels rather than mass-produced products such as readymade garments what makes it highly investment-intensive. Consequently, its development and survival in the world market place requires proper government policies, effective strategic management, and positive political environment. Besides, to uphold the strong market position, compliance with safety standards and the maintained of global benchmarks are essentials [11]. Likewise, the local shipbuilding industry also requires a balanced approach that includes visionary strategic investment, robust government backup, incorporation of modern technologies, and a skilled workforce for the substantial growth and to face future challenges. This study will evaluate both local and global shipbuilding trends and will examine the future of the domestic industry based on an analysis of its potential and emerging challenges, adoption of technologies and future market predictions. This analysis will rely on data collected from primary

and secondary sources, incorporating stakeholders’ perspective, a review of the literature, and academic journals.

There are few distinct research questions as mention below:

- What are the lessons learned from global shipbuilding history?
- What is the trend of global shipbuilding market and scope of the local shipbuilding?
- How can Bangladesh optimize the economic benefits from the shipbuilding sector?
- What are the prospect and potentials of local shipbuilding?
- What are the opportunities of local shipbuilding industry?
- What are the challenges of local shipbuilding industry?
- What is the smart and sustainable shipbuilding practice in the globe?
- What sustainable measures are needed for the development of the local shipbuilding industry?

Literature Review

Literature Review. Shipbuilding is a capital incentive, global in nature, diversified, forward and backward linkage oriented, and technology centered heavy industry and which need huge capital investment [1-2,18-19]. Export-oriented shipbuilding mainly smart shipbuilding is inherently a global industry. Bangladesh holds a distinguished heritage of shipbuilding industry, supported by an abundant, cheap, and young work-force. Local shipyards are equipped with modern machinery capable of constructing small or medium ships (10000 DWT) of international standard, maintain the cost approximately 10%-30% lower than those built in Japan, Korea, China and Western countries [4]. But the issue has become a major concern and hurdle in the era of smart technology under the impact of the Fourth Industrial Revolution (4IR). 4IR integrates digitization with physical manufacturing through smart technologies such as AI, ML, DL, DS, IoT, blockchain, digital twin, big data analytics, cloud computing, simulation, augmented and virtual reality, 3D printing, sophisticated materials technology, automation, and human-machine interaction, among other things [12,15]. The development of intelligent shipyards that are not only flexible, resource-efficient, and profit-maximizing but also guarantee tight integration between shipowners, shipbuilders, suppliers, and all other stakeholders within various business and value chains is the main goal of the 4IR in shipbuilding (shipbuilding 4.0) [3,20]. Therefore, in this digital era, a abundant and cost-effective young workforce is not a vital factor for the industrial growth of developing countries. To meet the requirements of the present era in shipbuilding industry, a technology-based skilled workforce with sufficient productivity is vital for the developing countries. If Bangladesh fails to fulfill these requirements, there is every possibility of missing the extent of sustainable economic development in this sector as well as falling behind the global trajectory, despite of having favorable territorial location [33,11].

Research Procedure. This study will examine both local and world shipbuilding trends and will review the capacity and capability of the present and future local shipbuilding industry by meticulous SWOT analysis, ongoing technological advancement, future market predictions and appropriate market segment. By applying mixed method research design and using qualitative, quantitative and policy analysis tools, the study will investigate the overall situation of the shipbuilding industry in Bangladesh. The methodology combines secondary data collection, historical and regulatory review, focus group discussions, quantitative forecasting, comparative benchmarking, and expert validation. This multi-pronged approach is aimed to achieve a comprehensive understanding of the sector’s economic, environmental,

regulatory, and social dimension. The lead researcher of this study is a naval architect by profession, with over two decades of field and executive-level experience in shipbuilding and ship recycling industries including serving as Managing Director, General Manager and work in several shipyards in Bangladesh (KSY, CDDL, DEW Ltd) and global arena (Wuchang Shipyard, Wuhan, China). Corresponding author professional affiliations and leadership roles have enabled direct access to ship recycling yards, regulatory agencies, workers' unions, and international collaborators. This unique position and experience allowed for extensive primary data collection across managerial, technical, and labor domains access that is typically unavailable to purely academic researchers. Author's dual role as both an industry practitioner and an academician from home and abroad further contributed to triangulating qualitative insights with technical and economic data, enriching the validity and contextual sensitivity of the analysis.

Methodology and Focus Group Discussion

Heavy industries are the multiplier of all other SMEs and are a national industrial development. Shipbuilding is a heavy and strategic industry. It needs backward and forward linkages. But for Bangladesh, such linkages are still very weak. There are gaps between the ambition and the capability of the local shipbuilding. The research objective was to evaluate the global shipbuilding trend and ascertain the challenges and the suitable market for local shipbuilding. However, for gathering information, an online Focus Group Discussion (FGD), involving personnel experienced in the respective field, was held. Interesting to know that, through the FGD, important information and ground reality have been discovered on both local and global shipbuilding. The discussion with FGD and resource personnel from home and abroad was very useful and helpful for the research.

In relation to the research objectives, the FGD was held to evaluate the following matters regarding local shipbuilding:

- Trend of global shipbuilding. Evaluate the trend of the global shipbuilding market. Evaluate the local shipbuilding capability.
- Depict the suitable market for local shipbuilding.
- Evaluate the future challenges of local shipbuilding.
- Suitable strategy for local shipbuilding.
- Improvement and Survival local shipbuilding

The FGD and informal discussions/interviews was held many times (more than 100 times) from May 2022 to Mar 2026 and more than 695 participants in different level from home, like Ministries and Officials (MOS, MOE, MOD, MOI, MOE, MOF, MOFA, MOP, DoE, DoL, DoS, etc.), government organization and bodies (CPA,

MPA, PPA, EPZ, Army, Navy, Airforce, BGB, Coast Guard, etc.), Shipyards (ASSL, WMSL, KSSL, KSY Ltd, DEW Ltd, CDDL, BN Dockyard, etc.), Industries and Associations (FBCCI, BGMC, BKMC, BTMC Bashundhara Group, PHP Industry, Walton, RFL Group, etc.), Universities and institutes (DU, BUET, CUET, KUET, KU, NSU, SAU, BMU, BUP, MIST, IUT, Barisal University, Brack University, Daffodil University, Marine Academies, etc.) and from abroad with their participants/representatives like international organization (IMO, UNDP, WB, JICA, ADB, EU, OECD, ABS, CCS, IRS, NKK, BV, Ardent Marine Singapore, Mitsubishi, etc.) and international universities (WMU, Osaka University, University of Yokohama, University of Basel, University of Paris, etc.).

Many important participants and representatives have attended and participated in the discussion and has given valuable information and suggestions. The FDG has conducted either in small group or in individually in different place and time in their convenient due their availability, situation and time constraints. They have attended both individually and small group in different place and different time throughout the study and research work from May 2022 to Mar 2026. A total of 695 interviews were conducted between May 2022 and Mar 2026 to gather multi-perspective insights into the shipbuilding industry of Bangladesh. These interviews included stakeholders from operational, technical, regulatory, environmental, professional and academic domains. The aim was to reflect the full spectrum of experiences, from grassroots laborers to global policy advisors. Table 1 shown below presents the summary profile of the respondents. All foreign experts were interviewed either physically or virtually via structured digital questionnaires and Zoom-based sessions, or sometime provided written responses through standardized forms. Their perspectives were crucial in evaluating how Bangladesh is perceived internationally, where its compliance gaps lie, and what global ship-owners need to consider Bangladesh a long-term recycling destination.

The 33 foreign experts included in the study were selected based on their active involvement in below.

- Classification societies (e.g., BV, CCS, DNV, LR, ClassNK, RINA, IRS, etc.)
- International funding agencies (e.g., IMO, UNDP, JICA, World Bank, ADB, environmental units)
- Technical consultants involved in shipbuilding industry around the globe (Japan, China, South Korea)
- Shipyards (from China, Japan, South Korea, UK, USA, Canada, India, Pakistan, etc.)
- Foreign Universities (WMU, Osaka University, University of Yokohama, etc.)

Table 1: Respondent Categories and Summary Profile

Respondent Type	No	Age Range	Gender (M/F)	Typical Role/Qualification	Location
Shipyard Workers	395	18–50	195/15	Semi-skilled/unskilled laborers	Dhaka, Khulna, Narayanganj, Barisal, Chattogram
Shipyard Owners/Managers	55	35–65	32/0	Business owners, managing directors	Dhaka, Khulna, Narayanganj, Barisal, Chattogram
Engineers/Technicians	95	25–60	90/4	Mechanical/Marine/Naval Architects	Yard premises, BUET, CUET, Foreign
Government Officials	39	30–60	25/3	Ministry of Industries, DoE, BSRB, Customs	Dhaka, Narayanganj, Khulna, Chattogram
NGO/CSO Representatives	34	25–55	19/17	Environmental and labor-rights activists	Dhaka, Khulna, Chattogram
Academics, Researchers	42	30–70	20/2	Professors, policy researchers	Dhaka, BUET, CUET, BMU, DU, etc., Foreign

Foreign Experts	35	35–65	17/3	HKC/EU/IMO consultants, class surveyors	Dhaka, Chattogram, Remote, Online,
Total	695				

History and Trend Analysis of Global and Local Shipbuilding

The Shipbuilding industry began its journey in the 1860s with the rise of industrial economy. In this era, the adoption of iron in shipbuilding construction and the emergence of improved steam propulsion systems made a groundbreaking revolution in this sector. The transformation was trusted by industrialists, as these robust ships could undertake longer voyages with optimized profit. Consequently, sailing vessels were mostly replaced by steamships by the late 19th century [21]. During this time, the United Kingdom became the market leader accounting for approximately 80% of the global shipbuilding market. Over the period 1900 to 1950, other European countries gradually joined the market leader to dominate over the world maritime sector. (Shadab). Till 1945, the continental European countries, particularly Germany, France, and the Netherlands accounted for 20% to 40% of global market. However, after 1986, the European maritime industry started to fall, while the UK's shipbuilding industry had already started to weaken during the first World War. Moreover, after the second World War (WWII), the contribution of United States, to the global shipbuilding industry was 85-90%. It declined to 55-60% by the late of 1910s and finally reached 10% by 1950.

In the 1950s, Japan's shipbuilding industry drew the attention of the global shipbuilding market by strengthening its competitiveness and expanding by leaps and bounds due to its integrated production technologies and substantial domestic demand. The country captured 50% of the market share and remained market leader during the 1960s. However, as per Lloyd's Register, the growth of Japan's commercial fleet was not as rapid as the shipbuilding industry. By 1973, Japan's contribution to the global shipping fleet was only 10%. Conversely, under the flags of convenience system recognized by the IMO and UNCTAD, Japan owned approximately 73% of the global fleet registered under such arrangements [22]. The introduction of open registration under the flags of convenience in the 1970s supported the boom of Japan's shipbuilding industry. According to the renowned shipbuilding expert Martin Stopford, the high competitiveness in the shipbuilding industry, its successful penetration in the export markets, specifically the huge demand of oil tankers from the independent ship owners facilitated the boom of Japan's shipbuilding industry [23].

Moreover, by the 1980's, Southeast Asia was recognized as the hub of the global shipbuilding industry, with the remarkable contribution of South Korea in the maritime sector. At the beginning of the

1980s, Japan accounted for 46.5% of the global share, whereas Europe contributed to 33.5%, and South Korea accounted for less than 4%. However, at the end of the 1980s, China accessed this market for the first time with a 2.3% share of the global market, whereas Japan held its strong position with 43% and South Korea accounted for 22%. By 1980, Europe's share had dropped to 10%, while the three South Asian countries collectively accounted for 70% of the global market [24]. Thereby, at the end of 1980s, the global leadership completely shifted from the West (Europe and USA) to the East (Asia).

The growth of the world shipbuilding industry is not consistent; rather, it has fluctuated over the times. After the Second World War, United Kingdom (UK) was the market leader. In the 1960s, Japan emerged as the dominant market player of the industry, but later lost its peak position to South Korea. Key factors such as comparatively lower labor costs, visionary shipbuilding strategies, robust government support, and a favorable currency exchange rate, played a significant role in making South Korea the global leader by 2003 [25]. Later, in 2009, a significant year marked by the global financial crisis, China surpassed Japan and South Korea to become the global leader following the proven tactics and methods [4]. China intelligently leveraged the global crisis to boost its shipbuilding sector. Initially the country concentrated on niches market such as cargo ships, tankers, and container ships. Historically, countries with comparatively high labor costs, have been unable to maintain their position in shipbuilding sector when governments withdraw their support. Even the strong domestic policies cannot sustain the industry without sufficient government subsidies. The drop of United States, United Kingdom, and other European nations in shipbuilding industry reflects the trend [18,23]. Their fall began in the 1960s, and today they only build military vessels and luxury ships such as luxury yachts and cruise liners. Presently, with over 45% of the market share, China dominates the global shipbuilding industry, using its technological prowess, shipbuilding quality, that has earned the client's confidence worldwide. South Korea and Japan account for 25% and 20% global market share and secure second and third place globally, respectively [6,26]. Usually, shipbuilding is a slow-moving industry defined by inconsistent market expansion as well as environmental and economic uncertainty. In addition, recent events like the COVID-19 pandemic and ongoing geopolitical conflicts, have increased the uncertainty in the shipbuilding industry. The trends in worldwide shipbuilding leadership are shown in Table 2 below, along with their likely reasons [27].

Table 2: Trend of Market Leadership and Analysis of Global Shipbuilding

Duration of Shipbuilding Leadership	Country	Causes of Lost Leadership
1860's-1950's	UK (Great Britain)	Local shipbuilding has not been modernized. The cost of labor for shipbuilding increases. Reduce your own fleet. lost its position as the world's leading political and economic
Mid1950's-mid1990's	Japan	High expense of building an outdated ship. High labor costs for shipbuilding. Reduce shipyards' R&D expenditures (less than 1 percent). widen the discrepancy between steel supply and demand. Raise the price of steel. Reduce government support.
Mid1990's to 2009	South Korea	High labor costs for shipbuilding. Widen the discrepancy between steel supply and demand. Raise the price of steel. The competitiveness of Korean shipbuilding has deteriorated due to the increase of the won, the country's domestic currency. Cut back on government assistance.
Since 2010' (it was earlier than Chinese planned)	China	Low cost of human resources. Low labor costs for shipbuilding. High labor costs for shipbuilding. Ambitious government initiative to enhance shipbuilding. expanding shipbuilding facilities. Excellent government strategy and policy. Government subsidies should be increased.

The indigenous shipbuilding history of Bangladesh is ancient and glorious. Chattogram, with its adequate shipbuilding facilities, used to build ships of up to 1000 dwt during the early 1800s. Though the Pakistani era of Bangladesh's shipbuilding history was dominated by public shipyards, the private industries have become pivotal in this sector in recent years. Currently, around 100 shipyards exist in Bangladesh that can build fishing, coastal, and inland vessels [2,28]. Moreover, aided by FAO, the Narayanganj-based High-speed Shipbuilding and Engineering Company (HSEC) Ltd handed over eight self-built food grain carrier vessels to the Bangladesh Inland Water Transport Corporation (BIWTC) in 1979. Furthermore, four deep-sea fishing trawlers were fabricated by HSEC and Japan's Mitsui Engineering and Shipbuilding Industry (MESI) jointly. In addition, by upgrading the facilities, the Western Marine Shipyard Ltd (WMSL) in Chattogram and Ananda Shipyard and Slipways Ltd (ASSL) in Dhaka shipbuilding firms have started foreign trade in recent years [24]. Notably, in 2008, Bangladesh was included in the list of ship exporting countries when ASSL exported its first ocean-going cargo vessel of 3500 DWT capacity to Denmark and Mozambique, together with small ferries and boats [29].

Bangladesh with its rich history, low labor costs and indigenous shipbuilding capabilities, have made notable progress and established itself as a small yet competitive player in the global market. Over the past few decades, the country has evolved from primarily focusing on ship recycling to becoming a shipbuilding nation. The local shipbuilding industry holds considerable potential and promise. Bangladesh has, however, found it challenging to keep up with the ongoing technological developments in shipbuilding around the world. Additionally, several recurring difficulties and common issues have impeded its progress [12,18]. It is anticipated that if the country focuses on selecting the right types and sizes of ships, captures even a small share of the global market, and addresses existing challenges,

it can create a shipbuilding sector that is sustainable. Furthermore, to become a sustainable ship-exporting nation after meeting domestic demand, Bangladesh must develop its shipbuilding sector to comply with international standards. Although some general studies exist on both local and global shipbuilding industries, no research has specifically focused on this particular issue. Therefore, this study aims to analyze global shipbuilding trends and provide recommendations to help the local shipbuilding industry achieve sustainable development.

Nearly a hundred of indigenous dockyards and shipyards are scattered across Bangladesh which are primarily managed by private industries, except for three public shipyards administered by the Bangladesh Navy. The private shipyards mainly use the salvaged materials including steel plates, machinery, and various components from the ship recycling industry in Bhatiyar, Chattogram [21,30]. The local industry comprises around 200 shipbuilding and repair firms, ranging from very small traditional workshops to medium-sized shipyards generating employment opportunity for several hundred thousand skilled and semi-skilled workers directly and engaging around two million people indirectly in various capacities. Moreover, the local shipyards have the facilities to build a diverse range of ships in different types and sizes, with four shipyards competent at constructing vessels exceeding 10,000 dwt. In addition, over the several decades, Bangladesh has maintained its global position among the top three maritime manufacturing nations [10]. For several years, the country has proudly maintained its ranking between 10th and 15th globally. However, for the sustainable development of this sector, Bangladesh needs to identify suitable international markets, overcome existing challenges by adopting effective strategies, enhance productivity, integrate smart technologies, and develop a skilled and competent workforce [4]. These are essential and undeniable factors for becoming a sustainable and competitive player in the global market.

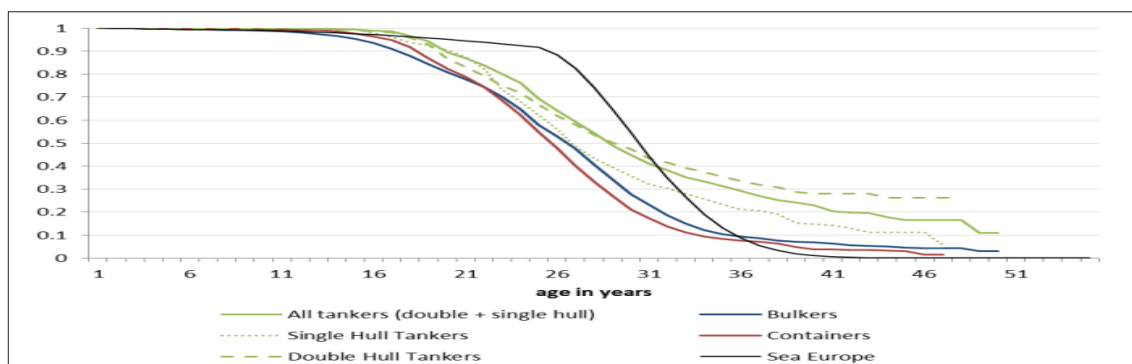


Figure 1: Survival rate by ship age (19,31-32)

Analysis of Future Vessel Requirements and Global Demand

Traditionally, the scrapping of vessels depends on various factors including the average operational lifespan of a ship, as well as the policy-oriented component like environmental rules, bunker fuel costs, technical obsolescence, freight rates, new-building pricing, EOL or used ship prices, and demolition prices [9]. Normally, the operational lifespan depends on the types of ships and the region. Usually, the disposal age of a tanker ranges from 25 to 30 years, for a container ship it is 17 to 26 years, where the bulk carriers have the longest scrapping age, ranging from 20 to 35 years. The percentage of scrapped ships escalated from 1% to 3.5% between 2006 and 2012, and again dropped at 2% in 2014. Despite these fluctuations, overall disposal rates stayed low, which is consistent with Figure 1's rising average age of scrapped vessels. As shown in the graphic, survivability rates by ship type and age are used to anticipate future trends in vessel demolition. 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 hulls are required by IMO standards for increased safety, single-hull tankers are decommissioned early. Global GDP, global seaborne trade, and global active fleet growth trends are shown in Figure 2 [33,8,34,32,27]

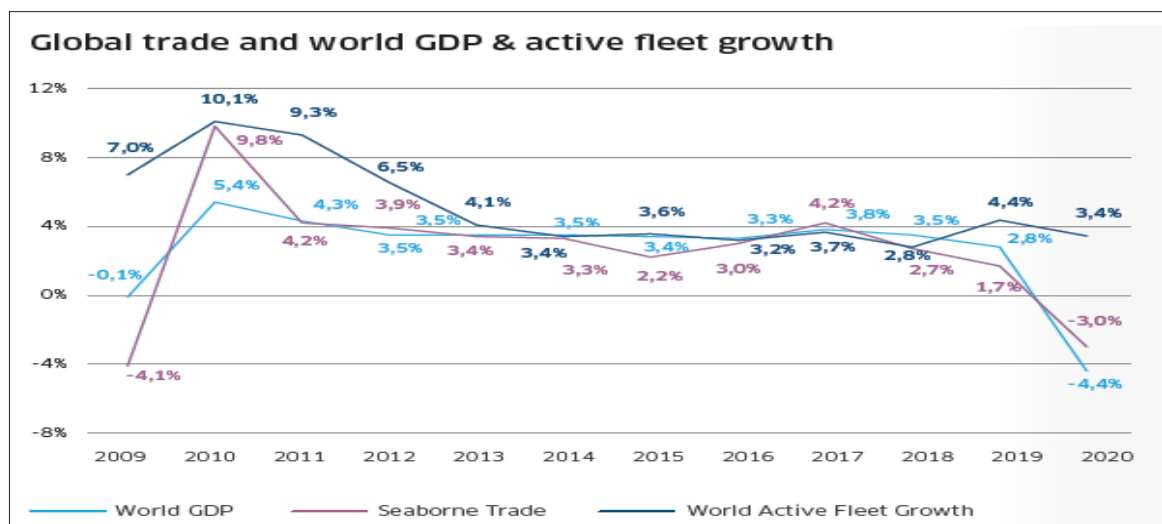


Figure 2: World GDP, Global Seaborne Trade and Global Active Fleet Growth [6]

International freight transport activity up to 2050 under three world trade scenarios based on differing trade liberalization levels has been forecast by the International Transport Forum (ITF) and OECD using a network model [31]. ITF used equilibrium-based OECD Economics Department international trade scenarios. Figure 3 shows ITF, Sea Europe, and SAJ seaborne trade predictions through 2035. By 2035, ITF's network model predicts 20.8 billion tons of seaborne trade. By the same year, Europe and SAJ expect seaborne trade to reach 16.2 billion tons [36-41]. Additionally, Figure 4 below shows the trend of domestic investment in local shipbuilding across different countries from 2010 to 2015 [18].

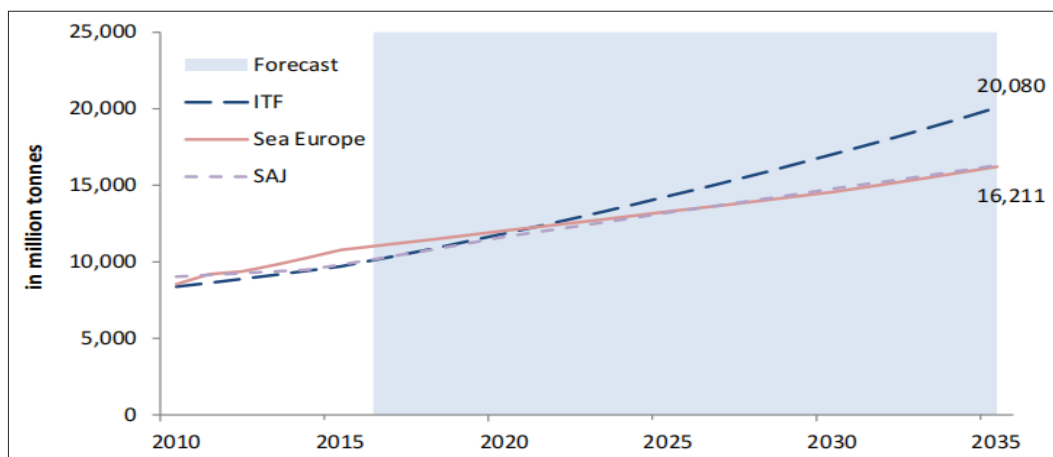


Figure 3: Forecast of seaborne trade from 2010-2035 by IFT, Sea Europe, SAJ, OECD [31,36-41]

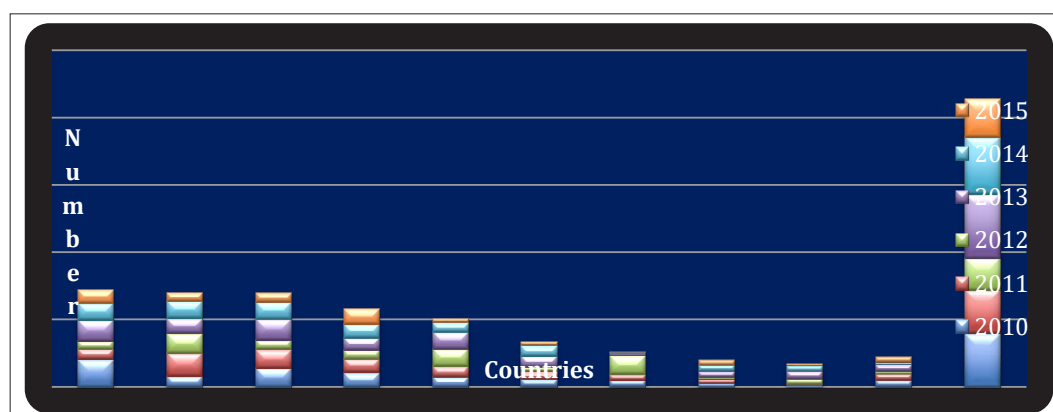


Figure 4: Trend of investment in local shipbuilding by own countries in 2010-2015 [18]

Based on demolition rates and historical data from 2016 to 2035, the estimated future vessel requirements is presented in figure:5. The new vessel needs are expected to total around 690 million GT, with 200 million GT for tankers, 315 million GT for bulk carriers, and 170 million GT for container ships. The graph projects that from 2030, the disposal-related requirements will decline, which may be due to global crisis scenario. Moreover, total new-building requirements from 2016 to 2035 are projected at about 1500 million GT: 460 million GT for tankers, 710 million GT for bulk carriers, and 335 million GT for containers, as per Figure 6. Notably, population and urbanization act as catalysts for the developments of seaborne trade. 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, with over half living in cities, and by 2030, about 70% of the global population will be urban [19,34]. A higher urban population produces a strong domestic market for goods and services and boosts economic growth and innovation, which should benefit seaborne trade.

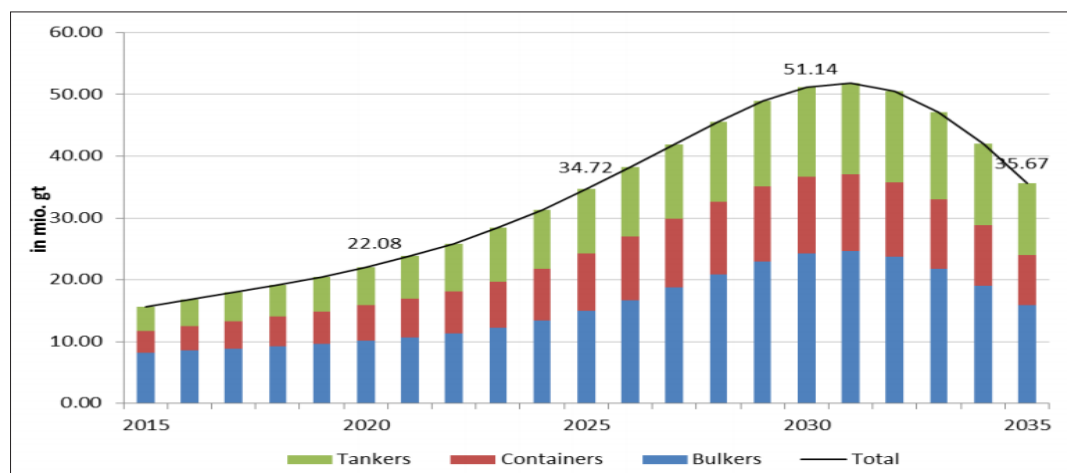


Figure 5: Forecast of future ship requirements related to ship disposals within 2015-2035 [19,41,42]

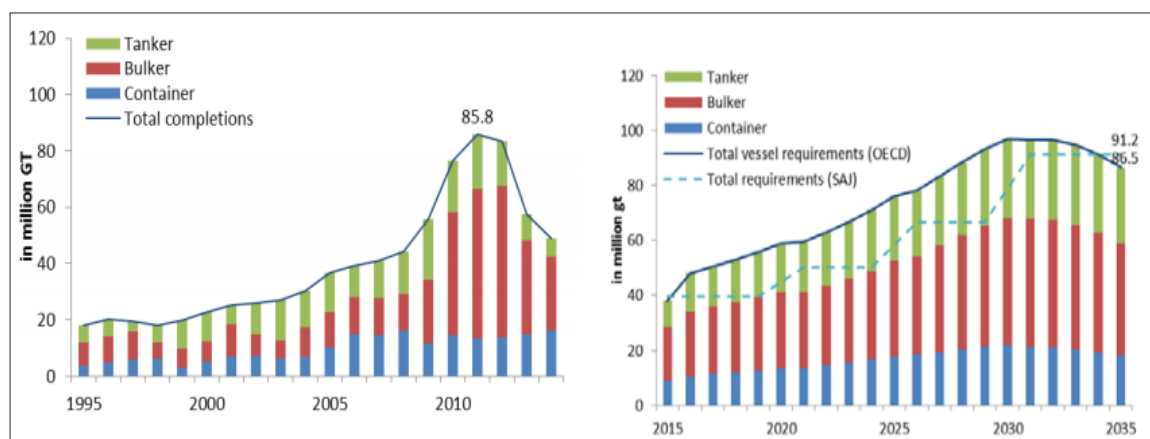


Figure 6: Completions (1995-2014) and forecast of future vessel requirements within 2015-2035 [34,42-44]

Forecast of Global Shipbuilding Market

Global economy mostly depends on the seaborne trade, where ships act as the primary mode of transportation. Currently, the shipbuilding sector is considered as the most profitable industry globally and contributes significantly to the national economies of many countries. According to Zakaria et al., [45], “R&D collaborations across business lines are driving the creation of innovative solutions and services that other units or groups can leverage”. Today, a high level of technological expertise is needed for designing and building modern specialized ships. For example, the mobile airports at sea such as nuclear-powered aircraft carriers can accommodate hundreds of aircraft and serve globally for decades without refueling. Likewise, nuclear submarines can stay underwater for a six month at a stretch and can strike targets from deep sea without being undetected [4]. Modern, large sized cruise ships, oil tankers, and bulk carriers look like floating cities in the deep sea. The key factors such as the GDP growth, economic growth, rising global seaborne trade, rising demand for cargo transportation by sea, trade agreements, technological advancements, market trends related to end-of-life (EOL) ships, marine regulations, and maritime transport sector automation are steering the world shipbuilding industry [46]. However, the market expansion may be impeded by the transportation and inventory costs, environmental concerns, and international crises like the COVID-19 pandemic, the Russia-Ukraine war, and the Israel-Iran conflict [33]. Figure 7a explains the forecasted global commercial and military shipbuilding market and indicates that the market is expected to expand to USD 176.1 billion by 2027 at a CAGR of 3.4 percent from 2017 to 2027. This rise is driven by seaborne trade, cargo transport demand, trade agreements, ship design technology, and automation [46, 47]. In comparison, Research and Industry (2022) predicted the worldwide shipbuilding market to be USD 241.5 billion in 2021. As seen in Figure 7b, their forecasts show the market reaching USD 271.4 billion by 2026, a CAGR of 2.4 percent. Large-scale LNG projects are expected to boost shipbuilding orders [13,49]. Increasing VLCC (Very Large Crude Carrier) demand, harsher environmental rules, the need to replace older ships, and vessel efficiency measures are expected to drive demand for new container boats [50].

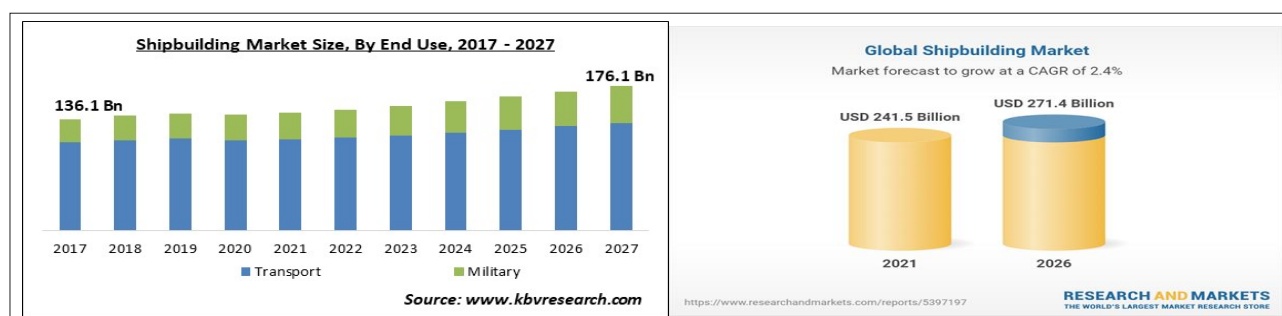


Figure 7a and b: Forecast global shipbuilding market in billion USD and with CAGR [49]

Today the global shipbuilding market is undergoing a transformative phase driven by sustainability and technological advancements. North America remains the largest market for shipbuilding, driven by robust commercial shipping activities. However, technological advancements and rising demand for energy-efficient vessels are key drivers shaping the market landscape. Currently, the commercial shipping section continues to govern, while the defense section is perceiving rapid growth due to geopolitical tensions. As per MRFR investigation and forecast, the shipbuilding market Size was estimated at USD 201.4 Billion in 2024. The shipbuilding industry is projected to grow from USD 226.3 Billion in 2025 to USD 500.63 Billion by 2035, where exhibiting a compound annual growth rate (CAGR) of 8.26% during the forecast period 2025 to 2035 and that has shown in figure 8 below [51]. The shipbuilding market is progressively concentrating on sustainability initiatives. Shipbuilders are adopting eco-friendly materials and advanced technologies to minimize environmental impact. AS a result, such trend echoes a broader commitment to reducing carbon footprints and conforming with harsh regulations. In the global shipbuilding market, the application segment is primarily dominated by commercial shipping, and that remains to represent the largest share compared to other sections like defense, leisure, fishing, and research. Additionally, the commercial shipping sector paybacks from the increasing global trade and the need for efficient transport solutions, leading to important investment in larger and more advanced and eco-friendly vessels. In the meantime, the defense segment is gaining traction as nations prioritize maritime security and increasing defense

budgets. And that creating extensive demand for naval vessels and global shipbuilding market forecast up to 2035 has been shown in figure 8 below [51].

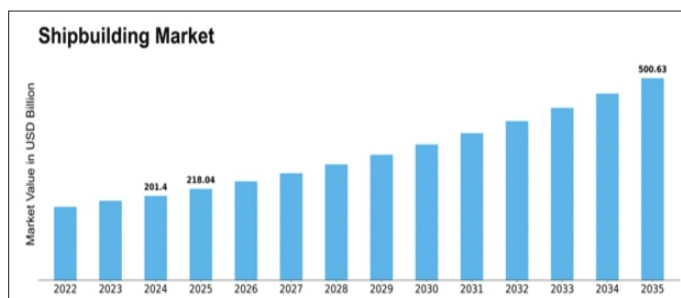


Figure 8: Global shipbuilding market size and prediction up to 2035 [51]

Suitable Market for Local Shipbuilding

The rapid expansion of middle class across Asia and Africa, causes the rising of shipbuilding labor costs in the 21st century. Consequently, China's shipbuilding market share, particularly small and medium-sized container ships, cargo boats, tankers, and multipurpose ships, is gradually declining and their position in this sector may be dropped significantly in the near future [2,4]. This change has created opportunities for the major shipbuilding countries like Vietnam, the Philippines, India, Bangladesh, Myanmar, Australia, Turkey, and others. Thus, to analyze the promising markets for Bangladesh, empirical research has been done, using quantitative and qualitative data collection approaches, including Focus Group Discussions (FGDs) multinational merchant seafarers and personnel from shipping companies in Bangladesh. Experts opined that Bangladesh is well-positioned to serve the niche market for 3,000–10,000 DWT small container ships, tankers, cargo vessels, multipurpose ships, and special-purpose ships. Bangladesh may penetrate this market with lower prices as this part is considerably ignored by the major international shipyards.

The niche markets consist of the vessels ranging from 1,000 to 2,000 DWT and from 10,000 to 20,000 DWT, including multipurpose, container, tanker, and cargo ships, play a significant role in the maritime sector. Therefore, the experts suggest that Bangladesh might target this ship market, as it has profitable future in the coming years. Additionally, for viable foreign trade operations, Bangladesh needs to develop its own merchant fleet, generating a new domestic market opportunity. Notably, sea area of Bangladesh, spanning approximately 118,813 sq. km, has immense strategic importance, as it serves as the primary direct connections to the rest of the world during regional crisis [24]. The Presence of Bangladesh Navy and Bangladesh Coast Guard across the sea area, is essential to maintain and safeguard the vast maritime zone of Bangladesh. These forces deploy ships at sea to address both the traditional and non-traditional security threats. Furthermore, landing crafts are unavoidable for maritime troop transportation. Thus, military vessels are needed for operational readiness in peace and conflict and opens up a promising niche market for BN-operated and private shipyards, and the country's extensive inland and coastal commercial vessel fleet.

The scale of the global shipbuilding industry is approximately USD 200 billion. The niche market segment accounts for around

USD 20 billion. Reports of UNCTAD, the World Bank, WTO, and OECD support that the global demand for container ships of various sizes is expanding steadily. However, countries like Bangladesh have opportunity to control this demanding market. In the near future, worldwide demand is projected to require a substantial number of new vessels, predominantly small to medium-sized categories. Furthermore, according to IMO regulations, the present fleet of single-hull tankers need to be demolished urgently which will create additional requirements for new vessels in this category. However, due to the rising of shipbuilding labor costs, China, the major market player, is predicted to gradually relinquish a portion of its small and medium-sized shipbuilding market-share. Thereby, Bangladesh may grab this opportunity to grow its niche ship building industry by using its young and low-cost labor force. Since 2009, Bangladesh's the small and medium-sized ships and boats have been exported to the various countries around the world. Notably, Bangladesh has the potential and capacity to capture at least 2% of the global shipbuilding market by 2030, yielding an annual export value of approximately USD 4 billion [11]. This sector can be utilized to generate USD 2 to 4 billion per annum by developing a skilled workforce, ensuring strategic government investment, and adopting meticulous planning. Currently, it is evident that, technological advancements such as digitization, robotics, IoT, AI, machine learning (ML), deep learning (DL), and data science can significantly enhanced productivity and operational efficiency in shipbuilding. Thus, increasing labor productivity and strengthening a skilled workforce are vital for sustainable growth of this industry [4]. Moreover, adherence to safety standards and global compliance is crucial for maintaining competitiveness in global markets [12]. Bangladesh must enhance its capability to meet the emerging challenges of 21st century and ensure its footprint in the global market.

Smart Port and Smart Shipping

The rise of smart cities driven by urban growth and rapid technological advancements has paved the way for smart ports. This modern concept utilizes the data-driven technologies, automation and digitalization to optimize logistics, enhance security, and reduce environmental impact [8]. Sophisticated digital tools such as Block chain, AI, ML, DL, DS, IoT, and big data sensors are being incorporated into port operations to facilitate the global trade [11]. 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 utilized in these endeavors [15]. Artificial Intelligence 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 [52]. In near future, Artificial Intelligence and smart technologies will be essential components for the future ship, shipping, and shipbuilding industries [12]. AI transforming shipping sector and future port operation has been shown in figure 9 below.



Figure 9: AI transforming shipping sector and future port operation [53,54]

Artificial Intelligence drives machines to sense, interpret, and act intelligently. Machine learning (ML) is an algorithm that strengthens AI system by analyzing data from the various sources [12]. It was promoted by Arthur Samuel in 1959. ML is also extensively used to combat spam, scams, and phishing [55]. AI algorithm is a potent tool for optimizing routes and schedules based on real-time traffic, weather, and vessel characteristics, thereby reducing transit times and fuel usage. DL is defined as a multi-layer neural network that is modeled after the human brain [36]. ANNs are strong prediction tools that link causal factors and analyze massive data sets of natural phenomenon data and their possible influences. Data science integrates multidisciplinary fields and uses various methods to evaluate and extract information from data. Today, autonomous ships monitor the ocean using AI-driven satellite data analysis, passive acoustics, remote sensing, and other environmental monitoring technologies that blend ML or DL [23,56]. In Modern port operations, ML, DL, ANN, or DS are used to boost efficiency, reduce costs, and enhance overall performance. These technologies improve port administration through data-driven decision-making, predictive analytics, and automation [14]. In a broad sense, AI enables machines, specifically computer systems to behave intelligently [57]. Today, industry and academia are increasingly dependent on AI technology, just as their dependence on steam engine, internal combustion engine, electricity or computers [12].

Artificial Intelligence and its related technologies are used in modern port development to incorporate automated mooring systems, shore power connections to reduce emissions, and intelligent, energy-efficient lighting systems. It highlights the ongoing modernization of port infrastructure to meet current demands. Besides, smart ports highly reinforce on improving security. Moreover, assessing and modernizing of port management software is essential, encompassing yard management, berth scheduling, and terminal operating systems (TOS). Notably, maintaining and operating various infrastructure and services

to ensure smooth cargo flow, safety, security, and environmental sustainability are strongly dependent on the effective use of port facilities. Today, digitalization is playing a pivotal role in the port facility management. Innovations such as collaborative platforms for stakeholder coordination and Port Community Systems (PCS) exemplify the adoption of smart technologies. To optimize port operations, smart ports employ digital tools like automation, sensors, data analytics, and the IoT. These technologies enable real-time tracking of cargo handling, infrastructure status, and vessel movements, ultimately improving operational efficiency and minimizing delays.

Currently, various port activities, such as cargo handling, customs processing, and vessel scheduling, are integrated seamlessly through advanced technologies. The use of modern technology ultimately boosts overall efficiency and reduces operational delays. In addition, to collaborate and share information, the Port Community System (PCS) is highly reliable to the Port authorities, shipping firms, terminal operators, customs agencies, and logistics providers. . PCS increases transparency, streamlines workflows, and facilitates the efficient movement of goods through the port. Smart asset management solutions employ sensors, RFID tags, and GPS tracking system to monitor the location, condition, and utilization of cranes, vehicles, containers, and port infrastructure to enable this shift [15]. These systems help extend the lifespan of critical equipment, enable proactive maintenance, and improve overall asset utilization. Predictive maintenance techniques are increasingly being implemented, where algorithms analyze sensor data, maintenance histories, and operational performance to anticipate potential equipment failures and schedule repairs in advance. This strategy not only increases the reliability and safety of port operations but also minimizes downtime and optimizes maintenance costs. Big data analytics, AI, and IoT sensors enable real-time port infrastructure and equipment monitoring. ML and DL algorithms can also predict cargo demand based on previous trends, helping ports manage inventory, labor, and resources [10].



Figure 10: An automated port and their smart activities [58-59]

Driven by the rapid adoption of smart technologies, the maritime industry is expected to see a rise in autonomous vessels navigating global maritime domain. These intelligent ships are capable of enhancing safety, reducing operational expenses, improving management, and boosting overall efficiency. Moreover, the incorporation of Artificial Intelligence (AI) and other smart technologies in the present port can streamline the port operation. One of the smart technologies, like IoT, can deliver real-time information on vessel performance, cargo status, and environmental conditions, which is analyzed by AI algorithms to optimize the port operations [11]. In addition, sustainability in the maritime industry will be ensured by AI, through fuel usage optimization, pollution reduction, and supply chain efficiency. AI-driven solutions will help shipping businesses meet environmental rules and sustainability goals. AI can help to construct more advanced predictive analytics solutions. These technologies ultimately support the industry stakeholders in making data-driven decisions and anticipate future trends through market dynamics. However, AI, ML, DL, DS, blockchain, and other smart technologies require substantial hardware, software, and professional labor investments. These high startup costs may hamper small and medium-sized shipping enterprises. The management and processing of large-scale data during technology integration raises privacy, cybersecurity, and safety risks. An automated port and

their smart activities have been shown in figure 10 above [58-59].

Sustainable Global Shipbuilding Practice and Lesson for Local Shipbuilding

Normally, the lifespan of a ship is around 30 years. Currently, the ship owners and operators strive to ensuring the safety and long-term operational reliability of their fleet by maintaining compliance with existing regulations and ensuring readiness for future standards [60]. Smart ships have the capacity to maximize onboard and onshore operations by digitizing alarm monitoring, power management, dynamic location, integrated navigation, and electronic engines. They provide excellent operational efficiency, enhanced safety, and greater environmental sustainability. This shift causes the expansion of data quantities and frequencies [61]. Developing intelligent ship mainly rely on the collection, analysis and application of data. Data are collected, analyzed and delivered to the appropriate stakeholders at the right time to support accurate decision-making. The dashboard of the smart ships can display the data for insights, notifications, and alerts and can also forecast and simulate optimal scenarios to improve ship performance understanding and operational decision-making [62]. Smart Shipyards and their activities has been shown in figure 11 below.



Figure 11: Smart Shipyards and their activities [63,64]

Modernizing existing ships through advanced technologies and turning them into ‘smart’ ships paves the way for addressing this challenge. By embracing advanced technology and digital tools, the maritime industry can improve efficiency, reduce costs, meet regulatory standards, and boost safety measures [65]. Moreover, Modern, intelligent shipyards provide sophisticated solutions that allow clients to leverage cutting-edge technology and stay competitive. However, smart ship technology marks a significant advancement in the maritime industry by integrating IoT, AI,

DL, ML, big data, and blockchain into ship systems, thereby boosting the overall operational efficiency [66]. Smart ships use digital technologies and AI [67] to improve productivity, reduce environmental impacts, and optimize working efficiency. They are able to minimize human error, enhance environmental consciousness, and prevent equipment failures, thereby improving overall safety through advanced sensors, real-time AI-driven data, and predictive maintenance systems. Additionally, personnel safety and operational efficiency increase by the smart system

by reducing operator workload with simplified reporting and better navigational support. Moreover, preventive maintenance to minimize costly breakdowns is controlled by AI-driven data analytics. Additionally, smart ships are capable of implementing robust cyber security measures and thus safeguard against cyber threats, thereby overall operational safety is ensured [68].

They can provide real-time tracking and control of emissions, thereby aiding compliance with environmental standards. Notably, smart ships are increasingly adopting clean energy solutions, including hybrid propulsions and renewable energy systems. They play a significant role in promoting the sustainable maritime industry through operational optimization and emission reduction. They are designed to accommodate changing regulatory standards, reciprocal to the new technologies, and thus address evolving standards and emerging challenges [69]. Smart ships are capable of precisely monitoring and controlling emissions and generating detailed reports on performance and emissions, thereby, facilitating regulatory compliance. Presently, smart ship technology significantly enhances safety through real-time monitoring and AI analytics, which can identify hazards, predict equipment failures, and generate early alerts for the crew [70]. However, by integrating the technologies IoT, AI, ML, DL, Block chain, and big data, smart shipbuilders are committed to innovation, providing clients with cutting-edge smart ship technologies to meet future maritime demands [71]. Smart shipyards provide advanced solutions to navigate modern maritime complexities. Embracing these technologies helps ship owners enhance efficiency, safety, and environmental sustainability ventures [72].

Modern digital system, supercomputer code and advanced technological infrastructure are the key components of smart ships. They support innovation and promote a more sustainable environmentally friendly supply chain. In this modern age, many international commercial contracts may be transformed into smart contracts, coded and executed by computer system, thus collectively contribute to the smart shipping systems [73]. However, in response to the proposal put forward by the several member states in 2017, the Maritime Safety Committee (MSC) of IMO, agreed to incorporate the Marine Autonomous Surface ships (MASS) in the IMO regulatory framework [74]. Advanced information technology, the vital factor of the 4th industrial revolution, promotes the development of autonomous vessel systems and the technologically advanced countries like China, the EU, Korea, and Japan are leading this sector through public-private partnerships [75]. In this modern age, smart ships are transforming the maritime sector and its key components by revolutionizing ship design and operations, eventually affecting shipbuilders, shipping companies, owners, system providers, and other stakeholders in the maritime technology industry [76]. Application of real-time remote vessel monitoring systems will boost safety, efficiency, trust, and global supply chain integration. It increases revenue and savings. Using AI in ships will enhance vessel autonomy; improve sailors' environmental awareness, reduce human errors and accidents. By modernizing decision-making algorithms and management systems smart ships are expected to lower marine accidents caused by man-made mistakes [77].

- Integrated with blockchain technology and IoT devices, smart contracts support transparent shipment tracking across the entire shipping value chain. They modernize the logistics systems as well by automating procedures, improving security, and providing real-time visibility updates [78]. A data centric approach expands the value chain, reduces the maintenance

costs enhance safety and efficiency in operations strategies [79]. Blockchain based smart contracts are capable of storing unchangeable and transparent records of all shipment details throughout the transportation process, thereby authorized stakeholders can track shipments in real time easily. The use of cryptography and consensus protocols ensures data integrity and authenticity, preventing fraud and unauthorized access, which helps foster trust across the supply chain participants [80]. However, issues like scalability, system integration, and regulatory compliance need to be addressed to facilitate broader implementation.

- Coupled with big data analytics, augmented reality provides a realistic and integrated experience for ship navigation. It presents the real-time view of the physical environment through virtual visual elements such as graphics, videos, and GPS data, to render the surroundings data [81].
- Maximization of ship and fleet operations needs analysis of various types of available sensor data including position, speed over ground, wind speed, fuel flow, shaft torque, shaft RPM, and emissions data are [82]. Smart sensors and satellite communication create an integrated network between onboard and on-shore systems, facilitating comprehensive condition
- Today, big data analytics is used to address the present challenges and improve decision-making in ships, shipping, and ports, resulting in improved safety, efficiency, and productivity. Over the past decade, the market pressure for transparency and increased ship-shore connectivity, the mandatory adoption of ECDIS, and the implementation of the EU MRV legislation has transformed the industry, making it increasingly depend on data transmission and knowledge collaboration [84].
- Cloud technology optimizes off-site and on-site workforce management, boosting operations, communication, and collaboration. Using cloud technologies, ship-owners and maritime organizations can manage centralized data systems and implement global data governance policies.
- Integration with IoT devices enables the collection of real-time data on shipment conditions and locations, which is automatically processed by smart contracts [85], thereby improving decision-making and optimizing routing.
- Supply chain management is increasingly being reshaped and transformed by blockchain, as it provides live tracking, enhances security, and facilitate automation via smart contracts. It enables the stakeholders to monitor product movement from origin to destination, thereby reducing fraud and ensuring data integrity [86]. It simplifies compliance check, streamlines workflows, decreases delays and manual efforts, provides equal visibility to all stakeholders such as manufacturers, suppliers, retailers, and regulators [87].
- To achieve net-zero emissions by around 2050 by reducing global greenhouse gas emissions from ships, IMO has established a legally binding framework [88]. GNG strategy of IMO aims lowering CO2 emissions per unit of transport effort from 2008 levels, thereby international shipping's carbon intensity is expected to drop by at least 40% by 2030 and reach net-zero GHG by 2050 [89].

The world economy is strongly reliant on maritime transport. Powered by a growing and more prosperous world population, the seaborne trade is projected to increase by approximately 35% by 2050. However, a shift towards a circular economy is increasingly influencing the sea trade, thereby reducing the carriage of coal and oil. On the other hand, driven by the rapid

expansion of specialized vessels supporting offshore wind projects, the market for container ships and gas carriers is expected to grow significantly. In near future, two important megatrends—Sustainability and Digitalization, will undoubtedly shape the future of the maritime industry [90]. Shipping is the most energy-efficient mode of transporting large cargo over long distances. However, the international shipping accounts for about 3% of worldwide greenhouse gas emissions, comparable to aviation yet it has a greater contribution to global sulfur and particulate matter levels [91]. The shipping industry is undergoing a rapid technological advancement. Smart ships and modern maritime technology hold great significance in today's maritime landscape [92]. After the launching of CSIC China's unmanned freighter, Japan also launched a Smart Ship Application Platform project [93], and European Munin, funded by Rolls-Royce, aims to deploy an unmanned vehicle by 2035. Yara Birkeland and Kongsberg envision automated maritime deliveries for replacing 40,000 trucks. Hyundai shines at maritime ICT. Finland is forming AAWA with Inmarsat and DNV-GL [94]. To achieve the IMO's Degree 4 automation goal, fully autonomous ships may be surfaced within 10-30 years [95].

Smart ships utilize advanced materials such as glass fiber, carbon fiber, and reinforced polymers (GFRP) in hull plating. Additionally, they develop innovative structures, including adaptive damping systems for thrusters and composite sandwich panels with Phase Changing Materials (PCMs), a thermoregulating material, for better insulation in refrigerated cargo ships [96]. Digital replicas of ships and their components, enable concurrent development with physical counterparts, supporting detailed analysis and continuous lifecycle optimization [97,98]. Using automation in shipbuilding, including robot for welding and assembly, as well as integrated systems for power management, navigation, and alarm monitoring, enhances operational efficiency [99]. Smart technologies optimize performance under various conditions such as changing cargo loads, shallow waters, and waves, while lowering maintenance costs by using corrosion-resistant materials and increasing cargo capacity by employing lightweight composites [100]. However, not all smart ships are fully autonomous. The integration of autonomous vessels is a critical component of the "smart ship" concept, utilizing advanced digital systems for self-operation [101].

Throughout the past decade, shipping companies have shown renewed interest in high-speed crafts (HSCs) for short-haul passenger and special-purpose cargo vessels. C-drive configurations are used with medium-speed engines today. One reduction can be achieved by a bevel gear within an aluminum alloy box inside the hull (upper gearbox), while a second reduction is performed by a contoured box at the lower end of the stern strut. The bottom gearbox consists of contra-rotating propeller shafts (figure 11). The thruster provides propulsive force and azimuth rotation for enhanced maneuverability in harbor and port and cruise control in high-speed vessels, monohulls, and catamarans. The thruster enables azimuth rotation through the two double-acting hydraulic actuators, with their respective ends attached to the strut and the hull structure. It ultimately simplifies the construction process and helps to reduce the overall weight and cost [102]. The azimuth rotation capability of vessel's POD removes the necessity for rudders and improves the high-precision steering. Lower gear box consists of a special drive -train design where the two contra-rotating shafts are fitted with two propellers. This design reduces the size and weight of the shafts, and the gears and propellers are mounted on the shafts by using an interference fit.

The transmission of high torsional loads is fully dependent on the interference fits, which have been utilized for several years with proven reliability [103]. The Shafts comprise oil grooves and helical ducts. When oil is injected between two tapered surfaces, a thin oil film is formed, which minimizes the friction between them and considerably reduces the mounting force required. Additionally, the injected oil reduces the required extraction force by as much as 90%. Sometimes composite materials made of epoxy resin and carbon fibers are used to manufacture the drive shaft within the hull. This shaft connects the inverter's output to the upper gearbox. In this fabrication cast aluminum alloy can play a significant role [104]. In addition, the transmission components of the lower gearbox, which are cast in EN 43300 T6 aluminum alloy, increase the production speed and reduce the costs [105]. The shafts of the contra-rotating propeller systems can be housed accurately, if the inner bearing seats are properly machined by using computerized numerical control machines. The lower gearbox may be made from high-strength steel to accommodate the contra-rotating shafts and gear wheels. Kinematic configuration of the POD drive-train and rotation system has been shown in figure 12 below.

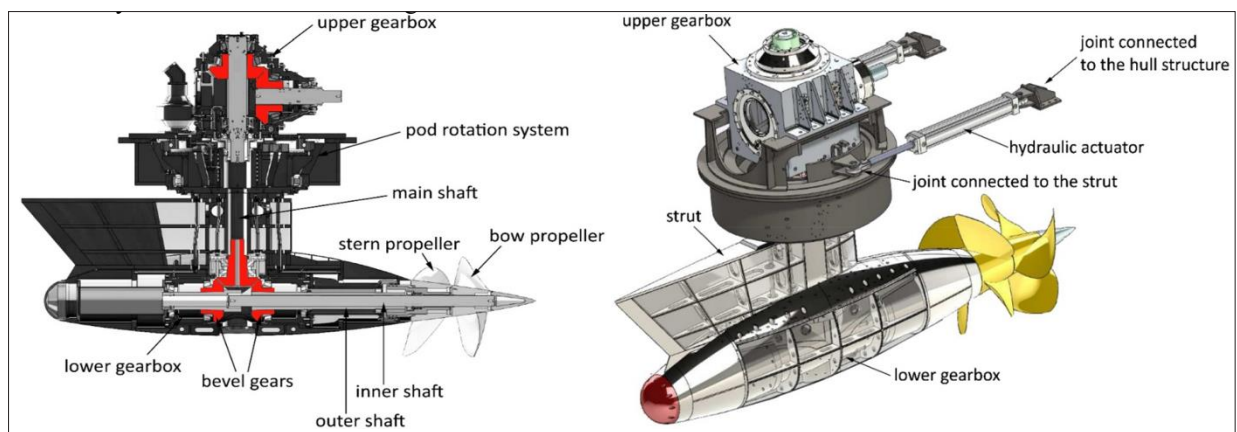


Figure 12: Kinematic configuration of the POD drive-train and rotation system

Smart shipbuilding ensures higher efficiency, cost reduction, better safety, and environmental sustainability. The smart technologies like AI, automation and data analytics enhances the entire shipbuilding process from design and engineering to construction and maintenance. This speeds up production, reduces operational costs, lowers human error, and curtails ecological impact. Additionally, digital twins and simulation tools are used to refine designs, minimize errors, and accelerate development [106]. Using of Robotics and automation can significantly optimize manufacturing efficiency, leading to quicker production and reduce labor expenses. Intelligent systems

streamline material flow, reduce delays and waste. To reduce down assembly time, smart shipyards use pre-fitted sections and modular construction methods [107]. To avoid human error and improve risk management, automation and robotics are used in smart shipyards. Data-driven predictive maintenance supports essential maintenance, reduces repair costs, and minimizes downtime. Reducing material waste and improving resource efficiency are the key characteristics of smart shipbuilding techniques. Human error is the main contributing factor to accidents in traditional shipbuilding, which can be reduced largely by automated systems and AI-based navigation. Additionally, smart systems can detect potential equipment failures, mitigate accident risks and promote safer operations [108]. Moreover, AI-powered systems optimize emergency response by analyzing situations and automating safety protocols [109].

Smart shipbuilding ushers in a new era for the industry, providing a more efficient, cost-effective, safer, and sustainable method of ship construction [110]. Incorporating green technologies like alternative fuels and energy-efficient systems, Smart shipyards can help to lower emissions and support environmental sustainability. Today, advanced technology is used in each and every corner of shipbuilding industry as well as in maritime sector. Like electricity, or computers, AI is now widely used in both industry and academia [12,36]. These technologies support data-driven decision-making, predictive analytics, and automation, resulting in substantial improvements in port management [14,111]. Digitalization is transforming shipyard facility management through innovations like collaborative platforms and innovative technology, ensuring safety, profitability, and timely delivery. Smart asset and logistics management systems strengthen this transformation through intelligent monitoring of the location, condition, and

performance of key shipyard assets such as cranes, vehicles, machinery, and infrastructure [15]. These intelligent systems enhance equipment longevity, enabling proactive maintenance, and optimizing overall asset utilization. The adoption of predictive maintenance techniques, where algorithms process sensor data, maintain records, and operational performance, improves early detection of potential failures and pre-scheduled repairs.

Today, real-time monitoring and operational assessment of infrastructure and equipment are made possible through big data analytics, AI, and IoT. Furthermore, ML and DL algorithms can analyze past data to project future ship demand, aiding in justified decisions regarding inventory, workforce, logistics, work scheduling, and resource allocation [10]. The Integration of AI and IoT into the shipbuilding industry plays a vital role in providing real-time data on markets and operations. AI algorithms can analyze this data to strengthen production, operations, and management [11]. Additionally, AI supports to achieve the maritime sector's sustainability goals by optimizing fuel use, reducing emissions, and boosting supply chain efficiency. In the near future AI is expected to improve predictive analytics, enabling stakeholders to take better data informed decisions and stay competitive by offering insights into market trends. However, integrating AI, ML, DL, blockchain, data science, and related technologies requires substantial capital deployment in equipment, software, and skilled personnel. These high initial costs could hinder small and medium-sized shipping and shipbuilding firms. Moreover, the deployment of these technologies involves large-scale data collection and processing, posing challenges related to data privacy, cyber security, and security management. Future smart ship and smart shipyard has been shown in figure 13 below.

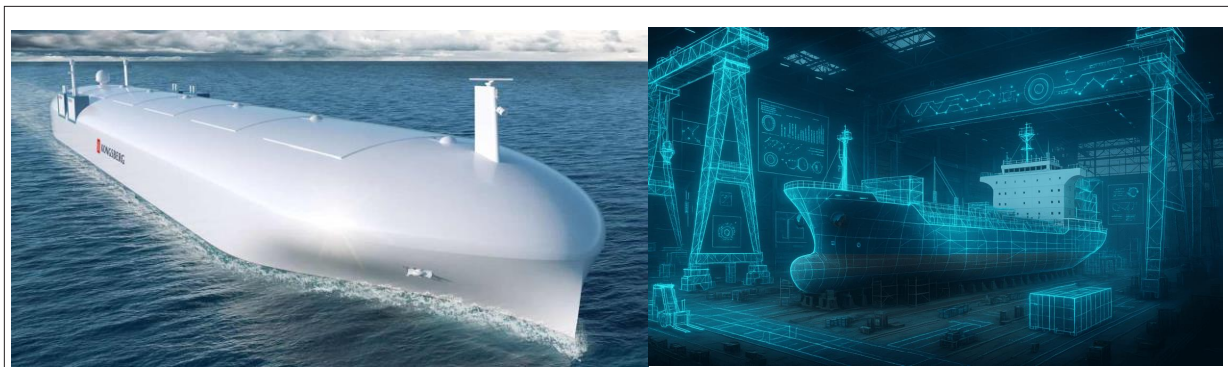


Figure 13: Future smart ship and smart shipyard [112]

The shipbuilding industry stands on the brink of a technological revolution, spearheaded by groundbreaking research and development initiatives. Leading companies are pioneering advancements in fuel-efficient engines and smart 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. It is imperative to implement environmentally friendly shipbuilding methods in order to mitigate the maritime industry's environmental impact. The industry may reduce its ecological impact by implementing sustainable design concepts, innovative materials, green building processes, and digitalization and green technology. A comprehensive approach that encompasses all stakeholders, from designers to shipyard operators, is necessary to implement sustainable practices.

Focus on maritime innovation and technological excellence. Hyundai Heavy Industries (HHI) is a prominent innovator in the maritime

industry. Focusing on decarbonization and digitalization, the traditional shipbuilder is evolving into a "future builder". This transition of HHI is fully dependent on the development of intelligent and secure engine control systems, eco-friendly technologies, and smart ship solutions. As a global leader in shipbuilding, HHI places strong emphasis on R&D to go beyond the boundaries of maritime innovation. Autonomous shipping, green energy solutions, and digitalization are the key focus areas of HHI. To optimize safety and efficiency, HHI is developing smart ships featuring AI-driven navigation systems. Their investment also focuses on the development of alternative fuels like ammonia and hydrogen, aiming to reduce carbon emissions in line with IMO regulations. They prioritize innovative solutions and collaborate with other companies to advance technologies such as blockchain enabled Class registers with Lloyd's Register. Their work on blockchain-based logistics, enhancing transparency and security across the global shipping industry. With a strong technological foundation and world-class production facilities, HHI has become

a world leader in the maritime industry and supplying thousands of vessels to clients worldwide.

Focus on Fuel-Efficient Engines. Fuel-efficient ships play a key role in decarbonization and cost savings, ultimately contributing to a cleaner ocean. Today, Shipbuilding companies are focusing on the production of more fuel-efficient ships by prioritizing fuel-efficient technologies. HHI is actively developing eco-friendly technologies like LNG and ammonia-fueled vessels, as well as next-generation propulsion systems, to promote decarbonization.

Advanced Materials for Faster Ships. Advanced materials are lightweight and durable. Using lighter material ships can move faster with consuming less fuel. This can reduce the wear and tear of the ship. Today, many shipbuilders are turning to advanced materials for their ships. HHI is investing in advanced materials and propulsion systems to build faster and highly efficient ships.

Investing in Smart Ship Technologies. Today's shipbuilding industry is focusing on smart technologies, including systems that enable ships to operate without human intervention. This can enhance ship's safety and reliability; reduce crew requirement, and curtail operational costs. HHI is highly focused on the development of autonomous shipping technologies and digital tools to improve shipbuilding productivity.

Improvement of Shipbuilding Efficiency. Advancement in technology is highly influencing the shipbuilding process. Digital tools can make ships more efficient and cost-effective. Digitalization streamlines the supply chain and supports improved communication among stakeholders. Digital tools can optimize ship design to enhance energy efficiency and reduce ecological footprint, as well as improve production efficiency and decrease waste. Digital supply chain management improves transparency and lowers the risk of environmental impacts.

- **Eco-Friendly Practices in Modern Shipbuilding.** Sustainable approaches are vital in modern shipbuilding. Shipbuilding companies are using eco-friendly materials for building ships and adopting green methods for decarbonization, which is essential for protecting marine ecosystems. Sustainable practices can lead to long-term savings and compliance with regulations.
- **Green Shipyard Practices.** A shipyard's ecological footprint can be conserved by adopting green shipyard practices. Damen Shipyards has incorporated a range of sustainable practices, including modular construction and energy-efficient facilities. Fincantieri has invested in green technologies, such as solar power and energy-efficient lighting, to enhance its environmental sustainability. 3D printing is used to reduce material waste and improve production efficiency, while digital twin technology reduces cost through virtual testing and simulation, thereby lowering the need for physical prototypes. Overall, automation can improve production efficiency and reduce labor costs.
- **Adoption of Green Practices.** Green technologies and practices is expensive than traditional methods. Limited awareness and regulatory frameworks can create barriers to the adoption of green practices. Hyundai Heavy Industries has invested in green technologies, such as solar power and energy-efficient lighting, to minimize its environmental impact.
- **Sustainable practices which are critical for reducing the environmental impact of shipbuilding, require a comprehensive approach that involve all stakeholders, from designers to shipyard operators. Defining clear sustainability**

goals and targets facilitate transformation. A culture of sustainability can be established by providing training and education on sustainable practices. Additionally, collaborating with suppliers, customers, and other stakeholders can support the detection of potential improvement areas. Mitsubishi Heavy Industries has implemented a range of sustainable practices, including energy-efficient facilities and waste reduction programs.

Potential and Prospect of Local Shipyards

Bangladesh has hundreds of indigenous private shipbuilding and repair yards spread throughout the country, which construct and manage almost all inland and coastal water transport vessels. Some of these yards possess a long history and well-established reputation in shipbuilding. Specifically, High-Speed Shipyard Ltd (HSSL) has been in operation for over 60 years in this sector. In the last few years, several private shipyards have reached international standards, building small and medium-sized ships for global markets. A few have even built the capability to manufacture merchant ships of up to 10,000 DWT. Notably, shipyards such as Annada Shipyard and Slipway Ltd (ASSL), Western Marine Shipyard Ltd (WMSL), Khulna Shipyard Ltd (KSYL), and Karnaphuli Shipyards and Slipway Ltd (KSSL) have secured orders from international ship-owners across various countries including Germany, Japan, Denmark, the Netherlands, the European Community, Mozambique, India, and Nigeria. These promising shipyards have successfully delivered numerous vessels to international clients. Moreover, other local shipyards are continuously improving their capabilities. This progress has created emerging opportunities to encourage foreign direct investment (FDI) into Bangladesh's shipbuilding sector [3,24].

Bangladesh has a long-standing historical legacy in shipbuilding and maritime activities, which continues to motivate both domestic entrepreneurs and foreign investors to engage in this sector. Around 100,000 mechanized country boats and around 40,000 inland and coastal ships are currently in operation across the country. These vessels transport over 85% of oil products, 65% of cargo, and 25% of passengers throughout the country. Local shipyards are engaged in the production and maintenance of all of these vessels. Bangladesh hosts over 100 native shipyards. Among them, four shipyards are capable of constructing classed and export-quality vessels up to 10,000 DWT, while several others are upgrading their facilities and capacity to enter the global market. Approximately 200,000 trained, semi-skilled, and temporary workers are employed in the shipbuilding industry, and this sector provides direct and indirect employment to nearly two million people. Table 3 and Figure 14 below illustrate that the productivity of Bangladeshi shipbuilding labor was 11.43 in 2009, with an average hourly labor cost of only USD 1.00. Moreover, the relative labor wage index was recorded at 0.45 in 2009, the lowest in the world, as presented in Table 4 and Figure 15. Although average hourly wages increased by 2021, they remain relatively low compared with global standards, maintaining Bangladesh's advantageous position in terms of cheap labor in shipbuilding. However, despite low labor costs, the sector remains confronted with challenges in terms of productivity and safety standards within shipyards. To address these challenges and remain competitive, the adoption of smart technologies in shipbuilding is now essential. This includes implementing modular construction concepts alongside extensive digitization, robotics, AI, ML, DL, DS [10,12].

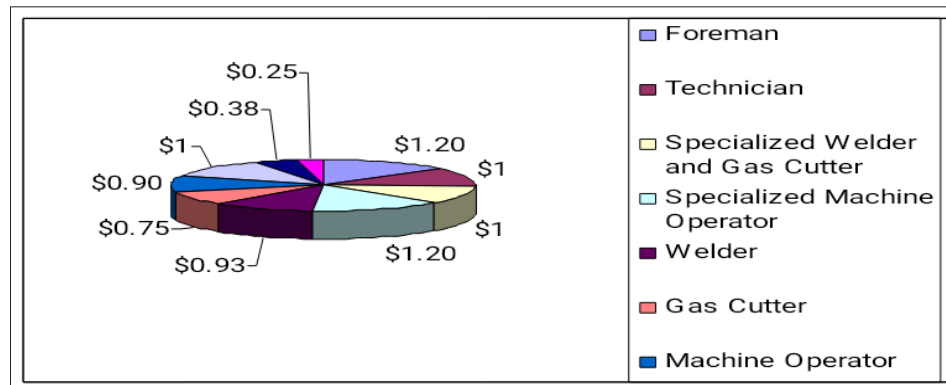


Figure 14: Average labor wage for class ship builds in local shipyards in 2009 [3,113]

Table 3: Shipbuilding labor productivity of different nations in 2009 (MSC Thesis 2010)

Country	Formula for Labor Productivity = Man-Years/Unit Output (in CGT)	Productivity
Japan	Using basic formula	1
European countries	Same	2
United States	Same	4
China	Same	6
India	Same	10
Bangladesh	Same	11.43

Table 4: Relative labor wage for different nations around the globe in 2009 [7]

Country	Relative Labor Wage	Country	Relative Labor Wage
Bangladesh	0.45	Canada	11
India	1	Japan	12
China	1 to 2	Italy	13
Singapore	3	France	13
Hong Kong	3	Denmark	13
Taiwan	3	Norway	14
South Korea	6	Sweden	14
U.K.	10	Finland	15
USA	10	Germany	15

Local shipyards in Bangladesh construct a variety of of boats and ships. The range of vessels constructed includes multipurpose vessels, coasters, dry cargo vessels, cargo coasters, passenger vessels or ferries (including lunch-type vessels), double-decker passenger vessels, tankers, container vessels, landing crafts, tugs, dump barges, supply barges, deck loading barges, self-propelled barges, dredging barges, research vessels, survey ships, hospital ships, tourist ships, inspection vessels, pleasure crafts, yachts, Ro-Ro ferries, crane boats, speed boats, hydrographic survey boats, work boats, pilot boats, water taxis, pontoons, catamaran vessels, sand carriers, troop-carrying vessels, fast patrol boats, offshore patrol vessels (OPVs), patrol crafts (PCs), light patrol crafts (LPCs), landing crafts vehicle (LCVs), landing craft tanks (LCTs), deep sea trawlers, among others. At present, the Department of Shipping registers nearly half of the 40,000 inland vessels that operate across the country's inland waterways and coastal region. Furthermore, greater than 100,000 country boats, powered by both manual and mechanical systems, are not subject to formal registration or organized statistical records. The Mercantile Marine Department maintains a registry of over 500 coastal vessels. Consequently, the actual number of vessels built by local shipyards is significantly higher than the number that has been registered with either DOS or MMD. Table 5 below provides the primary data, which includes the length (L), breadth (B), draft (d), deadweight tonnage (DWT), and other specifics, of the most frequently constructed types and sizes of ships for inland and coastal operations in the region [17,113].

Table 5: Principal data of common types and sizes of ships built locally for inland water

Types of Vessels	dwt or no of passenger	Length in Meter	Breadth in Meter	Draught in Meter	Usually, Ply
Multipurpose ship or Coaster	1500- 4000	60- 120	10- 16	3.5- 6.0	Coastal
Cargo	1000- 3500	50- 100	10- 15	3.0- 5.0	Inland & Coastal
Passenger ship or Launch	300- 1500 Passenger	60- 110	10- 20	3.0- 4.0	Inland
Tanker	1000- 4000	50- 120	10- 16	3.0- 6.0	Inland & Coastal
Sand Carrier	200- 500	20- 40	5- 10	2.0- 3.0	Inland
Barge	200- 1000	20- 60	6- 14	2.5- 3.5	Inland
Dredger	30-100	10-30	4-8	2.0-3.0	Inland

Analysis of Opportunities of Local Shipbuilding Industry

The shipbuilding business in Bangladesh has considerable potential for growth and capture a share of the global market. Bangladesh possesses the required resources to become a significant global shipbuilding nation by leveraging its young and cost-effective labor force, and rich maritime heritage. The local shipbuilding industry is characterized by the presence of domestic shipyards, a rich legacy of shipbuilding, and a big pool of young workers, all of which present promising opportunities for the sector to expand. Nevertheless, it is confronted with several distinct challenges that must be resolved and transformed into potential to facilitate sustainable expansion. Bangladesh has the ability to develop labor-intensive heavy industries such as shipbuilding, automobile manufacturing, food production, and mass production due to its substantial young population.

The primary potential and capacity are defined below:

- A significant advantage for Bangladesh is the availability of a low-cost shipbuilding workforce. Compared to other countries, the nation boasts an abundance of young, inexpensive labor, and its high-quality manual welding capabilities and skilled welders are frequently superior to that of countries such as China, Vietnam, and the Philippines. Bangladeshi maritime labor force has exhibited their discipline, diligence, hard work, obedience, and rapid learning abilities in the international labor market, which includes countries such as South Korea, the Middle East, Malaysia, and Japan.
- Local shipyards receive limited support from supporting and backward linkage industries, which provide materials and components at competitive prices. Re-rolling factories in Bangladesh produce various shipbuilding components using scrap metal sourced from the Bhatiyari ship recycling yards, maintaining a reliable and affordable supply of materials. A large number of SMEs are contributing to heavy industries like shipbuilding by serving as critical backward and forward linkage industries.
- Bangladesh, as a maritime nation, which has a rich history of shipbuilding, is a favorable investment destination for local and international businesses to invest in this sector. Additionally, Bangladesh's geographical location, which includes extensive coastal and riverine areas, is particularly conducive to the development of shipbuilding and other maritime operations.
- The country has a large pool of semi-skilled white-collar and blue-collar workforce, including naval architects, marine engineers, electronics and IT engineers, management professionals, welders, grinders, cutters, mechanics, carpenters, painters, and helpers. With limited training and skill development initiatives, this workforce can be efficiently transformed into productive human resources for the shipbuilding sector.

- A growing number of vocational training centers and technical schools are developing a skilled workforce for heavy industry. Shipyards such as Khulna Shipyard (KSY), BN Dockyard, Chittagong Dry Dock Ltd (CDDL), Dockyard and Engineering Work Ltd (DEWL), Western Marine Shipyard Ltd (WMSL), Karnaphuli Shipyard and Slipway Ltd (KSSL), and Annada Shipyard and Slipway Ltd (ASSL) annually produce thousands of skilled shipbuilding workers involved in various trades and professions, including welding, cutting, painting, carpentry, blacksmithing, mechanics, and electrical works.
- Classification societies are playing a significant role in promoting quality and class-certified shipbuilding, as well as certifying material lists for export-oriented ship construction. Renowned societies such as Germanischer Lloyd (GL), Bureau Veritas (BV), and Nippon Kaiji Kyokai (NKK) are contributing to the development of Bangladesh's shipbuilding capacity for international markets.
- The cost of shipbuilding in China has increased dramatically as a result of the country's rising living standards. It is anticipated that China may gradually lose a share of the small and medium-sized shipbuilding market, which will create chances for Bangladesh.
- Policy incentives such as tax-free activities for export-oriented shipyards, simplified regulations, import taxes on foreign-built ships, strategic development plans for the local industry, river dredging, and coordinated efforts with related sectors will further promote the sustainable growth and global competitiveness of Bangladesh's shipbuilding industry.
- The current global financial crisis and geopolitical scenario may lead to increased demand for cost-effective vessels, which could present a favorable opportunity for the shipbuilding sector of Bangladesh. The local shipbuilding sector has the potential to generate considerable export revenues and secure a share of the global market by producing and exporting high-quality ships.
- This sector provides extensive employment opportunities. Bangladesh has an abundance of a young and readily trainable workforce. Through focused training and skill development programs, this workforce can be upgraded to meet international standards. Additionally, there is a large pool of semi-skilled white-collar workforce available across diverse disciplines that, with appropriate training, and guidance, can become highly competent assets for the industry.
- Existing local shipyards are capable of constructing high-quality vessels at competitive prices. Moreover, there is a golden opportunity to expand supporting backup industries to enhance the domestic shipbuilding ecosystem, along with the development of backward and forward linkage industries through foreign collaboration. Within the next few years, shipbuilding has the potential to emerge as a dominant foreign

currency-earning sector for Bangladesh.

- Given Bangladesh's trade imbalance and export constraints, it is essential to explore new sectors to narrow this gap. Shipbuilding offers a sustainable solution, facilitating duty-free access to developed-country markets, along with creating significant employment opportunities.
- m. There is strong potential for Foreign Direct Investment (FDI) in the shipbuilding sector, with countries including China, Turkey, the Netherlands, and Australia demonstrating significant interest. Many foreign buyers, particularly in Europe and North America, are looking beyond China due to ongoing geopolitical tensions. These buyers frequently mandate the installation of their own equipment in ordered ships, creating opportunities for Least Developed Countries (LDCs) and developing nations such as Bangladesh.
- Stakeholders including the government, investors, shipbuilders, ship owners, and related entities increasingly recognize shipbuilding as a promising sector, with the potential to become a viable alternative to the Ready-Made Garments (RMG) industry in the near future.
- Discussions with focus groups indicate that Bangladesh is particularly well positioned for small and medium-sized shipbuilding. Experts suggest that the country has the potential to capture a significant share of the global market for multipurpose, container, tanker, and cargo ships in the 1,000–20,000 DWT range. These niche markets for small and medium-sized vessels are projected to remain strong in the coming years.

Analysis of Existing Challenges of Local Shipbuilding Industry

The shipbuilding industry of Bangladesh has struggled to sustain growth and operational consistency in its development due to a lack of coordinated initiatives from the government, stakeholders, along with common initiative both in public and in private sector. This has resulted in sluggish progress and limited ability to effectively penetrate the global shipbuilding market.

The key challenges are described below:

- Despite its rich heritage in shipbuilding, Bangladesh has struggled to maintain pace and consistency with rapidly evolving global technologies. Due to the abundance of cheap labor, many shipyard owners are hesitant to adopt advanced technologies. Local shipyards remain significantly behind in embracing smart and modern technologies for ship design and construction. Consequently, their quality management processes and product standards often fail to meet international benchmarks.
- There is a significant gap between industrial requirements and the curricula of mainstream educational institutions. Greater attention is required on technical and vocational education to bridge this gap. Universities and technical institutes have made limited progress in developing a skilled workforce and sustainable human resources due to inadequate training facilities, outdated curricula, insufficient research infrastructure, and prevailing attitudinal barriers.
- Policy planners, bureaucrats, bankers, and other key stakeholders often have limited awareness of the shipbuilding sector's potential. For sustainable progress, this industry must receive the same level of institutional support as the Ready-Made Garments (RMG) sector.
- The major local shipyards are situated in and around Dhaka, far from coastal areas, thereby limiting their capacity to construct larger vessels. Additionally, high bank interest rates and service charges remain a significant barrier to developing

the shipbuilding industry. Additionally, international buyers often require bank guarantees, but local banks require counter-guarantees from foreign banks, resulting in additional costs and reducing competitiveness.

- Bangladesh does not manufacture class-approved mild steel plates, frames, girders, stiffeners, longitudinal, machinery, fittings, and other essential shipbuilding materials and equipment required for the development of the export-oriented shipbuilding industry. There are weak backward linkages to support the industry. Bangladesh's shipbuilding industry is strongly reliant on imports for prime raw materials and resulting in higher production costs and vulnerability to global market fluctuations.
- The sector faces reputational challenges related to Ease of Doing Business (EODB), deterring Foreign Direct Investment (FDI). The industry lacks effective mechanisms for proactive information dissemination, motivation, and business promotion to prospective foreign buyers. Bangladeshi ambassadors abroad should actively promote the industry, while perceptions among shipbuilding stakeholders must also improve.
- Local shipyards lack proficiency in modern technologies and receive insufficient government financial support to adapt to the Fourth Industrial Revolution (4IR) and integrate smart technologies. This technological gap remains a critical constraint on the sector's sustainable development [10].
- One of the fundamental weaknesses is the existence of unethical practices within the sector, including dishonesty and attempts to gain illegal profits. Such practices undermine trust and hampers the development of goodwill in international markets.
- Private shipyards often face challenges in establishing a professional corporate culture, as management and key appointments are usually dominated by family members. This contributes to an unhealthy work environment characterized by mistrust and lack of confidence, undermining employees' sense of belonging to the organization. Moreover, inherited industrial enterprises, which are critical in capitalist societies, remain rare in Bangladesh.
- The technology currently used in local shipyards has yet to reach an advanced level, leading to inefficiencies and low productivity. There is a significant shortage of advanced shipbuilding tools, machinery, and expert operators, particularly those with expertise in digital and AI-enabled systems [12]. Furthermore, Bangladesh still relies extensively on foreign expertise for ship design.
- The sector also suffers from inadequate government support in mobilizing capital and addressing financial difficulties, both of which are critical for the growth and sustainability of heavy industries in any nation. Additional costs incurred from import LC commissions, counter bank guarantees, and other banking mark-ups make Bangladesh's weakens the competitiveness of the export-oriented shipbuilding sector compared to countries such as China, South Korea, Japan, Vietnam, the Philippines, India, and Brazil.
- Countries such as Vietnam, the Philippines, Indonesia, India, Brazil, and others are actively working to capture the surplus and niche shipbuilding markets. This presents a substantial threat and critical challenges to Bangladesh's shipbuilding sector. Opportunities are time-sensitive, local industry requires courage, clear vision, strategic direction, timely action, and political stability to be realized.
- Market analyses indicate that the global market demand

for new vessels, measured by the Compound Annual Growth Rate (CAGR), is increasing at approximately 4%. This growth, while presenting opportunities, also implies significant risks and intensified competition for new emerging participants and domestic investors.

- Infrastructure constraints, energy supply challenges, and land availability issues, and a poor Ease of Doing Business (EODB) environment are major obstacles to the rapid development of shipbuilding in Bangladesh. Moreover, few issues like reputational concerns, integrity issues, and bureaucratic constraints, and the attitudes of some local investors pose threats to the overall credibility of Bangladesh's shipbuilding sector. These factors erode the capacity to maintain goodwill and build confidence among foreign buyers.
- Poor management practices in local shipyards contribute to declining employee motivation and job satisfaction. As a result, indiscipline, high absenteeism, and poor retention rates of skilled manpower are common challenges in the sector. Additionally, there is an persistent outflow of skilled talent (like naval architects and engineers, managers, etc) including skilled manpower drain from Bangladesh's shipbuilding industry to foreign industries, reducing the availability of local skilled talent.
- The worldwide economic downturn triggered by the post-COVID-19 situation, coupled with severe geopolitical challenges such as the Russia-Ukraine war and Israel-Iran tensions, have adversely affected the global shipping and shipbuilding markets, leading to order cancellations and a general slowdown in business.
- The limited navigational depth of Bangladeshi rivers (maximum ~4 meters) limits the size of ships that can be built and launched from local shipyards. Maintaining sufficient navigational depth is further challenged by heavy siltation. Additionally, bridges and overhead cables create air draught restrictions, with a minimum clearance of 22 meters above high-water levels (monsoon) required for major rivers, further constraining ship size and design.
- There is a lack of supportive and well-structured government policies and strategic frameworks for the shipbuilding sector. The absence of effective policy development and execution, monitoring, and regular updating of export-oriented shipbuilding policies and strategies continues to hinder the sustainable growth of this industry.

Analysis of Current Status and Option for Local Shipbuilding **Current State of Local Shipbuilding**

Shipbuilding has historically been a large-scale business that is labor-intensive and technologically less advanced. However, the emergence of advanced high-strength steel with improved physical and chemical qualities has transformed ship construction since the 1950s [23]. Modern shipbuilding incorporates refined aesthetic finishes and work precision. Automation, advanced technologies, and line production manufacturing processes are increasingly incorporated, supported by a skilled workforce. Modern shipyards have widely adopted block or module construction, where large multi-deck segments are fabricated off-site, transported to the building dock or slipway, and integrated to finalize fabrication [18,24]. These modules are equipped in advance, pipes, electrical cables, and other systems to minimize installation work after assembly. Moreover, ship design and naval architecture are enhanced by hydrodynamic model testing in towing tanks or basins. However, the 4IR is expected to further transform the maritime sector including shipbuilding. At present, over 85% of

oil products, 75% of cargo, and 25% of passengers are carried by 40,000 inland and coastal ships and 100,000 engine-powered traditional boats and trawlers, which are built and maintained by local shipyards. However, the maritime and shipbuilding business in Bangladesh has a rich and illustrious history, which has encouraged both domestic entrepreneurs and international investors. Consequently, the nation has contributed significantly to foreign exchange earnings from this sector. Five indigenous shipyards in Bangladesh (WMSL, ASSL, KSSL, KSY, CDDL, DEWL) possess the capacity to build export-quality small and medium-sized vessels (1000 to 20,000 DWT), and several others are modernizing to access international markets. IMO regulations replacing single-hull tankers and rising container ship demand is likely to drive the need for thousands of small- and medium-sized ships in the coming years. Notably, government funding for waterways and water transport under the Annual Development Programmed (ADP) is below 5%, whereas roads receive more than 70%. Therefore, the sector remains vulnerable and requires substantial intervention to achieve balanced and sustainable growth and international standards. However, if supported by facilities and incentives similar to those enjoyed by the RMG sector, shipbuilding could produce higher net benefits.

Private Shipyards Usually Lack A Corporate Management Culture

In this case Management remains largely family-controlled, hindering professional development, as seen in ASSL, which faced challenges in maintaining its export performance due to family-centric management practices. A dominant perspective of 'rapid financial return' and 'greed' hinders sustainable growth of this sector. For example, WMSL failed to continue its export success due to shifts in investment priorities. Moreover, poor job satisfaction persists in shipyards as the workers do not receive industrial benefits like production bonuses, fringe benefits, or welfare facilities (medical, pension, travel allowance, and compensation) etc. Notably, owing to the availability of low-cost labor, owners neglect employee welfare, resulting in skilled graduates and trained personnel leaving for overseas jobs. Moreover, local shipyards often show reluctance to implement QHSE improvements. However, government pressure, foreign buyer needs, and awareness and training programs are needed to promote these norms internationally. Again, weak state diplomacy, poor country branding, and inadequate promotional efforts hinder export-focused shipbuilding growth. The analysis indicates that, local shipbuilding costs are 10-20% higher than competitors such as China, Korea, Japan, India, and Vietnam. Therefore, high prices, coupled with inconsistent electricity and gas supply and inadequate infrastructure, hamper industrial progress. Workforce productivity remains low despite the lowest relative labor wage globally. The government has a shipbuilding policy to boost the shipbuilding industry. However, its effective implementation should guarantee adequate appraisal and uniform priority to benefit public and private shipyards equally. At present, rising labor wages in China due to improved living standards are expected to shift some small and medium shipbuilding market share away from China, providing Bangladesh with a strategic opportunity. Currently, opportunities for foreign direct investment have emerged, with countries like China, Turkey, and the Netherlands expressing interest. Thus, establishing export shipyard zones could promote healthy growth [114,115]. As Bangladesh is suitable for constructing small to medium-sized container ships, tankers, cargo vessels, multipurpose ships, and specialized ships (3000–10000 dwt), and it has the potential to secure a competitive position in this niche market, by 2030, Bangladesh could achieve 5% share

of the global shipbuilding market, valued at approximately USD 10 billion.

Option for Local Shipbuilding

Dependence solely on low labor costs cannot ensure the sustainable development of the shipbuilding industry. Although historically low labor costs have offered a competitive advantage, the integration of advanced technologies is now crucial for cost efficiency and global market position. Moreover, overreliance on cheap labor risks undermining Bangladesh's position in the global market, especially as other shipbuilding nations continue to incorporate automation and intelligent technologies. Bangladesh has the potential to grow economically by promoting and using its export-oriented shipbuilding industry. Most of the entrepreneurs believe that local shipbuilding has a promising future due to the country's rich maritime history, favorable location, and substantial workforce. Bangladeshi ships built in compliance with international standards cost 10–30% less than identical ships built in Japan, Korea, China, Vietnam, or India [4,18]. However, continuing to leverage this advantage requires technological adaptation. The impact of the Fourth Industrial Revolution (4IR) has become a dominant narrative in the maritime and manufacturing sectors. The first industrial revolution leveraged water and steam in production processes, the second introduced electricity, and the third incorporated electronics and IT to support automation [116]. However, 4IR uses smart technologies like AI, ML, DL, DS, IoT, Blockchain, Digital Twin, big data Analytics, cloud Computing, Virtual and Augmented Reality, Simulation, Human-Machine Interaction, 3D Printing, and Advanced Materials Technology to transform manufacturing through digital technologies [12,15].

As a result, cheap labor and an abundant young population are no longer sufficient to support industrial development. If Bangladesh fails to develop its young population into a skilled and qualified workforce, the country may miss the critical opportunity for economic advancement and fail to keep pace with global development trends. However, the concept of 6th Generation Ports (6GP), capable of handling megaships carrying up to 50,000 TEUs with a 20-meter draft and utilizing advanced automation supported by efficient hinterland connectivity, is set to become operational shortly. The entire maritime sector, encompassing ships, shipping, and shipbuilding, is poised for significant technological advancement and more innovative. The core objective of the 4IR in shipbuilding is to develop intelligent shipyards, which are not only adaptable, resource-optimized, and operator-friendly but also ensure close integration among ship-owners, shipbuilders, suppliers, and all other stakeholders within business and value chains [12,30]. Without incorporating smart technologies and advanced ship design and construction processes, Bangladesh may encounter challenges in producing globally competitive vessels that guarantee safety, quality, and customer satisfaction in an increasingly competitive market. For considerable growth and achieving a notable market share of the global market, this sector requires a balanced and strategic approach. This includes sustainable strategies and feasible planning, continuous state support and appropriate capital injection, strict operational discipline, development of a skilled workforce and Integration of smart technologies to respond to future challenges [11,33,117]. The global shipbuilding market is estimated at approximately USD 200 billion, with the small ship segment valued at USD 20 billion where Bangladesh has the potential to secure a 5% share of the global market, valued at around USD 10 billion. To capitalize on this potential, the local shipbuilding industry must be properly guided and balanced. Promoting sustainable development and

achieving global market share will depend on coordinated efforts, strategic investments, technology modernization, and human resource development.

Findings from FGDs

From the discussion of FGDs and interviews, the trend of global shipbuilding has been evaluated and narrated with bags of information. We found that shipbuilding has gone into decline in high labor cost countries, due to the removal of state subsidies, and domestic industrial policies do not provide support. The British shipbuilding industry is a prime example of this, with its industries suffering badly from the 1960s. In the early 1970s, British yards still had the capacity to build all types and sizes of commercial vessels, but today they have been reduced to a small number specializing in defense contracts, luxury yachts and repair work. Decline has also occurred in other European countries, even after taking protective measures and industrial support policies. In the USA, the Jones Act has meant that commercial shipbuilding has continued, albeit at a reduced rate, or business protection has failed to penalize shipbuilding inefficiencies and contract prices have gone far higher than those of other shipbuilding nations. China is an emerging shipbuilder that overtook South Korea during the period 2008 to 2010 in the global financial crisis, as it won maximum new orders for medium and small-sized container and multi-purpose ships. China was firmly the world's largest shipbuilder with around 40% of the world's total orders (in 2021), and presently, their quality and technology have improved significantly. However, South Korea and Japan had become the world's second and third largest shipbuilding countries with a global market share of about 25% and 20% respectively (in 2021).

Nowadays, the impact of the 4th Industrial Revolution (4IR) on the worldwide industries has been discussed everywhere. Actually, 4th IR or Industry 4.0 is balanced to connect, integrate and automate everything on a grand scale: man, machine, materials, manufacturing process, products, logistics, customers and that across the whole spectrum. Full implementation of Industry 4.0 and shipbuilding 4.0 is still a long way away. Although shipbuilding is characterized by single units or small series production, shipbuilding 4.0 raises the question of how the shipyards need to be changed to survive in the market. In the shipbuilding 4.0 era, the shipyards need to have skilled engineers, naval architects, and specialists not only in technical science, but also in IT science.

However, the important findings have been summarized below:

- Bangladesh can make a huge economic progress by properly nourishing and utilizing this export-oriented shipbuilding industry. Entrepreneurs are also confident in the good prospects of the local shipbuilding industry.
- About 10000 (ten thousand) inland and coastal ships and around 50000 (fifty thousand) of mechanized country boats are plying all over the country, which carry more than 90% of oil products, 70% of cargo and 35% of passengers in total. All of those ships and boats are manufactured and maintained by local shipyards. So, local shipyards have developed adequate skills and knowledge of shipbuilding.
- Bangladesh has a glorious shipbuilding as well as a maritime history. The country is a seafarer's nation with tradition and success. We will be successful in the shipbuilding business in future also.
- There are around 100 indigenous shipyards in Bangladesh. More than 150000 skilled, semi-skilled and unskilled/casual workers are employed in this labor-intensive industry. And there are a few thousand naval architects, marine engineers,

and skilled shipbuilding workers are earning their bread and butter around the world.

- About 5 local shipyards is capable of making ocean-going ships around 10000 dwt. A few shipyards are developing facilities and capacity, aiming to enter the export market.
- Size of the global shipbuilding market is around USD 500 billion, where the small shipbuilding market is around USD 50 billion. The small niche shipbuilding market is suitable for local shipbuilders. Bangladesh has the potential to capture 2 to 5% of global shipbuilding market within 2035.
- In the coming future, the world will need a few thousand vessels, mostly small to medium-sized. The old single-hall tanker fleet will be replaced totally and immediately as per the IMO requirement.
- There is a serious demand for container ships in all sizes. UNCTAD, WB, WTO, and OECD have detected the high demand for container ships in the coming days.
- Some experts have viewed that the niche market of small-sized container, tanker, cargo, multipurpose and special types of ships with 3000-10000 dwt (approx.) is suitable for Bangladesh. Global renowned and bigger shipyards have less interest in this niche market. Bangladesh has all the potential and capacity to capture this market with a competitive price.
- Few experts have stated that Bangladesh is suitable for the small and medium-sized shipbuilding market. They viewed that Bangladesh has the golden opportunity to capture a handsome share of 3000-10000 dwt and 12000-20000 dwt multipurpose, container, tanker and cargo ships market. Those small and medium niche markets will be alive in the coming years.
- A good number of military ships are required for operational tasks for both BN and BCG in peace and wartime. And that is also a local niche market for BN-operated private shipyards, along with a huge local inland and coastal fleet.
- In future, we need to develop our own merchant fleet to maintain our export and import business of cargo, energy and other goods. There will be another local niche market for us. "m. Only cheap labor cost may not be the major competitive factor in future for shipbuilding. We need to identify possible areas of improvement based on the scientific studies, considering the present industrial structure and the future needs and requirements of shipbuilding [118-149]".

Limitations and Future Study and Acknowledgement

The global shipbuilding industry is versatile. The global shipbuilding market is highly dynamic and frequently fluctuates due to its nature and interrelationships with other trades. Research data collection has been more severely constrained by the limited availability of local sources and the course's short duration. The study and analysis have been limited to merchant ships, with the warship segment excluded. Such a study requires huge and accurate information; which is a costly matter. To counterbalance these limitations, available and accessible resources, such as publications and online information, have been utilized in this research. Again, there is minimal research on the local shipbuilding industry, and little original work has been conducted on this subject. Analysis and appropriate evaluation using comprehensive global and local shipbuilding market data, along with the preparation of an appropriate regression model, would yield better results. However enough effort has been taken to minimize the limitations.

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Conclusion

Shipbuilding is a holistic sector encompassing shipyards, maritime components producers, technical workforces, knowledge networks, service providers, and related stakeholders. Historically, in 1892, the United Kingdom accounted for approximately 80% of world ship production. This dominance was driven by the UK's leading position in world trade and its requirement for extensive merchant fleets to maintain global influence and colonial hegemony. However, the UK's marine construction sector started to decline during the First World War (WWI). Following WWI, the United States emerged as the global shipbuilding hub. During World War II (WWII), the US shipbuilding industry reached its peak, accounting for approximately 85–90% of the global market due to the massive wartime demand. After World War II, the US market share dropped considerably. In the 1950s and 1960s, Japan strengthened its industrial capacity through shipbuilding, emerging as the world player. Subsequently, in the 1970s and 1980s, South Korea prioritized the shipbuilding sector as a strategic industry and rapidly expanded its capacity. Finally, in the 2010s, China adopted similar policies, supported by substantial state investments, and established itself as the global leader in shipbuilding. On the other hand, Bengal's shipbuilding history has existed for centuries, rooted in its tradition of building boats and ships. The notable traveler Ibne Batuta visited Bengal in the 14th century and sailed back aboard a wooden ship built in a shipyard at Sonargaon, Dhaka. Caesar Frederick, a 15th-century European traveler, expressed that Chattogram was an important center of maritime construction. A fleet of ships was built in Chattogram for the Sultan of Turkey in the 17th century. Chattogram also constructed many Mughal warships. The Royal Navy used wooden-hulled ships built in Chattogram at the 1805 Battle of Trafalgar. Bengal has a centuries-old shipbuilding heritage, since the German Navy received the wooden-hull frigate Deutschland in 1818 from Chittagong.

The value of present global shipbuilding is approximately 200 billion USD, including the small ship sector alone representing USD 20 billion. The future global shipbuilding market will be approximately USD 500 billion (where small shipbuilding valued 50 billion USD) within 2035. Bangladesh has all potential to capture 2 to 5% of global share and to earn about 10 billion USD from global shipbuilding. This study recommends that, the government support, sustainable policy, inclusion of advanced technology, application of contemporary manufacturing process, skill development of workforce, foreign direct investment (FDI), and comprehensive effort are paramount to sustainable development of Bangladesh shipbuilding industry. Bangladesh has significant potential to emerge as a competitive player in the world shipbuilding market. The present positive trend, combined with rising export opportunities and foreign investment interests from countries like China, Turkey, and the Netherlands, bolsters this opportunity. Thus, developing dedicated export-oriented shipyard zones and adopting smart, viable strategies is critical. By capitalizing on its strategic location, maritime heritage, and competitive pricing in small and medium ship segments (1000 to 20000 DWT), Bangladesh can successfully capture this niche market and foster sustainable industrial development in the coming decades.

The Government of Bangladesh has formulated a primary shipbuilding policy to boost shipping and shipbuilding. But before implementation, proper assessment and prioritization are needed

to benefit public and private shipbuilding equally. Additionally, the state must support this promising sector with sufficient funding and strategic initiatives to unlock its full potential and ensure sustainable growth. Today's shipbuilding industry places greater reliance on smart technologies, including advanced fifth and sixth-generation ports and smart shipping systems, to ensure effective, sustainable, and market-driven shipbuilding that enhances profitability and facilitates sustainable growth. In view of the current opportunities, future challenges, and the suggested measures highlighted in this research, Bangladesh's shipbuilding sector should formulate viable policies (the means) and design effective strategies (the ways) to penetrate selected market segments, while optimizing production capacity. This approach could facilitate the long-term revival of the nation's lost glorious shipbuilding heritage. Modern technologies such as digitization; robotics, IoT, AI, machine learning, deep learning, and data science have considerably reshaped the global shipbuilding landscape. Therefore, improving workforce productivity and developing a skilled workforce is critical for long-term growth in this sector. Concurrently, ensuring safety and compliance with international standards is paramount to remain competitive in the international market. For significant expansion, the sector requires a balanced approach, including strategic investments, consistent government support, and focused human resource development to tackle future challenges effectively. By tackling critical issues such as productivity, technological adoption, and safety standards, Bangladesh's shipbuilding industry can bolster its international market position and contribute meaningfully to national development and economic development.

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