© May 2026 | IJIRT | Volume 12 Issue 12 | ISSN: 2349-6002

Investigative Study on Local Ship Recycling and Evaluation of Challenges with Recommendations

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***Abstract*—Ship dismantling, commonly referred to as ship recycling is essentially a converse engineering process involving the deconstruction of obsolete or EOL ships to recover recyclable materials in a safe and environmentally responsible manner. Over the past three decades, the majority of ship recycling activities have taken place in a few South Asian countries, primarily Bangladesh, India, China, and Pakistan—where vessels are typically beached and dismantled using labor-intensive methods and moderate safety precautions. These countries have played a crucial role in global ship recycling, handling the majority of EOL vessels with considerable efficiency, albeit often in a less professional or regulated manner. In fact, over the last twenty years, recycling yards in Bangladesh, India, and Pakistan have accounted for nearly 90% of global ship recycling by tonnage. The growing need for ship recycling has led to improved regulatory oversight at both national and international levels In Bangladesh, ship recycling has evolved from informal, beaching-based operations into a globally important sector. Currently, the country accounts for over 40% of global ship recycling tonnage, making it among the top ship recycling companies in the world hubs alongside India and Pakistan. The industry provides huge employment of a large number of semi-skilled laborers, particularly in poverty-prone coastal areas. It also supplies essential raw materials. However, the sector faces challenges in terms of coastal zone management, including environmental degradation, weak law enforcement, and occupational health and safety concerns. While fully green ship recycling—aligned with stringent European standards—remains expensive, a more viable and environmentally responsible model is possible by upgrading existing beaching methods commonly used in South. This study employs a mixed-methods design, combining secondary and primary data analyses, including a material flow analysis of 26 recycled ships over a period of seven years, over 500 structured stakeholder interviews (workers, yard owners, engineers, regulators, NGOs, and foreign experts), and ARIMA-inspired scenario forecasting to 2050. Results reveal critical gaps in Hong Kong Convention (HKC) and EU Ship Recycling Regulation (EU SSR) compliance—around 70% of yards (26) are certified and widespread deficiencies in workplace safety, environmental controls, and institutional enforcement.**

***Index Terms*—EOL, ARIMA, HKC, EU-SSR, sustainable and green recycling, SBSRB**

I. INTRODUCTION

Ship recycling is described as the dismantling process and recycling of End-of-Life (EOL) vessels; a practice known globally to be essential and sustainable (Hossain, 2015a, b). Thousands of old ships are recycled annually across the globe; hence, the industry of ship recycling is one that is environmentally important and economically feasible. On the other hand, the beaching technique continues to be predominant among many South and Southeast Asian countries because of the favorable tides and geographic benefits. Conversely, the most environmental-friendly and safe method known as the dry dock technique is mostly applied by highly developed nations such as in the EU and US but technique requires substantial construction and operation costs. The alongside or pier-breaking technique is practiced in some countries such as Turkey and China which is a middle-ground approach. Nations like Aliaga in Turkey, together with some places in Europe, continue to lead in advocating for high-standard environmental-friendly methods of ship recycling, rejecting the beaching and slipway techniques. Most of the ships that reach their end-of-life are stranded on the shores of countries such as Bangladesh, India, and Pakistan. However, it is not just the tidal forces that make these countries attractive – it has a lot to do with economic viability and practicality as well. With a high demand for the recycling of end-of-life ships, which were earlier dumped at sea and deemed useless, countries like Bangladesh are now employing hundreds of thousands of people in an effort to capitalize on this business opportunity. In Bangladesh alone, around 35% of the end-of-life ship tonnage in the world each year is recycled in the coastal region of the country. This is a business that employs more than 200,000 people and generates nearly a billion US dollars for the national economy. This trend seems to be catching on, with an estimated 20,000 ships, aged between 25 to 30 years, being recycled in the next few years.

The Hong Kong Convention was set up by the International Maritime Organization in 2009 in an effort to address this problem. Many South Asian shipyards now follow these standards and have been awarded green certifications. However, there is an additional layer where the European Union implemented its own rules in the year 2017. If the European Union decides to officially recognize HKC-2009 compliance as a standard, there will be a surge of investment flowing into places like Alang in India and Chattogram and Gadani in South Asia. This kind of boost will really push these ship recycling areas to upgrade their facilities. But for the beaching method to stay practical and sustainable here, the big three recycling nations in South Asia have to work together. They need to team up to shape better industry practices, protect the environment, keep workers safe, and make sure ship recycling keeps bringing in economic benefits for the region. The process of ship recycling is a vital international business that contributes towards environmental sustainability and resource recovery by disassembling end-of-life ships to recover valuable resources like steel, machinery, and equipment. Every year, a good number of ocean-going ships such as tankers, bulk carriers, and container are dismantled. In fact, about 90% of all ship recycling in the world takes place in South Asia because of its ideal location and relatively inexpensive labor. The coast of Chattogram, especially Fauzdarhat, is the principal port for ship recycling within the nation. In fact, ship recycling in Bangladesh has turned into a multi-billion-dollar industry since its inception in 1965. At present, this industry supplies more than 50% of Bangladesh raw materials for steel production and own shipbuilding. The industry is a major employer, generating employment for over 200,000 individuals, and sustaining the livelihood of about one million individuals, both directly and indirectly, making the industry an important contributor of income in economically fragile areas.

While the industry is contributing significantly towards the economy, the industry is facing increasing criticism because of its use of the beaching approach, which although is cost-effective but environmentally sensitive. In this research, the amount of reusable and waste products produced from ship breaking is considered at the field level, and how these products are managed in terms of reuse, recycling, and dumping through a model of the distribution channel is considered. The research uses ARIMA-based forecasting and scenario modeling; where findings suggest Bangladesh stands at a tough crossroads, but shows signs of resilience. Based on forecasts, it is expected that Bangladesh will continue its operation with recycling about 2.7 million GT on an annual basis under normal circumstances, but with the optimistic prediction, it might even rise up to 5 million GT each year for Annam, if modernization increases and favorable circumstances prevail. The above prediction, however, should be viewed in light of growing competition. Currently, India is the formidable competitor in this industry globally with regard to its technological sophistication with 120 HKC-certified yards and modernization efforts coupled with clear legal policies and huge investments in modernization (~$100 million). Pakistan decided to invest ~Rs12 billion (~$42 million) into its Gadani project which represents a significant geopolitical shift that might undermine Bangladesh's dominance in the region. However, local ship recycling sector Bangladesh still rely mainly on cheap labor and strategic geographical positioning (TBSNews, 2025; BIMCO, 2025; Dawn, 2025; Olgn News, 2025). The international regulations on ship recycling are changing significantly, influenced by initiatives such as the European Union Ship Recycling Regulation (EU SRR) and the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC 2009).

The implementation of more strict regulations in terms of environmental protection and occupational health and safety creates difficulties for traditional ship recycling facilities in South Asian countries. However, although India and Turkey managed to adapt their yards successfully in accordance with HKC and EU-

SSR, the progress achieved by Bangladesh appears to be rather slower because of owners' attitude (with some exception) and insufficient fund to modernize the industry. Till now only some yards (around 26) in the country have gained green certification. In 2018, Bangladesh adopted the Ship Recycling Act, setting an official objective to ensure that all existing shipyards will comply with HKC regulations by 2023. Even though Bangladesh failed to achieve its objective, but significant changes and development have taken place regarding infrastructure improve, regulations, and management of shipyards via the Shipbuilding and Ship Recycling Board (SBSRB) of the Ministry of Industries. This research provides a complete analysis of Bangladesh's ship recycling industry in the global context. The research covers the history of the industry, its present challenges related to regulations, comparative analysis between Bangladesh and other ship recycling countries, its socio-economic impacts, and finally uses market forecasting techniques to forecast future demand and identify strategies for meeting the changing global demands. As an analytical and research-oriented study, this research provides important insights on the present status of Bangladesh's ship recycling industry, its future course, challenges, and strategies for growth. In summary, the research covers all aspects of the Bangladesh ship recycling industry includes comparative analysis with other global competitors, challenges, and recommendations. Few research questions will be addressed through this research work. Exploring these issues will require an interdisciplinary approach, incorporating environmental science, public health, economics, and engineering, to advise Bangladesh on developing a sustainable ship recycling sector.

a. How Bangladesh can ensure optimal economic benefits while reducing health and environmental hazards in the scrap processing industry?
b. What is the total output from local recycling yards both usable and as waste materials?
c. Develop a channel design for distribution.
d. What investment strategies will be the most economical for yards to comply with HKC/EU requirements?
e. How will change in regulations worldwide affect international shipping and the market share of Bangladesh? Global modeling studies can predict future scrap supplies based on different compliance scenarios.
f. What institutional, financial, or knowledge-related obstacles prevent yard owners from implementing recommended practices?
g. What would be the potential for partial mechanization and/or alternative recycling processes (such as mobile facilities) in the context of Bangladesh?
h. What are the effects of ship recycling on surrounding communities (such as fishing villages and small-scale fishermen)?

II. DATA COLLECTION AND METHODOLOGY

2.1 Assessment of Local Ship Yards' Material Output

The method of data gathering adopted in this study is designed to offer a detailed and localized study of the ship recycling process in Bangladesh, filling the void left by previous studies based on external criteria. The period of data gathering stretched for seven years, from 2009 to 2016, and was done in different yards of ship recycling in Chittagong. Sixteen ships of various kinds were studied during that period; there were 5 bulk carriers, 5 tankers, 6 container carriers, 5 cargo ships, and 5 ships of other kinds (passenger ships and offshore vessels). Ship selection was purposive and was meant to provide a sample of ships with varying designs, age (15-25 years), and location (Asia, Europe, Americas). Ship selection criteria were the LDT capacity (8,000-60,000 MT), operational experience, and adherence to regulations governing ship breaking operations. Data was obtained through participation of the researcher (naval architect) working together with Bangladesh Ship Breakers Association (BSBA), ship breaking yards, and regulatory bodies including the Department of Environment (DoE), Ship Building and Ship Recycling Board (SBSRB), Chittagong Port Authority, and Bangladesh Navy. The use of different stakeholders in the study provided more reliable data that reflected practical experience (Hossain, 2015a; Hossain and Zakaria, 2018; Mikelis, 2013; Hossain, 2019b).

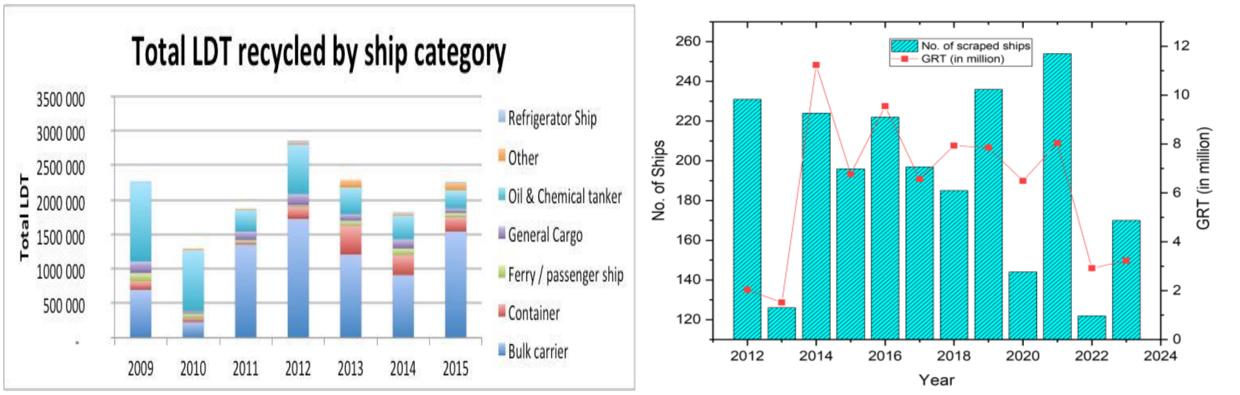


Figure 1: Total LDT of ships recycled in Bangladesh by type/category/number within 2009 to 2024.

2.2 Primary Data Collection from Local Ship Recycling Industry

In this research, Author has put efforts for showing the real distribution channel of reusable and waste material from local industry of Bangladesh through the analysis at ground level (Bois, 2009; Eolog, 2025) that has been gathered through the active participation of the author during the period of seven years (from 2011 to 2017). Information about ship recycling process has been obtained from actual ship recycling company based in Chittagong that has been provided by different stakeholders as well as Bangladesh Ship Breakers Association (BSBA). Inventory of reusable and hazardous waste material from recycled ship has been prepared on the basis of collected data by author. The findings are based on primary field observations and have taken considerable guidance from the methods adopted in existing literature and research articles. Primary and basic data regarding the quantity of output for various materials/components, as well as hazardous materials, from various types of recycled ships, has been gathered from the industry through direct involvement from the researcher (Chowdhury, 2019). However, nuclear waste, along with other discharges, including atmospheric pollutants and pollutants discharged into the water bodies, have not been considered in this study (Eolog, 2025; Hoque & Emran, 2016). In total 26 recycled ships of different types/categorizations, as well as lengths (LDT), have been considered as samples in order to calculate the annual average output of reusable materials. In this research study, 5 bulk, 5 tankers, 6 container carriers, 5 cargo and 5 others different types of vessels were used as samples. In order to prepare inventory of different types of items and material output of each of these vessels, a period of six to eleven months is required. Table 1 provides details of these 26 sample EOL vessels. It is for the first time that such a comprehensive sampling data analysis is being carried out in Bangladesh. Figure 1 below provides the Total LDT of ships recycled in Bangladesh by type/ category during 2009-2015.

Sl No	Ship Category/ Type	Sample Ships No	Range of LDT	Manufacture/Build Year
1.	Bulk Carrier	6	11834 to 21592	1978 to 1986
2.	Tanker	5	11182 to 29324	1981 to 1989
3.	Cargo	5	5008 to 18302	1984-1990
4.	Container	5	6698 to 16053	1977 to 1992
5.	Other Ships (Refrigerator, Ore Carrier, Passenger, LNG/LPG, Motor, Floating Restaurant, etc)	5	5625 to 25997	1966 to 1981

Table 1: Summaries fact and figure of 26 sample EOL ships.

2.3 Secondary Data Collection

The study begins with the gathering of secondary information from various sources in order to set the basic context. The sources include:

a. Government and other institution's reports (Ministry of Industries, BSRB, DoE)

b. international institutions' reports (IMO, UNCTAD, NGO Ship-breaking Platform)

c. Academic journals, books, and policy papers

d. Industry and shipyard records where available (tonnage, number of ships, steel production)

e. Media reports and grey literature

f. Practical experience over the past 20 years

The current research follows the mixed methods research paradigm to conduct research into the ship recycling industry in Bangladesh. Quantitative and qualitative approaches have been combined along with the policy studies method to achieve an all-encompassing analysis of the subject matter under consideration. Statistical data pertaining to the volume of ship breaking, number of jobs generated, quantity of scrap steel produced, accident rates, and violations of environmental norms have been collected over the last two decades to examine trends within the industry. The findings from this research show that there is a delicate but significant path that the ship recycling industry of Bangladesh will need to traverse through in the wake of HKC implementation. The results presented by this study were derived based on both on-ground information, first-hand information from more than 500 different sources in addition to the author's past experience/relationship with the industry over a period of 20 years and secondary information from global ship scrapping data ranging from the years 2014 – 2024. This research will extract the important implications that will be made in the four main themes: institutional preparedness, working environment, competitive advantage in markets, and global compliance policies.

2.4 Focus Group Discussions (FGDs)

In order to incorporating all ship recycling-related stakeholders, the following groups will be considered for conducting focus group discussions (FGDs):

a. Workers from the shipyard (skilled and unskilled workers)

b. The management of shipyards

c. The government (Department of Environment, BSRB)

d. Representatives from NGOs (YPSA, Shipbreaking Platform)

e. Expertise from local and international sides, Yard Owners & executives

f. Eco-activists and labor activists

The FGD will consist of 6 to 10 participants and will be conducted using a semi-structured questionnaire. The themes include the community's perception of safety in the workplace, challenges in compliance, socio-economic consequences, and need for modernization.

III. DATA ANALYSIS AND RESULT OF REUSABLE MATERIAL OF LOCAL SHIP RECYCLING

3.1 Assumption. The fundamental inputs of this study are the variety of reuseable materials and wastes of various sizes from 26 end-of-life vessels dismantled and recycled in Bangladesh as mentioned in Table 1 above. Material flow analysis (MFA) software STAN and Microsoft Excel are being used for inputting, processing, compiling, analyzing, calculating, and determining quantitative data (such as annual reuseable and waste materials generated by the industry). Releases including nuclear wastes and atmospheric pollution emissions and diffuse water pollutants are excluded from the scope of this research. All material flows emanating from the process are divided into two broad categories of flows; economic value stream (EVS) and non-economic value stream (NEVS). EVS stream refers to the stream of material products that can be sold for re-use or recycling purposes, leading to financial inflow into the recycling center. NEVS stream refers to the stream of material products that have to be disposed of in waste treatment facilities or landfills, thereby leading to cash outflows from the recycling center. The division of material stream into EVS and NEVS can vary among yards since the stream depend on factors such as geographical location, recycling procedures, demand for second-hand materials, presence or absence of forward and backward linkages industries, among others (Hossain, 2018c). Assumptions have been made based on scenarios, where there is a local market in Bangladesh for ferrous and non-ferrous scraps, and second-hand markets for mechanical devices, electrical and electronic reuse waste, cables, pipes, outfits, household items, insulation products, liquids like waste oil, sludge, fuel oil, lubricant oil, hydraulic oil, solvents, chemicals, etc., and machinery. Any material scraps, waste liquid from end-of-life ships, old insulation materials, and different electrical and mechanical items, old household items, and furniture can be sold in the local market in Bangladesh. Developed or developing nations might find it astonishing that practically everything collected or produced from end-of-life ships could be sold and utilized by the people of Bangladesh (Hossain, 2018b). The cost and price of collecting and selling reusable materials in the local market are not discussed in this research paper

3.2 Material Output Analysis and Process.The general process of ship recycling is opposite to the process of ship construction. Construction of ships is based upon design and takes place through welding of series of sections, blocks, and modules. The main structure of the ship, which comprises its hull and superstructure, is constructed first (the usual sequence being from bottom to top). After that, all types of machinery, accessories, mechanical and electrical installations, safety accessories, various systems, pipework, cabling, various fittings, and other accessories are added to the ship's structure. Dismantling and recycling of any ship happens in the exact opposite way of how a ship is built and in many stages. When dismantling an old ship to recycle it, it will begin with the removal of the various items that are not bolted down such as kitchens and bathrooms, different electronic and electrical equipment, communication and navigation tools, mechanical and electrical machines, pipes, cables, and finally the hull and superstructure of the vessel. The dismantling process of the metal hull and superstructure follows the exact opposite order of ship building. Thus, it will be possible to apply material flow analysis (MFA) successfully to compile, analyze and quantify the reusable and waste materials that come out as products from the recycling of an end-of-life ship in a shipyard. The outcomes of material flow analysis (MFA) greatly rely on the correctness of the input data and knowledge about the various sub-processes involved in the recycling process of a ship. It will not be feasible to perform material flow analysis (MFA) of shipyards without having knowledge of the material composition of ships, design and construction, and the relationship between the input and output flows of sub processes. Quantity of waste that can be extracted from the end-of-life products is based on the recycling process being followed. In some cases, removing the insulation, flooring, tiling, and cement works will provide very little or even no EVS at all. Also, the minor steps within the pre-cutting step are dependent on the availability of reused insulation in the local market and its ability to be separated without causing any harm. For instance, in countries such as Bangladesh in Southeast Asia, glass wool insulation panels are sold in their original state by the resellers to satisfy the demands of cold storage plants, shipyards, and different manufacturing industries (Hossain, 2018b, c). My observations revealed that even used and broken furniture available in the local markets and people buy this type of junk and use as fire wood in their houses. Similarly, the last drops of all kinds of oils such as lubricating, diesel, hydraulic, bilge, and many other types of solvents and chemicals both old and outdated have a very high level of demand in the local market in Bangladesh. The demand for almost all the products/metal recovered from the ships that reach their end-of-life cycle has a great demand among the network of secondary processing firms established in the vicinity of the ship recycling yards in Bangladesh. Therefore, linkage industries and the local market for the local recycling industries are extremely important regarding the consumption of reusable and waste material.

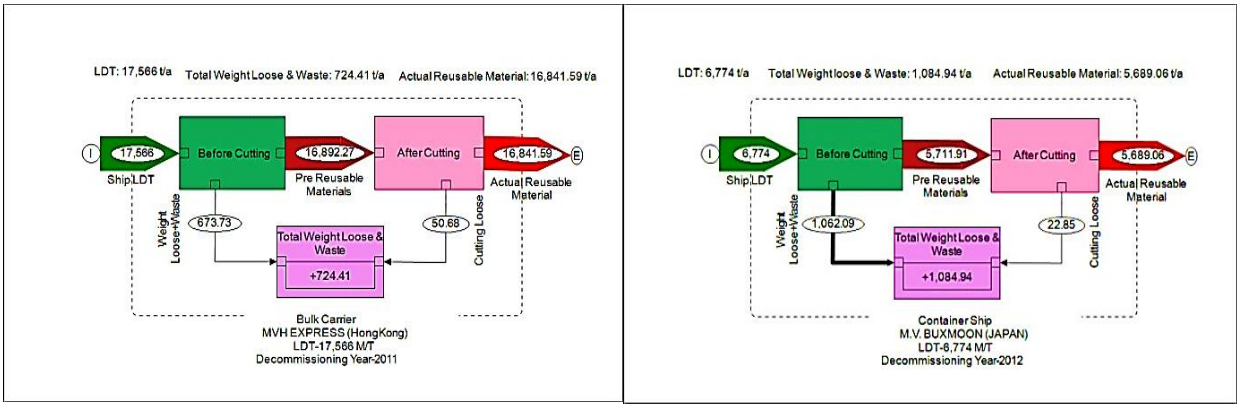


Figure 2: Reusable material flow diagrams of two sample bulk and container EOL ship

The total recycling procedure can be grouped into three main stages: precutting, cutting, and post-cutting. The stage of precutting comprises different kinds of surveying and preparations done before the gas cutting procedure takes place. The EVS and NEVS generated from precutting and cutting are inputs for post cutting, where separation takes place. It has been found by me through calculations using MFA that about 1.0% to 2.0%, and 2% to 4% of LDT of the ships sampled are generated from NEVS and EVS, respectively. Cutting process is the process that involves actual cutting of the steel hull and machinery into smaller pieces. The cutting process can be further classified into two sub-processes - primary cutting process and secondary cutting process. Primary cutting process is the process in which the hull of a ship is cut into ferrous blocks and nonferrous items that are removed from the hull. By the calculation of the MFA technique, it can be assumed that on an average basis about 72 to 93% and 1.5 to 5.5% of LDT of the sample ships originates as EVS and NEVS from the cutting process. Post cutting involves three sub-processes - collection and storing, sorting and segregating, and transporting. NEVS and EVS coming out of sub-process sorting and segregating are then passed through the sub-process of transporting. In the sub-process of transportation, EVS will be transported either for reuse or recycling while NEVS will be taken either to landfilling areas or for dispose of. By using MFA, I have quantified and calculated that 1.0 to 3.5 percent of LDT from sample ships (on average) will be either disposed of as waste or considered as NEVS, and 73 to 95 percent of LDT from EOL ships can be either reused or recycled within the local market or considered as EVS (Hossain, 2018c). About 20 to 30 percent of the total NEVS weight can typically be recovered as EVS in the separating sub-process phase of the post-cutting process. The calculations, results, analyses, facts, and figures for various types and sizes of EOL ships have been detailed in my PhD research paper.

In the context of this research study, all research articles and technical documents concerning material accounting of end-of-life ships have been studied. Unfortunately, there is not much literature available like that of automobile or aviation industry, amounting only to a dozen papers. For developing material flow diagrams using STAN software, inputs and outputs of each process need to be provided by the user (Hossain, 2017b). The inflow of inputs in a process that could be split into two or more outputs according to the ratio provided. This sort of information is obtainable through the reconciliation of information regarding the composition of materials in the ship. From such information, STAN calculates the worth of each flow. In the Ph.D. research conducted by the corresponding author, the MFA was performed for 27 types of ships at their end-of-life stage. According to the corresponding author, the MFA approach may serve as an instrument for depicting, analyzing, estimating, planning, and comparing various scenarios that might occur in the course of breaking and recycling of any EOL vessels. Figure 2 presents a reusable material flow chart of a Bulk Carrier and a Container Carrier EOL vessel recycled in the yards of Bangladesh. As for Figure 3, it represents the outcome of the reusable material of various sizes of 5 bulk and 6 container EOL vessels (Hossain, 2018b, c).

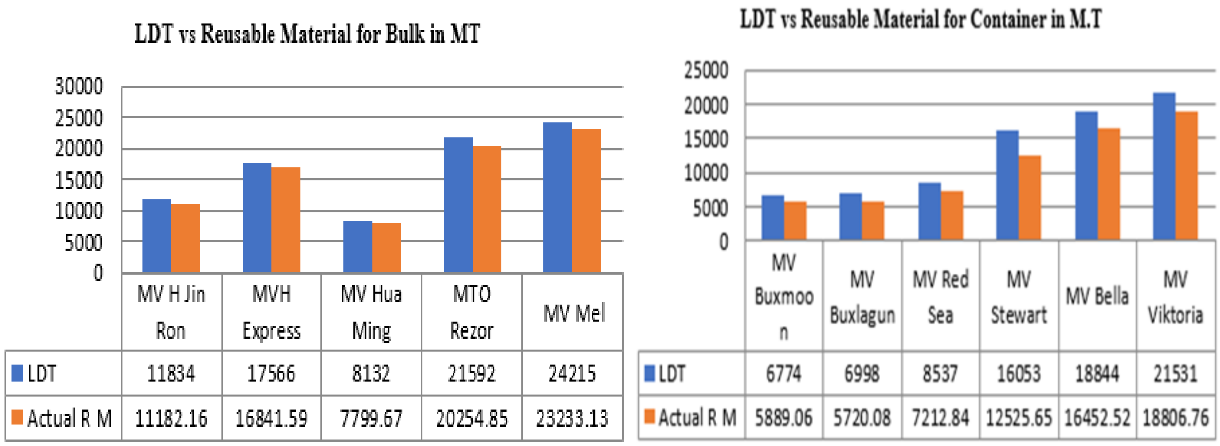


Figure 3: Estimation and output of reusable material of different types and sizes of ships

3.3 Reusable Material Output Calculation and Result.

Ship recycling produces a wide variety of reusable materials, often including hundreds to thousands of unique items per vessel. In this research, the author faced the demanding challenge of compiling a detailed inventory of materials and components from 26 end-of-life (EOL) ships. Due to the industry's restrictive nature and the vast amount of data involved, this endeavor required significant effort over seven years. To support this data-heavy project, the researcher formed a dedicated team of six data entry staff and two supervisory managers. In accordance with the guidelines outlined in the Hong Kong International Convention for Safe and Environmentally Sound Recycling of Ships (HKC, 2009) (Gramman et al., 2007; Gregson et al., 2012), the reusable materials recovered from the sample of ships analyzed in this study were classified into four major categories. These classifications were further sub-classified based on the designs and constructions of ships, employing the professional knowledge of the researcher as a naval architect. Literature on the topic provided useful guidance during the classification process (Andersen, 2001; Arab News, 2024; Abdullah et al., 2010; EC Regulation, 2006; Eolog, 2025; Hossain and Zakaria, 2010a). The information was collected manually and entered using MS Excel Spreadsheet. Categories of Reusable Materials from EOL Ships are illustrated in Figure 4.

- Metal Items: This category encompasses both heavy and light steel plates, brass, copper, MS pipes, nickel, galvanized iron, stainless steel sheets, aluminum, zinc, chains, anchors, shaft plates, cast iron, and a variety of ferrous and non-ferrous scrap materials.
- Machinery, Equipment, and Accessories: This includes primary engines, generators, gearboxes, propellers, rudders, pumps, condensers, radiators, heat exchangers, air conditioning systems, fire safety apparatus, lifeboats, kitchen tools, and personal protective gear.
- Electrical/Electronic Devices: Covers electrical wires, transformers, motors, navigational and communication devices (like radar and GPS), television sets, washing machines, computer devices, and other types of electrical tools.
- Suitcase/Other Usable Parts: Covers doors, hatch covers, port glass windows, cranes, winches, capstans, valves for different kinds of liquid systems, ladders, furniture, and sanitary fixtures.

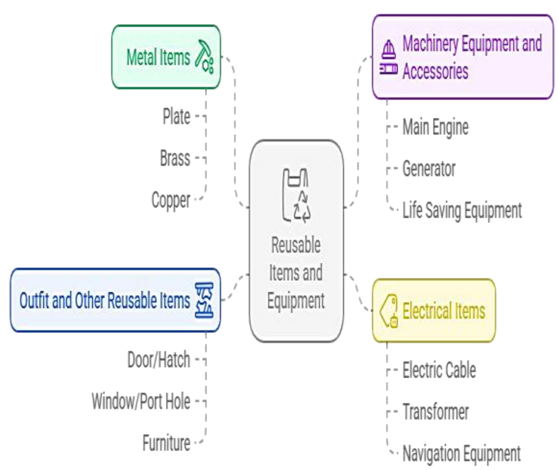


Figure 4: Illustration of reusable items and equipment extracted from EOL ships.

Based on the collected data the amount of reused materials produced annually by the ship recycling industry in Bangladesh lies between 1,833,461 metric tonnes (MT) and 1,989,252 MT in 2018. The determination of material quantities and flows was done manually and through software support such as MS Excel and the MFA software STAN (EC Regulation, 2006; Eolog, 2025; Hossain & Zakaria, 2009; Hossain & Zakaria, 2010a; Hossain, 2015a). It was found from comparative analysis that the results from manual calculation differed from the STAN calculation by a maximum of 0.4%, whereas the results from Excel calculation were not observed to differ (Hossain, 2018b, c; 2024). Table 2 depicts the mean output of the reusable material (in MT per year) based on various ship types, while Figure 5 shows the correlation of Light Displacement Tonnage (LDT) and output of reusable material (Hossain, 2018b, c; 2024). The complete process of compiling, visualizing, and interpreting the results for 26 selected ships was conducted using Excel programming and broadsheet (Hossain, 2015a; Hossain, 2023g). Moreover, Figure 13 illustrates a conceptual model of the distribution channel of the material flow, comprising both reusable materials and waste, from a selected container ship recycled at a local shipyard in Bangladesh (Hossain, 2015b).

Sl. No	Type of Ship	Average LDT per year	Reusable Material Factor (%)		Average Reusable Material per year (MT)
1	Cargo	111,486	0.67	Min.	74,696
			0.78	Max.	86,959
2	Bulk Carrier	1,094,566	0.94	Min.	1,028,892
			0.98	Max.	1,072,675
3	Tanker	579,542	0.95	Min.	550,565
			0.97	Max.	562,156
4	Container	186,583	0.8	Min.	149,266
			0.87	Max.	162,327
5	Other	120,169	0.25	Min.	30,042
			0.8	Max.	96,135
6	Total	2,092,346		Min.	1,833,461
				Max.	1,980,252

Table 2: Reusable material factor and amount of materials output in MT in 2018.

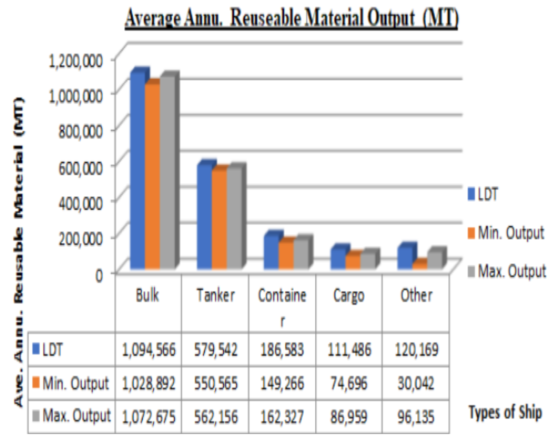


Figure 5: Average annual LDT against average annual reusable material output in MT in 2018

3.4 Reusable Materials Factor and Annual Output (Economic Value Stream, EVS)

Reusables martial around 73-95% of LDT (1,833,461-1,989,252 MT/year) based on the classification framework adopted from HKC (2009). These reusable materials have been found vital for local industries that require ship building, construction, and small-scale industry production activities (Hossain, 2015a; Sujauddin et al., 2017). Around 97% of materials including glass wool insulation (worth USD 110 per ton in Bangladesh compared to USD 100 per ton in India) are processed and recycled locally due to high demands in secondary markets (Hossain and Zakaria, 2018; Sarraf et al., 2010). Reusable material parameters and annual production have been illustrated in Table 3.

Ship Type	Reusable Factor (% LDT)	Annual Output (MT, Min–Max)
Bulk Carrier	75–92	450,000–550,000
Tanker	73–90	500,000–600,000
Container Carrier	78–95	400,000–480,000
Cargo Ship	76–93	350,000–420,000
Other Types	74–91	133,461–139,252
Total	73–95	1,833,461–1,989,252

Table 3: Reusable Material Factors and Annual Output (2009–2016)

IV. DATA ANALYSIS AND RESULT OF WASTE MATERIAL OF LOCAL SHIP RECYCLING

4.1 Waste Material Process. According to the Bangladesh Environment Conservation Act 1995, hazardous waste is defined as any waste which by reason of their physical and chemical properties or due to their nature, whether on their own or as a result of interaction with other materials, are capable of having detrimental effects on human beings as well as on the environment. There are mainly two classifications of hazardous waste: one organic material such as polymer and other minerals (inert material), including heavy metal or asbestos. In case of organic hazardous waste, it may be converted through a chemical process into a less hazardous form. Incineration may also be able to integrate with the energy recovery method (waste to energy). High capital costs are required for the use of the technology. However, the method can deal with a wide variety of hazardous wastes. Landfilling is relatively cheap and simple if implemented securely. But, it can never be guaranteed that landfilling will be successful in the long run. Again, co-processing in cement kilns may serve as another method besides incineration. The initial capital cost is relatively small. The process needs only the pretreatment facility and a high kiln temperature of 2000°C. The hazardous minerals are not combustible and will require land filling, after undergoing physicochemical treatment initially. It is thus necessary to reduce waste formation and increase material recovery and recycling. Yet, upstream efficiencies and clean technologies will drastically cut down waste production. On the other hand, for the balance, it becomes essential to have safe waste disposal that prevents the leakage of toxic chemicals into the environment. The physico-chemical process applied to the waste results in toxic sludge formation which can be treated in a special landfill site. In general, the major sources of the waste and substance include the waste and substance from the recycling yard or the EOL vessel. For instance, wastes and substances that might be part of the ship structure itself, and waste and substance that could be contained in the vessel. I categorize the waste materials and substance from the local recycling yard into six groups based on HKC 2009 guideline, and to make the classification easy, I have referred to certain literatures (Lamb, 2003; Jobaid et al, 2014; Neser et al, 2007; Hossain, 2006; Gregson et al, 2010; and Abdullah et al, 2010). Below is the division of the waste materials and substance.

According to Bangladesh Environment Conservation Act 1995, “hazardous waste” means any waste, by reason of its intrinsic nature or of its chemical, physical, or reactive qualities, or owing to contamination by substances of any description, is capable of being harmful to the environment or human beings. Hazardous waste may be divided into two general categories, organic material (e.g., polymers) and inert material (minerals). Organic hazardous wastes may be decomposed, meaning that toxic chemicals will undergo chemical modification into harmless substances. Incineration may be used along with energy recovery process (waste-to-energy) but demands huge investment. However, it treats all types of hazardous wastes. Landfilling method can be used as it demands low investment. This can be considered only in case when it is performed safely. But still there is a chance of failure in case of landfilling method in the long run. Once again, co-processing can be another alternative for incineration. In this method the initial investment demand is low. This is because of the requirement of only a small amount of equipment like the temperature of the kiln which goes up to 2000°C. Hazardous minerals cannot be incinerated but landfilled only after physico-chemical treatment. It is thus crucial to avoid any waste formation and maximize recycling/recovery of the waste material. Nevertheless, efficient utilization of resources through clean production can help in minimizing waste formation significantly. On the other hand, the remaining part must be handled properly to make sure that it poses no danger to releasing the toxic chemicals. The physico-chemical treatment process results in the production of toxic sludge that can be dumped in a carefully engineered landfill. Wastes generated from recycled or end-of-life ships are usually the main sources of these materials. For example, wastes and substances that might be contained within the structure of the ship and waste materials that might exist within the ship. I have classified waste material and substances produced from the local recycling yard into six classes according to the HKC 2009 guideline. In the course of classification, I have sought assistance from ship design and construction principles as a naval architect, and also sought help from some relevant literature sources (Lamb, 2003; Jobaid et al., 2014; Neser et al., 2007; Hossain, 2006; Gregson et al., 2010; and Abdullah et al., 2010). The classification of waste materials and substances is shown below.

a. Asbestos and asbestos-containing waste, insulating material, etc., including glass wool, ceramic wool, dampening and other insulating material, etc.

b. Cementing material, ceramic rust and dust, iron rust, dust and scales, ash from fire, incineration ash, glass waste from cathode-ray tube, glass dust and particles, waste zinc residues, and other landfill waste, etc.

c. Waste from combustion, burning, paint and coating, hexavalent chromium compounds, pharmaceutical waste such as medicines, incinerated waste, etc., including polyvinyl chlorinated (PVC) or polychlorinated biphenyl (PCB) or polychlorinated terphenyl (PCT) or polybrominated biphenyl (PBB) or other polybrominated analogues, oil rags.

d. Bilge water, fuel oil, lubricating oil, hydraulic fluid, organic solvent (halogenated & non-halogenated, volatile organic compounds, thinner), other mineral oil, micro-organisms and sediment, obsolete chemicals and other liquid waste, pesticides and insecticide spray, etc.

e. Heavy metal, toxic metal, etc. (such as Lead, Mercury, Cadmium, radioactive materials, etc.) that are generally contained in batteries, anodes, nuts & bolts, connector, lighting fixtures, thermometer, level indicator, coupling, bearings, fire detector sensors, communication/navigation systems, alloys, soldering machines, cable insulation, motors & transformers, computer screens, fire alarm system, etc.

f. Ozone-depleting substance (ODS), gas cylinder, fire-fighting liquids and other hazardous waste of explosive nature, etc. (CFC, CO2, Halon, AFFF, etc).

The categories of waste materials and substances from end-of-life (EOL) ships are shown in Figure 6

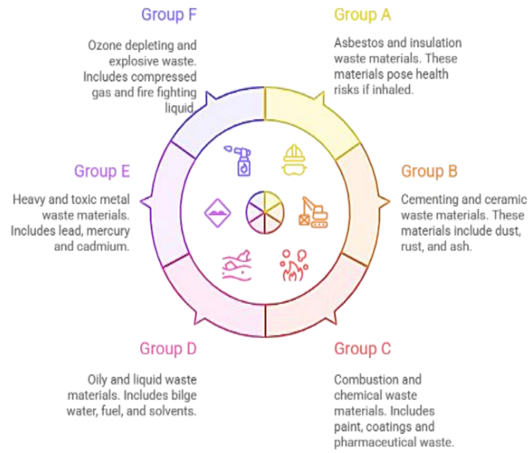


Figure 6: Categorization of waste materials and substances of EOL ships.

In all situations, separation and segregation of the dangerous waste should be accomplished as early as possible. Furthermore, combining of dangerous waste should never be carried out. Proper handling and labeling of waste should be made by the recycling yards prior to disposing it in any form. The methods of land filling and incineration offer many benefits and demerits (Muhibbullah, 2014). Land filling is known to have relatively low cost of installation and operation. The land space required is very large and long-term maintenance is needed after closing the site. It may also serve as a source of environmental pollution if the hazardous materials were to leach into the environment or be emitted to the atmosphere, hence the need to control the evolution after its closure. On the other hand, one of the disadvantages of incineration is the fact that it is a source of atmospheric pollution as it produces considerable amounts of smoke and ashes (slag, bottom ashes) requiring further processing. Besides, it does not help recover the thermal energy released from the burning waste except when the process is used to generate power. Therefore, the production of hazardous waste which needs processing and disposal must be reduced through proper management (Hossain, 2015b and Hossain, 2015c), efficiency measures as well as recovery, recycling and reclamation. Nevertheless, both landfilling and incineration can prove beneficial on a per need basis. In order to calculate and determine the quantity of waste materials, I have taken assistance from free commercial software such as Microsoft Excel and MFA software STAN along with manual calculation. It has been observed that there is a slight difference of up to 0.4% between the result of waste material determined manually and that of the STAN software, while there is no difference between the results of MS Excel.

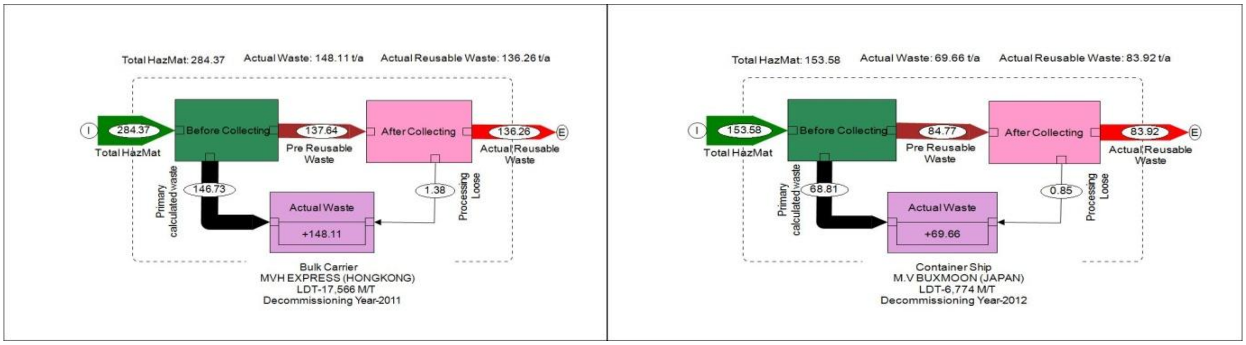
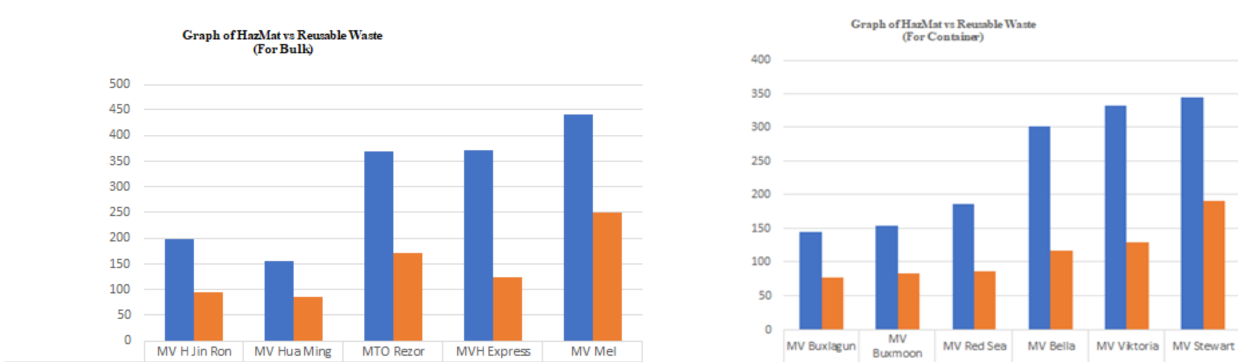


Figure 7: Waste material flow diagrams of two sample EOL ship

In each case, isolation and segregation of the hazardous waste must be accomplished as soon as possible. Moreover, the mixing of hazardous waste must never happen. The recycling yards must make sure that the waste is packaged and labeled correctly, weighed, and documented prior to treatment and disposal. Land filling and incineration have different strengths and weaknesses (Muhibbullah, 2014). Landfilling is relatively inexpensive in terms of both capital and operation cost. It needs a considerable amount of space as well as long-term maintenance, which continues even after landfill closure. It may also be the cause contamination of the environment owing to leaching or emissions into the atmosphere of these toxic materials which necessitating regulation during its post-closure process. Incineration has received criticism for polluting the atmosphere by releasing large amounts of smoke and residues such as bottom ashes and slag that require additional disposal processes. Additionally, incineration is not effective in capturing the thermal energy that could have been derived from the waste (unless used for waste to energy). As such, there is a need to reduce the production of hazardous waste that needs to be treated and disposed of effectively (Hossain, 2015b and Hossain, 2015c). However, both land filling and incineration can prove useful on case-by-case basis. In order to calculate and evaluate the quantities of waste generated, assistance has been taken from various commercial software packages, i.e. Microsoft Excel and material flow analysis (MFA) software, i.e., STAN, alongside manual calculations. It has been noticed that, in comparison with STAN package result, my manual result of waste generated differs only by 0.4%. However, there has been no variation between my result and result generated using MS Excel. Figures 7 show the flow diagrams of waste materials generated while recycling the end-of-life (EOL) bulk and container ships. Figures 8 show the outputs of waste materials generated through recycling of five bulk and six container EOL ships (Hossain, 2018b, c; 2024).



	MV H Jin Ron	MV Hua Ming	MTO Rezor	MVH Express	MV Mel
Total HazMat (MT)	200	156.53	371	372.8	441
Reusable Waste (MT)	95.36	85.89	172.85	124.81	251.6

	MV Buxlagun	MV Buxmoon	MV Red Sea	MV Bella	MV Viktoria	MV Stewart
Total HazMat (MT)	144.96	153.58	187.3	302.11	333.35	344.89
Reusable Waste (MT)	77.3	83.92	86.24	118.12	129.66	191.77

Figure 8: Estimation and output of waste material of of 5 bulk and 6 EOL container ships

4.2 Waste Material Output Calculation and Result

The estimation of the quantity of waste produced, as well as its determinants, was performed by using both manual computations and computer applications. The software products that were used for calculations were Microsoft Excel and the MFA tool known as STAN [21, 28, 29]. As can be seen, results obtained by hand differed by no more than 0.4% from the figures produced by STAN, whereas outputs acquired from Microsoft Excel were fully consistent with manually calculated data (Eolog, (2025); Galley, 2014; Hossain et al., 2010a). Figure 9 depicts the average annual amount of dangerous waste (in metric tonnes) that has been produced by various groups of EOL ships recycled in Bangladesh and Figure 10 represents the annual asbestos quantity (in metric tonnes) from diverse types of EOL ships recycled in Bangladeshi ship recycling yards. Table 3 contains precise yearly figures (minimum and maximum estimates) of each group of waste, based on the sample of 26 obsolete ships dismantled in 2018. All data presented here have been gathered, analyzed, and processed personally by the author over a period of seven years via direct participation in the shipbreaking industry. Data processing and analysis have been carried out in customized Microsoft Excel spreadsheets and programming scripts (Hossain, 2019b, c; 2025c).

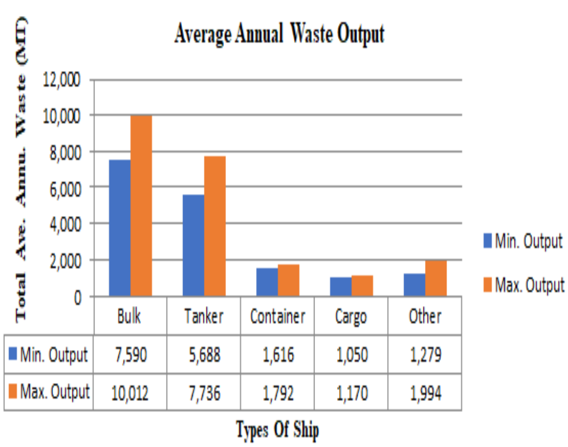


Figure 9: Total average annual HazMat or Waste output in MT from different EOL ships

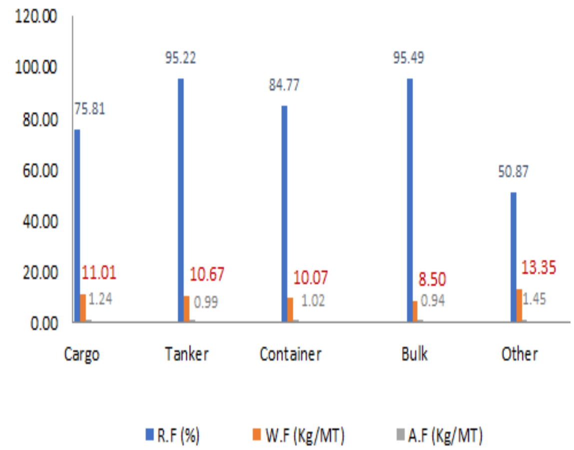


Figure 10; Relation among average reusable, waste and asbestos factor of EOL ships

4.3 Waste Material Output Calculation and Result

For the estimation of the amount of waste produced and factors related to it, a method that involves both manual computation and electronic devices was applied. In order to calculate and verify the findings, Microsoft Excel and Material Flow Analysis (MFA) software called STAN were utilized [21, 28, 29]. It can be seen that the results obtained manually differed from the results provided by STAN not more than 0.4%, whereas the results acquired by using Microsoft Excel were fully identical to the ones calculated manually (Eolog, (2025; Galley, 2014; Hossain et al., 2010a). Figure 11 depicts the average annual hazardous waste production (in metric ton) from different types and sizes of end-of-life (EOL) ships recycled in Bangladesh, while figure 12 represents the annual average asbestos production (metric ton) for different types and sizes of end-of-life (EOL) ships recycled in Bangladesh ship recycling yards. Annual data (including both minimum and maximum levels), for each type of waste generated, are listed in Table 4 below. All the data presented in this paper have been recorded, arranged, and analyzed based on fieldwork experience gained while studying 26 obsolete ships scrapped in 2018 (Hossain, 2019b, c; 2025c). All the field research and analysis undertaken within this study have taken place during a span of seven years. Data analysis and presentation were performed using Microsoft Excel spreadsheets.

Sl. No	Type of Ship	Average LDT per year (MT)	Total Waste (Land-filled, Incinerated, and Bilge Waste)							
			Average Land-filled Waste Per Year (MT)		Average Incinerated Waste Per Year (MT)		Average Bilge Waste Per Year (MT)		Total Average Hazardous Waste Per Year (MT)	
1	Bulk	1,094,566	3042	Min.	2,188	Min.	2360	Min.	7590	Min.
			4078	Max.	2,861	Max.	3073	Max.	10012	Max.
2	Tanker	579,542	2244	Min.	1,357	Min.	2087	Min.	5688	Min.
			3030	Max.	1,854	Max.	2852	Max.	7736	Max.
3	Container	186,583	718	Min.	524	Min.	374	Min.	1616	Min.
			808	Max.	574	Max.	410	Max.	1792	Max.
4	Cargo	111,486	582	Min.	260	Min.	208	Min.	1050	Min.
			648	Max.	290	Max.	232	Max.	1170	Max.
5	Other	120,169	580	Min.	299	Min.	400	Min.	1279	Min.
			849	Max.	562	Max.	583	Max.	1994	Max.
Total		2,092,346	7166	Min.	4,628	Min.	5429	Min.	17223	Min.
			9413	Max.	6,141	Max.	7150	Max.	22704	Max.

Table 4: Annual average amount waste produced in MT from different EOL ships

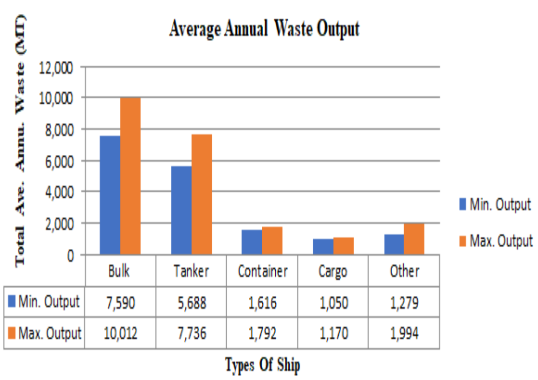


Figure 11: Total average annual HazMat or Waste output in MT from of EOL ships

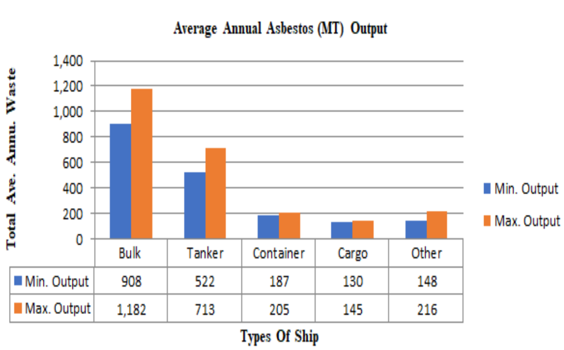


Figure 12: Average annual output of asbestos in MT

4.4 Disposal and Management of Waste

Numerous surveys and studies in ship dismantling yards in Bangladesh indicate that around 97 percent of glass wool and other forms of insulation removed from end-of-life ships are recycled back into the market via local contractors. Insulation waste is then resold as insulation materials for use in many industries such as shipbuilding, construction, small industries, and cold storage units. Just about 3 percent of such insulation wastes end up in TSDF mainly when they become unusable due to contamination. Such high rates of recycling are largely attributed to the relatively good condition of insulation materials at the time of extraction and the demand for such materials locally. For example, the average price of second-hand glass wool insulation in Bangladesh is USD 110 per metric tonne compared to an approximate price of USD 100 per metric ton in its neighboring country India (Chowdhury, 2019; Dawn, 2023; Dawn, 2025; Eolog, 2025). The prices highlighted above indicate that there exists economic feasibility in the process of insulation material recovery in the South Asian ship-recycling sector. It should be mentioned that other types of ship-related wastes such as bilge water, sludge, spent chemicals and solvents, as well as damaged furniture are often sold to local individuals. Most often these wastes are used to make bricks in the kilns, construct makeshift houses or used in the manufacturing process of small-scale enterprises. The stripping off of insulation, flooring, and tiling, sub-processes usually carried out during the pre-cutting phase, may not cause significant environmental releases, particularly when the stripped-off materials are in good condition and stripped off using low-impact technology. In India, for instance, good quality insulation panels are sold directly to buyers who require such insulation panels to meet the demands of cold storage operators and other similar industries (Cencic & Rechberger, 2008; Dawn, 2023; EC Regulation, 2006). Moreover, there is an extensive secondary processing industry associated with the ship dismantling facilities in Bangladesh. Many companies have emerged to recycle and reuse various materials such as machinery, furniture, electronics, and metals for industrial purposes (Abdullah et al., 2023; Clarksons, 2016; Dawn, 2025; Eolog, 2025). The varied and vibrant flow of materials obtained from the ship recycling process demonstrates a complicated circular economy network, which depends on the demands of the market, material quality, and method of recycling used.

Material Flow Analysis (MFA) can be a useful tool for understanding, planning, and comparing different scenarios regarding the recycling of end-of-life (EOL) ships. This technique helps people understand how materials flow in the recycling process, pinpoint important stages of re-use and/or disposal, and balance the flow of recovered materials/components. When comparing second-hand markets in two large centers for ship-recycling operations such as Alang in India and Chattogram in Bangladesh, one realizes that there is much economic activity in reselling recovered materials from scrapped ships. For example, in the case of Alang, the legal trading commodities are electric cables (USD 1-2 per kg), electric motors (USD 1 per kg), insulation sheets made of glass wool (USD 0.02 per kg), sludge (USD 0.02 per kg), used oils (USD 8-15 per barrel), and scrap machinery (USD 1 per kg) (Hossain 2023a, c; 2024). On the other hand, the second-hand market of Chattogram shows somewhat higher price levels for similar products: electric cables (USD 1.2-2.2 per kg), electric motors (USD 1.2 per kg), insulation sheets made of glass wool (USD 0.2 per kg), sludge (USD 0.2 per kg), used oils (USD 10-16 per barrel), and scrap machinery (USD 1.2 per kg). Figure 26 below shows a schematic diagram of the channel flow of reusable and wastes from a recycled container ship in a local ship recycling yard in Bangladesh. The figure demonstrates the flow channels that recovered wastes follow for sorting, processing, selling, or disposal—giving a glimpse of the circular economic network existing within ship recycling operations in the area. The hazardous wastes or material considerations along with yearly production have been presented in table 5 below (Hossain 2023c, 2024).

In the course of conducting the research during the time period between 2012 and 2018, the author made regular trips to the ship recycling yards in Chattogram, Bangladesh. During those trips, the author had the opportunity to make close observations as well as collect the necessary information. At first, it became clear that all documentation related to recyclable and dangerous waste materials had been rather unorganized, and reporting depended mostly on estimation without any accurate weighing and tracking systems. Yet, now things have changed significantly for the better in many aspects of the industry. Improvements in the management of hazardous substances are evident, where safety measures concerning their proper storage and disposal have become much more defined. Safety procedures with respect to working in confined areas and at high altitudes have also received much attention. Effective fire safety policies have been put in place across various yards, while personal protective equipment is also being enforced for workers. Cutting and painting operations are performed on hard surfaces in order to reduce contamination of the environment. There have also been improvements with respect to worker facilities, which include recreational and resting places as well as showers and accommodations.

Moreover, emergency evacuation plans and rescue processes have been devised and put into action in several shipbreaking yards. There has been a tremendous progress in asbestos control and management, such as the removal, treatment, and proper disposal of asbestos-containing substances. Hazardous waste is now effectively catalogued and managed, and preventive environmental policies are being adopted along with environmental awareness campaigns. Health and social planning of the workers have been emphasized, considering the health and security of the workers. Notably, many ship-breaking yards have begun employing naval architects and technicians for the smooth operation of the yards, while training workers to meet current technological requirements and global regulatory standards. Due to the developments in these areas, thirteen out of the total number of local yards have been able to become certified according to the criteria set by the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC). In addition, six other recycling yards are also being processed and it is estimated that all of them will be certified according to the HKC criteria very soon. By the next year-end, it is expected that over thirty yards operating in Bangladesh will be HKC-certified. However, in order to maintain its leadership in the international ship recycling business, Bangladesh should ensure at least forty HKC-certified yards in operation. This is certainly not an easy task to accomplish. Reaching this objective will be a challenging task that will require proactive involvement on the part of the government and business organizations. Constantly improving infrastructure, regulatory compliance, environmental management, and the human resource pool will be necessary to achieve sustained success in the international arena.

Waste Category	Waste Factor (kg/LDT)	Annual Output (MT, Min–Max)
Asbestos (Group A)	0.5–2.0	1,000–4,000
Landfillable (B)	0.3–1.5	600–3,000
Incinerable (C)	0.2–1.2	400–2,400
Bilge/Liquids (D)	0.3–1.8	600–3,600
Heavy Metals (E)	0.1–0.5	200–1,000
Ozone-Depleting (F)	0.05–0.3	100–600
Total	1.45–7.3	17,215–22,702

Table 5: Hazardous Material or Waste Factors and Annual Output (2009–2016)

V. COMPARATIVE ANALYSIS OF LOCAL SHIP RECYCLING WITH OTHER COUNTRIES

The comparison between Alang of India, based on a field survey of the recycling process of 241 ships during 2011-2013, brings to the limelight many commonalities and distinct differences concerning ship recycling practices. There are high rates of material recovery per Light Displacement Ton (LDT) in the case of Bangladesh, owing to strong domestic demands and less limitation in resales. Bangladesh recovers more material in all categories as seen in Table 8 below. Reusable products vary between 750 and 920 metric tons per 1,000 tons of LDT while in Alang, it varies from 600 to 725 metric tons. However, it is evident that both places face almost equal challenges in terms of hazardous wastes such as asbestos, incinerable, and bilge liquids. From Table 3 and Table 5 above, one can read about the yearly average output of usable and waste products of ships classified into bulk carriers, tankers, container ships, and general cargo ships. As shown above, again table 6 provides comparative results of material outputs from Bangladesh and India in kg per ton of LDT of End-of-life ships (Hossain 2024). The following are the observations:

- Bangladesh has achieved greater maximum recoveries for all types of ships, notably the bulk carriers and tankers.
- Waste production has been constant irrespective of ship type, but the modes of waste disposal differ depending on the local capability for waste management.

Material Type	Bangladesh (kg/LDT)	Alang, India (kg/LDT)
Reusable (EVS)	730–950	700–900
Asbestos	0.5–2.0	0.6–2.2
Landfillable	0.3–1.5	0.4–1.8
Incinerable	0.2–1.2	0.3–1.5
Bilge/Liquids	0.3–1.8	0.3–2.0

When compared further, one can notice that Alang has a stricter regulatory system, being governed mainly by the Gujarat Maritime Board and similar organizations. The situation is different in Bangladesh because its institutions include the Ship Breaking and Ship Recycling Board (SBSRB) and the Department of Environment (DoE). Thus, there is a certain necessity for enhancing their institutional capacity and capabilities. However, at the same time, Bangladesh manages to recover materials effectively thanks to high local demand and the informal sale process. In addition, documentation in this country improves in terms of recording inventories instead of making estimations but there are still certain issues with data reliability.

VI. DISTRIBUTION CHANNEL MODEL OF LOCAL SHIP RECYCLING

The author has presented the existing distribution channels for both reusable and waste materials from the local industries in Bangladesh, which has been presented in Figure 26 based on practical experiences gained during the last ten years. Distribution channel for a typical container ship is depicted in Figure 26 below. Material distribution channels have been effectively optimized by the Material Flow Analysis process (MFA). This is because it has helped to achieve maximum material efficiency by minimizing environmental impacts (Cencic & Rechberger, 2008; Watkinson, 2012; Hossain 2019a). However, there have been many significant advancements of ship recycling industries in the following aspects over the last decade: hazardous waste disposal; safety measures in confined spaces and high places; fire hazards; PPE; controlled cutting/strip painting; facilities for workers (rest, recreational activities, showering, accommodation); emergency measures; confined space entry techniques; asbestos control; hazardous waste inventory/hazardous waste storage; environment consciousness; worker health and welfare planning; use of naval architects/technicians; and training workers on technology and laws (periodically). Now 17 yards in Bangladesh have got their HKC certification, but still, 12 other yards are expected to get their certification in the current year or very soon. Although more than 30 yards are expected to have got their "ready" certifications within the next one year, Bangladesh requires more than 40 yards with HKC certification as it wants to retain its global supremacy, and thus immediate help is needed by the government and owners (Hossain 2025c).

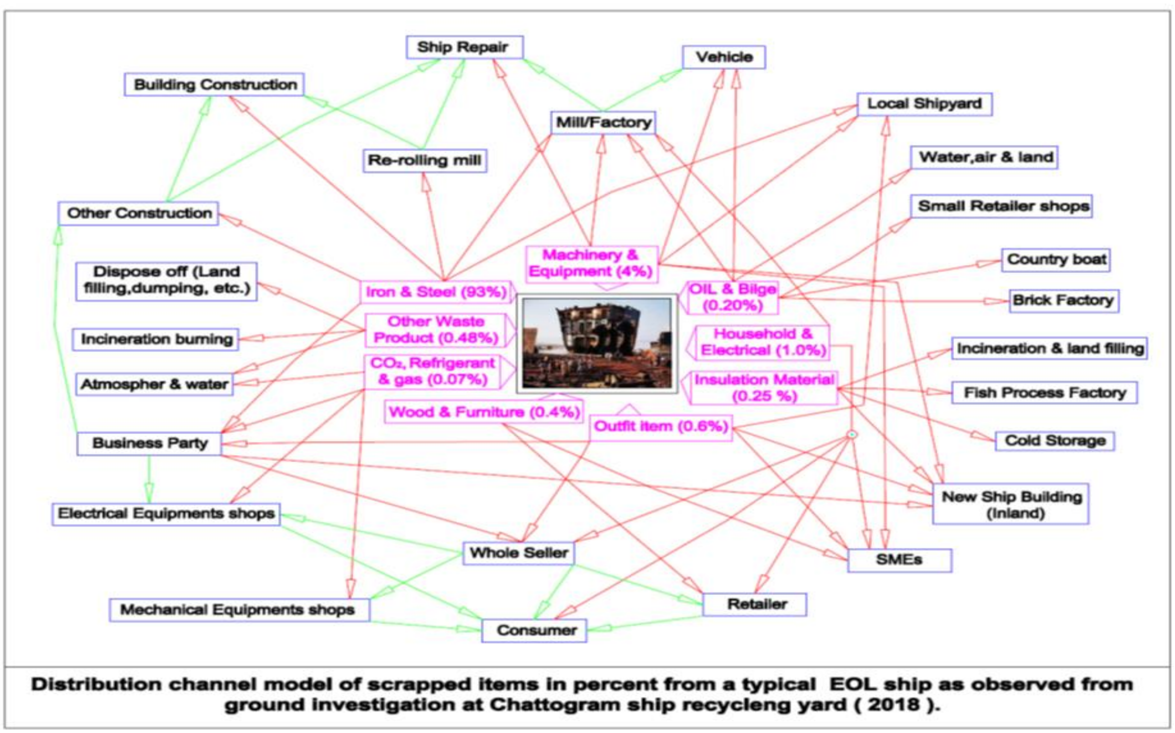


Figure 13: Distribution channel model of scrapped items of EOL ships in Bangladeshi yards.

VII. FUTURE OUTLOOK OF LOCAL SHIP RECYCLING INDUSTRY

The recycling yards of Bangladesh have received comparatively less amount of investment from within and outside the country for the improvement of their facilities compared to their regional rivals. Till now, almost all investments for their improvement have been made via the IMO's SENSREC initiative which has been providing financial assistance for a technical assistance project sponsored by Norway since several decades. The major focus of SENSREC has always been on reforms such as legislation enactment, training programs, and regulation building. Recently, towards the end of 2023, Norway invested approximately 1.36 million dollars in funding green yard upgradation and waste treatment. The basic motive behind this investment was to minimize the environmental damage caused by shipbreaking activities in Bangladesh. Through sustainable practice promotion and green technology adoption, the initiative aims at safeguarding local ecologies while mitigating climate change globally. Presently, Bangladeshi ship recycling industry earns a yearly revenue of Tk 12,750 crore. Additionally, the industry offers job opportunities to people in poverty-stricken regions, involving a total of two lakh people (Hossain 2025c). It has served as an excellent source of improving livelihoods. The industry has immense scope with more than a million people participating in its direct or indirect operations. Each year, a total earning of US$130 million is achieved by the industry (Mohiuddin et al., 2023). The estimated earnings from the ship recycling industry of Bangladesh up to 2030 have been depicted in figure 14 below (Hossain, 2024).

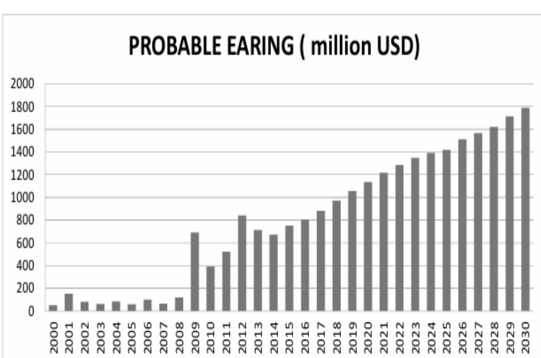


Figure 14: Estimated earnings from the ship recycling industry of Bangladesh

In the financial year 2015-16, the revenue generated from importing 250 scrap ships was estimated at Tk 8.22 billion while during the next financial year, the number of imported scrap ships decreased to 188, earning revenues of Tk 6.32 billion for the government. The importation of scrap ships reached 202 in the next financial year, earning revenues of Tk 5.96 billion (Tk 596 crore). Figure 14 depicts a graph showing the projected earnings from ship recycling industries in Bangladesh (Mohiuddin et al., 2023). From the figure, it can be seen that earnings have been increasing over time. However, due to lack of HKC-certified recycling yards in Bangladesh, Bangladesh may not be able to retain its status in the international market, and as a result, a crisis will soon ensue in the steel and other related industries.

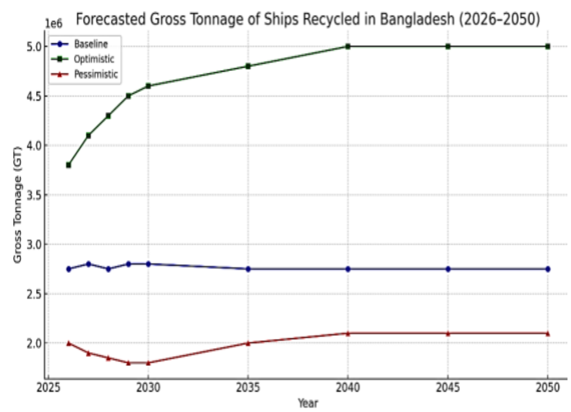


Figure 15: Future projected Gross Tonnage (GT) of Ships Recycled in Bangladesh (2026–2050)

There are several reasons why the ship recycling industry in Bangladesh is set to experience considerable growth in the future. First, the low cost of labor makes the recycling process more efficient. Most materials collected through ship recycling activities, including metal products, have high demand in the local economy, being used for construction and manufacturing (Hossain, 2018c and d). In addition, with the impending graduation of Bangladesh from the LDC status, the need for the development of national infrastructure becomes paramount, requiring large quantities of iron. The absence of natural deposits of iron ore in the country necessitates its importation, but the ship recycling industry meets about 60% of Bangladesh's needs for steel. While ships' parts in developed countries are usually not recycled after demolition but in Bangladesh scrapped, reuse of these parts plays a positive role in terms of environmental sustainability in the sense that it eliminates the need for creating anything new. Moreover, the shipbuilding industry in the country relies mostly on recycled material, highlighting the significance of this practice in contributing to both economic development and the environment (Hossain, 2015; 2023a, d, and f). In order to create a feasible forecast, the gross tonnage (GT) for the years 2014 to 2024, available at IHS and UNCTAD records, will be utilized with ARIMA time series analysis to determine future volume of scrapped ships. Future projection of Gross Tonnage (GT) of Ships Recycled in Bangladesh (2026 – 2050) has been given above in figure 15 through ARIMA time series forecasting.

VIII. FUTURE CHALLENGES OF LOCAL SHIP RECYCLING OF BANGLADESH

The ship-recycling sector in Bangladesh is an economic activity that accounts for up to 60 percent of the country's steel requirements and supports the development of inland shipyards using recycled material from Bangladesh. It is a highly competitive industry, considering the advancement in Indian and Pakistani shipyards in compliance with international laws (Maritime Executive, 2025, BIMCO, 2025). The ship-recycling industry in Bangladesh takes advantage of cheap and abundant labor supply and high domestic demand for recycled materials. Consequently, there is no need for the production of new products, promoting environmental sustainability in contrast to developed nations where recycled materials are not utilized (Maritime, 2025; Olgn, 2025; Eolog, 2025). Nevertheless, the development of Bangladesh from the Least Developed Country (LDC) list and the need for increased infrastructure development, which requires importing iron as there is no iron ore in Bangladesh, highlights the importance of the industry in saving foreign exchange (Maritime Executive, 2025a; Eolog, 2025). Even with such advantages, Bangladesh has acceded to the HKC in June 2023, but as of mid-2025, only 13 yards out of the local 20 (will soon become) meet HKC standards, while India has 120 compliant yards accounting for 95% of their total, and Pakistan does not have any (Maritime, 2025; BIMCO, 2025), while in 2023, Bangladesh recycled about 46% of the world's scrap steel, while India recycles 33% and Pakistan 16.6% of the world's recycling tonnage in 2022 (Eolog, 2025; Dawn, 2023). The number of scrapped ships in India, Bangladesh, Pakistan, and China in a year (2023-2023) has been shown in figure 16 below (NGO Ship-breaking Platform, 2024).

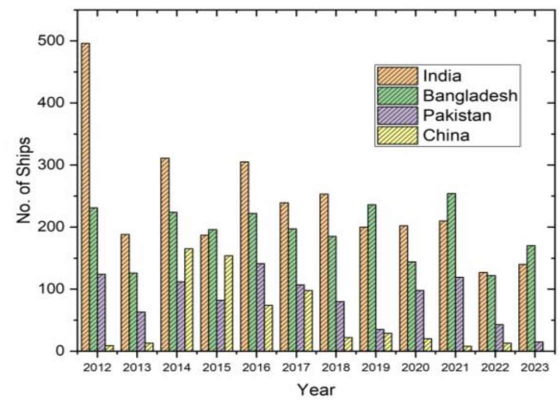


Figure 16: Yearly number of scrapped ships in India, Bangladesh, Pakistan, and China

But experts state that Bangladesh may find itself at a loss when it comes to its market dominance, with the green yards of India receiving funding through donations and gaining an edge over it as Pakistan also starts developing its Gadani yards (Eolog, 2025; Olgn News, 2025). The high standards set by India and the Recycling of Ships Act of 2019, along with its strict requirement for Ready-for-Recycling certificates, put India in a more advantageous position (IndustriALL, 2025). Given that Pakistan has become part of the HKC since December 2023, make significant investments to transform Gadani into a "model green" yard (Arab News, 2024; BIMCO, 2025; Dawn, 2025). In order to remain competitive in the industry and avoid having its EOL vessels migrate to other countries, Bangladesh will need to urgently certify and modernize its shipbreaking yards so that they comply with the HKC requirements. According to ARIMA style forecasts, there is a baseline business-as-usual scenario of ~2.7 million GT per year until 2050, an optimistic scenario of ~5 million GT per year in case of green yard development, and a pessimistic scenario where shipbreaking capacity may fall below 2 million GT per year. Based on the above analysis, five key policies could be developed: (1) legislation in accordance with HKC standards and regulations by establishing a regulatory body; (2) financial support for green yards and ensuring health and safety standards among workers; (3) financing options and incentives for yard modernization; (4) national information system and R&D investment; and (5) regional/global engagement for positioning Bangladesh as a preferred "green" destination under ESG mandates

8.1 Regulatory Enforcement and Policy Frameworks
The Bangladeshi regulations, under which the Ship Breaking and Recycling Rules, 2011 operate, do not fully conform with HKC guidelines. As such, there was a stoppage in shipments of ships for recycling to Bangladesh as a result of non-compliance (Maritime, 2025, TBSNews, 2025). However, draft amendments were proposed through the IMO-sponsored Norway-based project known as SENSREC with regard to Basel, Rotterdam, and Stockholm agreements as well as HKC to bring Bangladesh's laws in line (IMO, 2024 and 2025). Pressure from stakeholders, including NGOs, demands stringent monitoring and penalty systems to ensure conformity (IMO, 2024). Even though new rules are expected in 2025, the fragmented nature of the framework and weak implementation make Bangladesh less competitive. In contrast, India has enacted a strong framework through the Recyling of Ships Act, 2019 (PIB, 2019). Since joining the HKC in December 2023, Pakistan is formulating a Federal Ship Recycling Act and provincial legislation in Balochistan. However, its Gadani shipyards still rely on obsolete legislation with little monitoring, creating hazards both environmentally and physically (Dawn, 2023). The International Labour Organization (ILO) and International Maritime Organization (IMO) have been helping Pakistan overcome its legal deficiencies by providing yard approval and hazardous waste management laws that comply with the terms of the HKC (Dawn, 2023). Despite this, until the legislation is enforced, Pakistan will remain disadvantaged.

8.2 Financial Investment and International Support
The ship recycling sector in Bangladesh, even as economically important as it is, has seen little foreign investment relative to the competition. While initiatives like the one under the IMO called SENSREC, which has been backed by Norway, have provided technical support, with USD1.36 million set aside in late 2023 for green yard improvements and waste treatment plants (IMO, 2024), upgrading the facilities to meet HKC requirements needs investment in the hundreds of millions of dollars, posing a significant challenge considering limited credit availability (Maritime, 2025). In contrast, India has poured over USD100 million worth of donor and government funding into developing 120 "green" yards across various sites, such as those in Alang and others, through cranes, hard-stands, and waste plants that have allowed it to quickly certify 120 yards as HKC-ready (Eolog, 2025; Olgn News, 2025). Similarly, Pakistan has set aside Rs12 billion (~USD42 million) in June 2025 to develop Gadani as the benchmark green ship yard with state-of-the-art technology, roads, hospitals, and waste processing plants (Arab News, 2024; Dawn, 2025).

8.3 Technological Modernization and Yard Infrastructure
In terms of technology, the ship recycling yards in Bangladesh have been found to be lagging behind their competitors in that out of more than 40 yards currently operating, only 13 yards have obtained HKC certification. This is through private efforts rather than through improvements (IndustriALL, 2025; Islam, 2025; Eolog, 2025). Inadequate mechanization through the use of slipways and modular cranes has affected their effectiveness and compliance. The 120+ green yards in India at Alang have sophisticated technology like shore cranes and forklifts (Eolog, 2025). Pakistan's Gadani shipyards, which have been traditionally less mechanized in the past, are scheduled for major upgrading by June 2025 when an investment of Rs12 billion is made with focus on new technology and better waste management to meet green shipping objectives (Arab News, 2024; Dawn, 2025). The maritime minister of Pakistan stressed the need for Gadani yards to modernize if it has to survive (Arab News, 2024). Bangladesh, whose dependence on few mechanized beach yards, lags behind India's well-developed infrastructure and Pakistan's upcoming investments.

IX. PROPOSITION AND RECOMMENDATION FOR LOCAL SHIP RECYCLING

As opposed to the minimal foreign investments in Bangladesh, the Indian ship breaking industry has received a huge boost in terms of modernization, which was achieved through over USD 100 million of foreign and governmental donations. As per industry experts, this much funding helped build about 120 yards in India for recycling ships using a modern technology called ‘Green Ship Recycling Yards’, which include state-of-the-art equipment like cranes, concrete yards, and waste recycling facilities. President of BMOA, Anam Chowdhury, explained this difference during his interview with the Business Standard newspaper. He said, "With over $100 million funding from international donors, India has developed 120 green yards on the coast of Alang in Gujarat to recycle ships following the HKC. On the other hand, Bangladesh has established merely five green yards in the past decade, which cannot enable it to beat India in this respect. "It seems that this year, Bangladesh may lose its position as the country with most number of green yards," (Eolog, 2025; Maritime, 2025; BIMCO, 2025). Such huge investment has led India to quicken its pace in certification and establishment of 120 yards in accordance with the guidelines of Hong Kong Convention (HKC), according to BIMCO report, decreasing its reliance upon external aid for the purpose of upgrading basic yard facilities. Likewise, the Government of Pakistan has started investing heavily to upgrade its ship-recycling industry. In June 2025, the government allocated Rs 12 billion (~USD42 million) to turn the Gadani ship breaking yards into a “model green facility.”

Proposed upgrades include new cranes, equipment that controls pollution, improved infrastructure for workers, as well as road construction and health care facilities along with educational institutes and waste processing facilities. Previously, Gadani was one of the top locations worldwide for the disposal of old ships, where they were taken apart and metals recycled, including steel. Although the amounts that Pakistan invests are small compared to others around the world, they reflect an intention to improve its facilities and better environmental regulation (Arab News, 2024; Dawn, 2025). On the other hand, Bangladesh has struggled to attract smaller amounts of foreign money, while India and Pakistan have been more successful in doing so. It is very challenging for Bangladesh to keep its competitiveness because of such huge disparities. In order to compete in the international market, the rest of the shipyards (about 15 shipyards) should get HKC certificate. Otherwise, the nation will fail in the race in this respect. However, due to the exorbitant cost of establishing green yards, the owner of the yards is still reluctant about this. Building one single ship recycling yard needs at least Taka 200 million to 300 million, which is equivalent to 2.5 million USD. Similarly, it costs around Taka 12 billion (approximately 100 million USD) to transform the whole recycling sector into an industry capable of surviving the global competition.

The ship recycling sector in Bangladesh will have tough competition with India and Pakistan (once their up-gradation process ends). Bangladesh has ratified the Hong Kong Convention (HKC) in 2025, and within the first quarter of 2026, nearly 26 yards comply with HKC criteria. Practically speaking, almost all yards (95%) of India are certified according to HKC criteria, while 60% of the yards in Bangladesh have done this task (40% yet to be compliant). It is a threat to the market share of Bangladesh (Hossain 2025c; Maritime, 2025; BIMCO, 2025). According to experts, there is a danger for Bangladesh as they will lose the battle to the yards of India (as India succeeded with large donor-funded “green yards”). On the other hand, Pakistan, contributing around ~16.6% share of global recycling share (2022), has recently signed HKC in December (2023), and now they are doing modernization of Gadani (Hossain 2025a, c). In this respect, Pakistan also going to catch the global race shortly. Therefore, environmental compliance is a great issue for Bangladesh. In this connection, local recycling yards in Bangladesh need to get HKC certificate soon and upgrade others, which do not comply with the standards, or else the EOL vessels will move to Indian recycling yards and modernizing Pakistani yards. Now, India has made it compulsory to have ‘Ready for Recycling’ certificates and proper waste management with its Recycled Ships Act 2019. In addition to that, Pakistan’s government has made a plan to make a “model green” yard by investing in Gadani (Eolog, 2025; Arab News, 2024; Dawn, 2025). Considering all these, there is no alternative route left for Bangladeshi local recycling yards and Bangladesh to develop itself except modernizing. To achieve this end, Bangladesh must:

- Invest in modern infrastructure, state of the art cutting and dismantling system along with concrete floors and mechanical lifting equipment [Hossain, 2025b].

- Build more TSDF facilities to deal with hazardous wastes.
- Improve workers' training and make use of PPE mandatory (Hossain 2024).
- Create a monitoring and controlling agency like the Indian Gujarat Maritime Board.
- Promote collaboration among all stakeholders for financing and technical assistance (Hossain 2024).
- Government financing and technical help (Hossain 2025c).
- Seek foreign investment or assistance.
- Adopt and implement sustainable recycling system (Hossain 2025c).
- In order to comply with HKC, local recycling yards should also come up with SRFP (Hossain 2024).
- Local recycling yards should get ready for ratification of HKC and some EU RRC soon, because failure to do so would complicate their recycling businesses in future [Mohiuddin and Hossain, 2023a].
- The government can offer financial incentives in the form of tax rebates, accelerated depreciation allowances, and import duty exemptions to encourage investments in green yards which includes impermeable flooring, drainage systems, shore cranes, and waste treatment facilities [Hossain, 23b, Mohiuddin & Hossain, 2023b].
- On-site Medical and Safety Facilities can be established, ensuring that all major yard clusters are equipped with medical and safety facilities with dedicated emergency staff (Hossain 2024).
- Multilateral aid (such as from the IMO, World Bank, ADB, JICA) and domestic budget allocations can be combined to develop a financing model to help improve local yards, especially those of smaller recyclers (Hossain 2025c).
- Government may inject a suitable budget in line of global competitor to modernize the whole sector for its sustainability and development.

X. CONCLUSION

The ship recycling industry of Bangladesh, which has traditionally been considered an exemplary leader in terms of volume and cost efficiency, has reached a crucial point in its development path. As evidenced by this paper, the implementation of the HKC 2009 convention on the safe and environmentally sound recycling of ships, combined with increasing international demands related to labor and environmental protection, is dramatically changing the face of the competition in this market niche. Through analyzing various sources of field data (over 500 interviews conducted with stakeholders), as well as the ship recycling trends in South Asia and other regions, this research has critically evaluated the readiness of Bangladesh in comparison with its major competitors in the region, especially India and Pakistan. Though Bangladesh has made some notable achievements including ratification of the HKC, developing Ship Recycling Facility Plans (SRFPs), and involvement in international projects funded by donors, the country's performance is highly inconsistent and disjointed with heavy dependence on external technical support. A large number of its yards continue to be non-compliant or semi-compliant with the HKC guidelines. The ship-recycling industry of Bangladesh which ranks first in the world generates huge economic gains through employment and steel production by processing about 2,000,000 LDT per year. However, several issues including manual recycling process, pollution and poor SHE guidelines still prevail in the industry. This research paper, using on-ground data for seven years from 26 end-of-life ships, determines the amount of usable material (73%-95% LDT, 1,833,461-1,989,252 MT) and hazardous material (1%-5.5% LDT, 17,215-22,702 MT).

The suggested model for ship recycling process and material distribution channels serve as the basis for a sustainable practice utilizing the advantage of lower labor costs in Bangladesh and high market demand. By ensuring the improvement of safety, environmental issues, and regulatory issues using proper investment and training according to HKC and EU guidelines, sustainability can be achieved without compromising Bangladesh's leading position in the industry. Persistent monitoring and balanced leadership, funding, and stakeholder involvement are critical elements required in this regard. It is possible that we may help gain access to commercial credit by Partnering with state and private banks to make low-interest "green" loans. We may finalize and enforce the draft Ship Recycling Act which is totally in line with HKC rules along with those of Basel, Rotterdam, and Stockholm conventions. These rules should include provision for mandatory facility authorization, inventory of hazardous materials, proper waste disposal practices, and environmental impact assessments. We may establish a Ship Recycling Regulatory Authority (SRRA) which will have members such as Ministry of Industries, Ministry of Environment, Ministry of Shipping, Department of Labor, BUET, Bangladesh Maritime University/BMU as academic advisor, and other authorities. All ship recycling facilities should be made mandatory to comply with approved SRFPs and obtain certification under HKC within a set time limit, say couple of years. As of 26 of Bangladesh's local recycling yards meet the requirements of the HKC (or HKC certified). Another dozen yards in Bangladesh will soon get HKC certification out of a total number of 40+ operational yards. Delays in implementation and ambiguous enforcement mechanisms represent an important bottleneck in the process. Stakeholder interviews point out skepticism regarding effectiveness of government audit systems, as well as uncertainties as to whether those yards which do not meet the requirements will be effectively taken out of the list. Such limbo situation has already led to low investments and lack of planning in the industry, and such problem is expected to become even more pronounced in years following 2025. The way to go for Bangladesh's industry is not against international standards but adaptation to those and benefiting from a new demand wave. Now is the time for action before the market changes permanently in favor of those who are better prepared. During the coming year, all other yards located locally will receive the HKC certificate. However, still remain at the top spot in the international market; Bangladesh needs to have more than 40 HKC certified yards with sustainable production capacity. To ensure safe and ecologically sustainable in the ship recycling process, strong rules and international standards need to be first be put into place and enforced. The labor and environmental dimensions present perhaps the most urgent challenges.

Sustainable ship recycling process and system need to be practices in local yards is paramount. Efforts should be made to enhance environmental monitoring and control by boosting the capabilities of relevant departments and establishing laboratory facilities. Although some yards have embraced reforms and other yards need also follow the others. Steps need to be taken to raise the safety standards and working conditions for the employees. It has to be made sure that personal protective gear and equipment are accessible and utilized. Before beginning the beaching process, every hazardous material needs to be labeled and special care need to be ensured. The promotion of research and development in ecologically friendly ship recycling technology need to be a priority for universities, governments and pertinent stakeholders. Hong Kong International Convention or HKC 2009 for the Safe and Environmentally Sound ship Recycling, which offers a thorough framework for ship recycling operations, we need to ensure the implementation immediately to all ship recycling yards. South East Asian three countries (Bangladesh, India and Pakistan) have taken such challenging load of ship-recycling as a great job to save the global environment. Because those three populated and developing countries consumed and reused almost 98% of material output from the recycling process. A little improvement of process can enhance it as a novel job. Government may inject a suitable budget in line of global competitor to modernize the whole industry for its sustainability and profit optimization.

REFERENCES

[1] Andersen, A. B. (2001). Worker safety in the ship-breaking industries (Sectoral Activities Programme Working Paper WP.167). International Labour Organization, available at: https://www.ilo.org/public/english/dialogue/sector/papers/shipbreak/wp167.pdf, accessed on 11 Aug 2025

[2] Arab News, (2024), International Maritime Organization launches major ship recycling project in Pakistan, 1 October 2024, available at: https://www.arabnews.pk/node/2605790/pakistan, accessed on 11 Aug 2025

[3] Abdullah, H.M., Mahboob, M. G. and Biruni, A.A. (2010), Drastic expansion of ship breaking yard in Bangladesh: a cancerous tumor to the coastal environment, In Proceedings of the International Conference on Environmental Aspects of Bangladesh (ICEAB), Japan, Sep 2010, accessed on 11 Aug 2025

[4] Ahamed S. U., (2011), Legislation, regulations and court orders for ship breaking and recycling industry in Bangladesh, Seminar on ship recycling: Bangladesh perspective, Jul 2011, accessed on 11 Aug 2025

[5] Abdullah, A., Awal, Z.,Alamgir, Z., Mia, M., Mim, F. and Dhar, U. K., (2023) "A Review on Ship Recycling Industry in Bangladesh from Global Perspective," Journal of Ocean and Coastal Economics: Vol. 10: Iss. 1, Article 4. DOI: https://doi.org/10.15351/2373-8456.1165, accessed on 07 Aug 2025

[6] Ahammad, H., and Sujauddin, M. (2017). Contributions of ship recycling in Bangladesh: an economic assessment. IMO-NORAD SENSREC Project, London, UK, 78, accessed on 08 Aug 2025

[7] Basel Convention. (1989). Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. United Nations Environment Programme, available at: http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx, accessed on 11 Aug 2025

[8] BIMCO, (2025), Ship recycling is about to change, available at: 25 June 2025, available at: https://www.bimco.org/news-insights/bimco-news/2025/06/25-hkc/, accessed on 11 Oct 2025

[9] Bois R. D., (2009), “Information and analysis bulletin on ship demolition”, Ship-breaking.com; July, 2009, accessed on 11 Aug 2025

[10] Brennon B., (2016), List of All Ships Scrapped Worldwide in 2016, September 9, 2017, available at: http://rstudio-pubs-static.s3.amazonaws.com/306134_ebb046c5dff146cdb01fccc14b45c635.html, accessed on 11 Oct 2025

[11] Clarksons, (2016), Busy year for scrapping 2016, accessed on 28 Jul 2018, accessed on 11 Aug 2025

[12] Churchill, G. A., (1995), Marketing Research Methodological Foundation, Sixth edition, Harcourt Brace College Publishers”, 1995, accessed on 11 Aug 2025

[13] Chowdhury M. S., (2019), Study report on child labour in the shipbreaking sector in Bangladesh, University of Chittagong, accessed on 15 Sep 2025

[14] Cencic O., and Rechberger H., (2008), “Material Flow Analysis with Software STAN,” Journal Environment Engineering Management, Vol 18, Oct 2008, accessed on 15 Sep 2025

[15] Choi, J. K., Kelley, D., & Murphy, S. (2016). Environmental and economic assessment of ship recycling strategies. Journal of Cleaner Production, 114, 287–296. https://doi.org/10.1016/j.jclepro.2015.10.019, accessed on 11 Aug 2025

[16] Demaria, F. (2010). Shipbreaking at Alang-Sosiya (India): An ecological distribution conflict. Ecological Economics, 70(2), 250–260. https://doi.org/10.1016/j.ecolecon.2010.09.006, accessed on 11 Aug 2025

[17] Devault, D. A., Beilvert, B., & Winterton, P. (2017). Ship breaking or recycling? A review of environmental, economic, and health perspectives. Environmental Science and Pollution Research, 24(33), 25752–25764. https://doi.org/10.1007/s11356-017-0138-2, accessed on 11 Aug 2025

[18] Das, J., & Ali Shahin, M. (2019), Ship breaking and its future in Bangladesh, Journal of Ocean and Coastal Economics, 6(2), 9, accessed on 09 Aug 2025

[19] Dawn, (2023), Pakistan ratifies Hong Kong Convention for ship recycling, December, 2023 available at: https://www.dawn.com, accessed on 11 Aug 2025

[20] Dawn, (2025), available at: https://www.dawn.com/news/1920881/ilo-launches-study-to-reform-ship-recycling-sector#:~:text=initiative%20prepares%20Pakistan%20to%20meet,acceded%20to%20in%20December%202023, 29 Jun 2025, accessed on 11 Aug 2025

[21] EC Regulation, (2006), Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste, 2006, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006R1013, accessed on 11 Aug 2025

[22] Eolog, (2025), Ship recycling market analysis: Bangladesh, India, and Pakistan, available at: https://eolog.com/en/bangladesh-could-lose-top-position-in-the-global-shipbreaking-market/#, 12 Jan 2025, accessed on 09 Oct 2025

[23] Gramman, H., Mutlu, F., and Rogge, J., (2007), Ship-Building Development and Research Strategies for Useful Fulfillment of Ship-

Dismantling Processes, Joint Project of Turkish Undersecretariat for Maritime Affairs and Germanischer Lloyd for the period 2006/2007, accessed on 09 Oct 2025

[24] Gregson N, Crang M, Ahamed FU, Akhter N and Ferdous R., (2010), Following things of rubbish value: end-of-life ships, 'chockchocky' furniture and the Bangladeshi middle-class consumer, Geoforum, 41(6):846–854, 2010, accessed on 09 Oct 2025

[25] Gregson N, Crang M, Ahamed FU, Akter N, Ferdous R, Foisal S, and Hudson R., (2012), Territorial agglomeration and industrial symbiosis: Sitakunda–Bhatiary, Bangladesh, as a secondary processing complex, Economic Geography 88(1):37–58; Dec, 2012, accessed on 09 Oct 2025

[26] Galley, M. (2014). Shipbreaking: Hazards and liabilities. Springer, available at: https://doi.org/10.1007/978-3-319-04699-0, accessed on 09 Oct 2025

[27] Hoque, M., & Emran, M. M. (2016), Role of ship-breaking industries in Bangladesh and ILO guidelines: a critical discussion. Global Journal of E-Economics, 16(3), 9, accessed on 09 Aug 2025

[28] Hossain, K. A., and Zakaria N. M. G., (2009), "Service provides and supporting industries of shipbuilding sector on Bangladesh and its impact on overall development of shipbuilding", Proceedings of the 6th International Conference & 13th Annual Paper Meet, Dhaka, Mechanical Engineering Division; The Institute of Engineers, Bangladesh (IEB), 30-31 Dec 2009, accessed on 11 Aug 2025

[29] Hossain, K. A., and Zakaria N. M. G., (2010a), "Ship Recycling Prospects in Bangladesh," Proceeding of MARTEC 2010; 8th International Conference of Marine Technology, BUET, Dhaka, Aug 2010, accessed on 11 Sep 2025

[30] Hossain K. A., Iqbal K. S. and Zakaria N. M. G., (2010b), A Study of Socio-Economic and Ecological Impact of Ship Recycling in Bangladesh, The Journal of NOAMI, Vol.27, No.1, page 35-47, Jun. 2010, accessed on 29 Sep 2025

[31] Hossain, K. A., (2015a), "Overview of Ship Recycling Industry of Bangladesh," Journal of Environmental and Analytical Toxicology, Vol 5, Issue 5, July 2015, accessed on 23 Sep 2025

[32] Hossain K. A. (2015b), Leadership Qualities for 21st century Leaders, Journal of Management, Social Science and Humanistic, Volume 1, Issue 2, May 2015, accessed on 23 Sep 2025

[33] Hossain K. A., (2015c), Essential Tips and Tactics of motivation, Journal of Management, Social Science and Humanistic, Volume 1, Issue 1, April 2015, accessed on 23 Sep 2025

[34] Hossain, K. A., (2017a), "Ship recycling status of Bangladesh and annual reusable material output," Journal of Toxicology, Vol 2, Issue 2, Oct 2017, accessed on 11 Aug 2025

[35] Hossain, K. A., (2017b), "Ship recycling practice and annual reusable material output from Bangladesh ship recycling industry," Journal of fundamentals of renewable energy and application, Vol 7, Issue 5, Sep 2017, accessed on 11 Aug 2025

[36] Hossain, K. A., and Zakaria N. M. G., (2012), "Underlying Problems of ship-recycling industry in Bangladesh and way forward", 6th International Mechanical Engineering Conference & 14th Annual Paper Meet 2012; 28-29, Sep 2012, accessed on 11 Aug 2025

[37] Hossain, K. A., (2018a), "SWOT Analysis of China Shipbuilding Industry in the Third Eyes", Journal of recent advancement of petrochemical science, Volume 4, Issue 2, Jan 2018, accessed on 11 Aug 2025

[38] Hossain, K. A., (2018b), "Analysis of important steering factors which give Success to Global Shipbuilding Leaders", Journal of recent advancement of petrochemical science, Volume 4, Issue 5, Jan 2018, accessed on 11 Aug 2025

[39] Hossain, K. A., (2018c), "Calculation of Yearly output of reusable material of Ship Recycling Industry of Bangladesh," Journal of Recent Advancement of Petrochemical Science, Vol 5, Issue 3, Jun 2018, accessed on 11 Aug 2025

[40] Hossain, K. A., (2018d), "Material Flow Analysis (MFA) is A Better Tool to Calculating Reusable Material for Ship Recycling" 11th International Conference of Marine Technology, UTM, Malaysia, Aug 13-14, 2018, accessed on 11 Aug 2025

[41] Hossain, K. A., and Zakaria N. M. G., (2018e), "Proposed Sustainable Ship Recycling Process for South East Asian Recycling Yards" 11th International Conference of Marine Technology,

UTM, Malaysia, Aug 13-14, 2018, accessed on 11 Aug 2025
[42] HKC. (2009). Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships. International Maritime Organization, available at: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/The-Hong-Kong International-Convention-for-the-Safe-and-Environmentally-Sound-Recycling-of Ships.aspx, accessed on 11 Aug 2025
[43] Hiremath, A.M., Tilwankar, A.K. and Asolekar, S.R., (2015), Significant steps in ship recycling vis-a-vis wastes generated in a cluster of yards in Alang: a case study, Journal of Cleaner Production 87, pp: 520-532; Jun 2015, accessed on 11 Aug 2025
[44] Hossain M. M. and Islam M. M., (2006), Ship Breaking- Towards Sustainable Management" Published by YASA, Chittagong, ISBN: 984-32-3448-0, Jul 2006, accessed on 29 Sep 2025
[45] Hossain K A, (2019a), 'Material Flow Analysis Technique for Material Assessment of Ship Recycling Industry" Bangladesh Maritime Journal, BSMRMU, Vol 3, Issue 1, Jan 2019, accessed on 11 Aug 2025
[46] Hossain K A, (2019b), "Development of an Assessment Model for Ship Recycling Industry in Bangladesh" Proceedings of the 2nd International Conference on Industrial and Mechanical Engineering and Operations Management (IMEOM), Dhaka, Bangladesh, December 12-13, 2019, accessed on 11 Aug 2025
[47] Hossain, K. A., (2021), Sustainable Ship Recycling Regulation and Process in Contest of Bangladesh, Navy Journal 7 (1), 1-23, Dec 2021, accessed on 11 Aug 2025
[48] HRW, (2023a), Human Rights Watch Report, available at: https://www.hrw.org/news/2023/09/27/bangladesh-shipping-firms-profit-labor-abuse, 27 Sep 2023, accessed on 01 Aug 2025
[49] HRW, (2023b), Human Rights Watch Report, available at: https://www.hrw.org/the-week-in-rights/2023/10/06, 06 Oct 2023, accessed on 01 Aug 2025
[50] Hellenic, (2025), Weekly ship recycling report available at: https://www.hellenicshippingnews.com/wp-content/uploads/2025/05/Weekly-Ship-Recycling-Report-03-May-09-May-2025_compressed.pdf, accessed on 11 Aug 2025
[51] Hossain, K. A., et al, (2023a), Evaluation of present ship recycling scenario and opportunity for Bangladesh, Journal of Environment and Analytical Toxicology (JEAT), Vol 13, Issue 4, April 2023, ISSN 2161-0525, accessed on 11 Aug 2025
[52] Hossain, K. A., et al., (2023b), Global Major Ship Recycling Players and Their Fate in Future, International Journal of Novel Research & Development (IJNRD) 8 (5), Jun 2023, accessed on 18 Aug 2025
[53] Hossain, K. A., (2023c), Analysis of present global ship recycling status and challenges for Bangladesh, Global Scientific Journals (GSJ), Vol 11, Issue 4, April 2023, ISSN 2320-9186, accessed on 11 Aug 2025
[54] Hossain, K. A., (2023d), An overview of merchant ships, International Journal of Research and Development (IJNRD), Vol 8, Issue 6, June 2023, ISSN 2456-4184, accessed on 11 Aug 2025
[55] Hossain, K. A., (2023e), An Overview of Naval Ships, Scientific Research Journal (SCIRJ) 11 (6), ISSN: 2201-2796, June 2023, accessed on 11 Aug 2025
[56] Hossain, K. A., (2023f), Evaluation of prospects and challenges of local ship recycling industry in context of global, In Proceedings of the 6th Industrial Engineering and Operations Management Bangladesh Conference, IEOM Society International, available at: https://ieomsociety.org/proceedings/2023dhaka/19.pdf, accessed on 11 Aug 2025
[57] Hossain, K. A., (2023g), Analysis of present global ship recycling status and challenges for Bangladesh, Global Scientific Journals (GSJ), Vol 11, Issue 4, April 2023, ISSN 2320-9186, accessed on 11 Aug 2025
[58] Hossain K A, (2024), Analysis of ship recycling, ISBN-13, 979-8343259971, Oct 2024, Amazon, US.
[59] Hossain K A, (2025a), Evaluation of Internet of Things (IoT), ISBN-13, 979-8306216980, Jan 2025, Amazon, US
[60] Hossain K A, (2025b), Artificial Intelligence (AI), ISBN-13, 979-8328010290, 2025, Amazon, US

[61] Hossain, K. A., (2025c), Bangladesh's Ship Recycling Industry in the Global South: Readiness, Regional Competition, and Reform Imperatives, Sustainability 2025, 17, 10998, Vol:17, Issues:24; MDPI; Dec 17, 2025; Available from: https://doi.org/10.3390/su172410998

[62] Islam, S. M. M. U., (2025), Upcoming challenges of the ship recycling industry in Bangladesh, The Daily Star, 4 April 2025, available at: https://www.thedailystar.net/law-our-rights/news/upcoming-challenges-the-ship-recycling-industry-bangladesh-3863051, accessed on 11 Aug 2025

[63] Industriall, (2025a), Global union report on ship recycling in Bangladesh, available at: https://www.industriall-union.org, accessed on 11 Oct 2025

[64] Industriall, (2025b), Progress and challenges in Bangladesh's shipbreaking sector, https://www.industriall-union.org/progress-and-challenges-in-bangladeshs-shipbreaking-sector, accessed on 11 Oct 2025

[65] IMO, (2024), International Maritime Organization, SENSREC project updates for Bangladesh, available at: https://www.imo.org, accessed on 11 Oct 2025

[66] IMO, (2025), available at: https://www.imo.org/en/mediacentre/pages/whatsnew2229.aspx#:~:text=Adviser%20to%20the%20Ministry%20of,and%20injury%20to%20the%20workforce, 26 Feb 2025, accessed on 11 Aug 2025

[67] ILPI Paper, (2016), Ship-breaking Practices in Bangladesh, India and Pakistan; Published by International Law and Policy Institute (ILPI) on May 18, 2016, accessed on 11 Aug 2025

[68] Jain K. P., Pruyn J. F. J., and Hopman J. J., (2013), Critical Analysis of the Hong Kong International Convention on Ship Recycling", International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering; Vol:7, No:10, 2013, accessed on 23 Sep 2025

[69] Jain, K.P., Pruyn, J.F.J., and Hopman, J.J., (2014), Influence of ship design on ship recycling, Maritime Technology and Engineering, pp. 269–276, CRC Press, 2014, accessed on 23 Sep 2025

[70] Jain K. P., Pruyn J. F. J. and Hopman J. J., (2017), Material flow analysis as a Tool to improve ship recycling, Journal of Ocean Engineering, pp. 674-683, Vol 13, Aug 2017, accessed on 23 Sep 2025

[71] Jobaid M. I., Khan M. M., Haque A.K.M. K, and Shawon I. A. 2014, "Ship Recycling and Its Environmental Impact: A Brief Overview of Bangladesh", IOSR Journal of Business and Management, Vol 16, Issue 10, Ver I, Oct 2014, accessed on 23 Sep 2025

[72] Kutub, M. J. R., Falgunee, N., Nawfee, S. M., & Rabby, Y. W. (2017), Ship breaking industries and their impacts on the local people and environment of coastal areas of Bangladesh. Human and Social Studies, 6(2), 35-58, accessed on 11 Aug 2025

[73] Linkedin, (2023), available at: https://www.linkedin.com/pulse/norways-1364-million-investment-green-revolutio-bangladeshsh7j0f#:~:text=Norway%20has%20pledged%20a%20substantial,yards%20into%20environmentally%20friendly%20facilitie, 09 Nov 2023, accessed on 11 Oct 2025

[74] Lamb,T., (2003), Ship Design and Construction, Vol. I., Jersey City: Society of Naval Architects and Marine Engineers, ISBN 0-939773-40-6, 2003, accessed on 11 Oct 2025

[75] Mambra S., (2017), What is Green Ship Recycling, Green Shipping Marine Environment, Marine Insight, Oct 04, 2017, available at: https://www.marineinsight.com/environment/what-is-green-ship-recycling, accessed on 28 Jul 2025

[76] Legaspi, R. D. (2000), Ship recycling: analysis of the shipbreaking countries in Asia, accessed on 11 Aug 2025

[77] Mohiuddin G., and Hossain, K. A., (2023a), Strategic Plan to Ratify HKC 2009 by Bangladesh: Challenges & Approach toward implement SRFP in local yards toward Green Ship Recycling, International Journal of Novel Research & Development (IJNRD) 8 (5), May 2023, accessed on 11 Aug 2025

[78] Mohiuddin G., and Hossain, K. A., (2023b), Analysis of Present Global Ship Recycling Status and Challenges for Bangladesh, Global Scientific Journal 11 (4), May 2023, accessed on 11 Aug 2025

[79] Mohiuddin, G., Kh, Hossain, okar A., & Ali, M. T., (2023), Evaluation of present ship recycling scenario and Oppurtunity for Bangladesh, Environmental & Analytical Toxicology, accessed on 11 Aug 2025

[80] Mandaviya, M. (2019), Ship recycling bill will boost Indian economy. The Statesman. https://www.thestatesman.com/opinion/ship-

recycling-bill-will-boost-indian-economy-1502834117.html, accessed on 11 Aug 2025
[81] Maritime Executive, (2024), NGO highlights continuing problems in ship recycling in 2023, February 2024, available at: https://maritime-executive.com/article/ngo-highlights-continuing-problems-in-ship-recycling-in-2023, accessed on 11 Aug 2025
[82] Maritime Executive, (2025), To save Bangladesh's ship recycling industry, phase in the HKC, available at: https://maritime-executive.com/editorials/op-ed-to-save-bangladesh-s-recycling-industry-phase-in-the-hkc#, accessed on 11 Oct 2025
[83] Muhibbullah M, Molla M H, Ali K M B, Sarwar M I, and Hossain N., (2014), Health Hazards and Risks of Ship Breaking Activities in Bangladesh: An Environmental Impact Assessment Approach, European Journal of Advanced Research in Biological and Life Sciences 2(1): 1-15 pp. Jun 2014, accessed on 11 Oct 2025
[84] Mikelis, N. (2013). Ship recycling markets and the impact of the Hong Kong Convention. WMU Journal of Maritime Affairs, 12(1), 87–102. https://doi.org/10.1007/s13437-013-0040-2
[85] Neger, G., and Unsalan, D. (2012). Environmental impact assessment of ship breaking and recycling industries in Turkey and Bangladesh. Journal of Environmental Protection, 3(11), 1506–1514. https://doi.org/10.4236/jep.2012.311166
[86] Nikos Mikelis, (2017), What Will 2017 Bring to the Ship Recycling Industry? Available at: http://www.maritime-executive.com/editorials/what-will-2017-bring-to-the-ship-recycling-industry, accessed on 28 Jul 2025
[87] Neser, G. and Unsalan, D., (2007), Amounts of wastes and their management in the ship dismantling zone of Turkey, Presentation for The Second International Conference on dismantling of obsolete vessels; Jun 2007, accessed on 28 Jul 2025
[88] Nost T.H. Halse A. K., Randall, S., Borgen, A.R., Schlabach, M. Paul, A., Rahman, A., and Breivik, K., (2015), High Concentrations of Organic Contaminants in Air from Ship Breaking Activities in Chittagong, Bangladesh, Environmental Science and Technology, Issue 49 (19), 11372-11380, 2015, accessed on 28 Jul 2025
[89] NGO Shipbreaking Platform (2024). Annual Lists of Scrapped Ships (2012-2021). Accessed June 23, 2023. https://shipbreakingplatform.org/annual-lists/, accessed on 11 Aug 2025
[90] Olgn News, (2025), Comparative analysis of ship recycling yards in South Asia, available at: https://www.olgn.news, accessed on 11 Aug 2025
[91] PIB, (2019), Press Information Bureau, 2019, India's Recycling of Ships Act, 2019, available at: https://www.pib.gov.in, 17 Dec 2019, accessed on 11 Aug 2025
[92] Pasha, M., Mahmood, A. H., Rahman, I., & Hasnat, A., (2012), Assessment of ship breaking and recycling industries in Bangladesh—An effective step towards the achievement of environmental sustainability. In International conference on agricultural, environmental and biologica, accessed on 11 Aug 2025
[93] Patwary, M. S. H., & Bartlett, D., (2019), Impacts of shipbreaking industry in Bangladesh: Search for a sustainable solution. European Journal of Engineering and Technology, 7(5), 64-79, accessed on 11 Aug 2025
[94] Rabbi, H. R., & Rahman, A., (2017), Ship breaking and recycling industry of Bangladesh; issues and challenges, Procedia engineering, 194, 254-259, accessed on 13 Aug 2025
[95] Rahman, S. M. M., and Kim, J. (2020). Circular economy and sustainable ship recycling: A case study of Bangladesh. Marine Policy, 120, 104143. https://doi.org/10.1016/j.marpol.2020.104143
[96] Reddy, M. S., Basha, S., Kumar, V. G., Joshi, H. V., & Ghosh, P. K. (2004). Quantification and classification of ship scrapping waste at Alang-Sosiya, India. Environmental Monitoring and Assessment, 89(2), 173–182. https://doi.org/10.1023/B:EMAS.0000031716.69335.86
[97] Sarraf M., Lauridsen F S., Dyoulgerov M., Bloch R., Wingfield S. and Watkinson R., (2010a), "The Ship Breaking and Recycling Industry in Bangladesh and Pakistan", Report of International Bank for Reconstruction and Development, The World Bank; Dec 2010
[98] Saha R K, Islam M S, and Rahman M M., (2013), "Safety Management for Bangladeshi Ship Breaking Industries Perspective", Global Journal of Researches in Engineering, XIII (V), 2013
[99] SEP Paper, (2016), Science for Environment Policy (SEP), "Ship recycling: reducing human and environmental impacts; Issue produced for the

European Commission DG Environment by the Science Communication Unit", UWE, Bristol, available at: http://ec.europa.eu/science-environment-policy, Thematic Issue 55, 2016. accessed on May 17, 2017

[100] Sarraf M, Stuer-Lauridsen F, Dyoulgerov M, Bloch R, Wingfield S, and Watkinson R., (2010b), The ship breaking and recycling industry in Bangladesh and Pakistan, The World Bank Report No 58275-SAS, 2010

[101] Splash247, (2024a), available at: https://splash247.com/bimco-urges-imo-to-resolve-contradictions-in-ship-recycling-conventions/, accessed on 11 Aug 2025

[102] Splash247, (2024b), available at: https://splash247.com/bimco-launches-ship-recycling-alliance/, 14 Nov 2024, accessed on 11 Aug 2025

[103] Stopford, M., (2009), Maritime Economics. Routledge, New York, USA, 2009, accessed on 11 Aug 2025

[104] Sivaprasad, K., et al, (2008), Sustainable development index for ship recycling, Proceedings of the Second International Conference on Dismantling of Obsolete Vessels, Glasgow September, Session 6, 2008, accessed on 13 Aug 2025

[105] Sivaprasad K., (2010), "Development of best practices for ship recycling processes," Thesis Submitted to the Department of Ship Technology, Cochin University of Science and Technology, India, Dec 2010, accessed on 13 Aug 2025

[106] Sheikh, W., (2021), Retaining competitive advantage in ship recycling under the new regulatory framework: a case study of Bangladesh, accessed on 13 Aug 2025

[107] Supe, V., (2023), The future of ship recycling in India, LinkedIn, available at: https://www.linkedin.com/pulse/future-ship-recycling-india-vidyadhar-supe/, accessed on 13 Aug 2025

[108] Shipping Inbox, (2024), Green steelmaking and the complex legacy of ship recycling, 2 December 2024, available at: https://shippinginbox.com/green-steelmaking-and-the-complex-legacy-of-ship-recycling/, accessed on 03 Aug 2025

[109] SENSREC, (2025), available at: https://www.imo.org/en/mediacentre/pages/whatsnew-2229.aspx#, accessed on 11 Aug 2025

[110] Sivaprasad K., (2010), "Development of best practices for ship recycling processes," Thesis Submitted to the Department of Ship Technology, Cochin University of Science and Technology, India, Dec 2010, accessed on 11 Aug 2025

[111] Shipbreakingbd, (2025), Environmental Pollution-Ship breaking in Bangladesh, available at: https://shipbreakingbd.info/environmental-pollution/, accessed on 29 Sep 2025

[112] Sujauddin, M., Koide, R., Komatsu, T., Hossain, M. M., Tokoro, C. and Murakami, S., (2016), Ship Breaking and Steel Industry in Bangladesh: The Material Flow Perspective, Journal of Industrial Ecology, Vol 10, Mar 2016, accessed on 29 Sep 2025

[113] Sujauddin, M., Koide, R., Komatsu, T., Hossain, M. M., Tokoro, C., & Murakami, S., (2015), Characterization of ship breaking industry in Bangladesh. Journal of Material Cycles and Waste Management, 17, 72-83, accessed on 13 Aug 2025

[114] Sujauddin, M., Koide, R., Komatsu, T., Hossain, M. M., Tokoro, C., & Murakami, S., (2017), Ship breaking and the steel industry in Bangladesh: a material flow perspective. Journal of Industrial Ecology, 21(1), 191-203, accessed on 13 Aug 2025

[115] TBSNews, (2021), Bangladesh remains on top in ship breaking, October 22, 2021, available at: https://www.tbsnews.net/dropped/industry/bangladesh-remains-top-shipbreaking-319333, accessed on 07 Aug 2023

[116] TBSNews, (2025), Bangladesh top global ship recycling again, available at: https://www.tbsnews.net/economy/industry/bangladesh-top-global-ship-recycling-again-541874, 24 Jul 2025, accessed on 11 Aug 2025

[117] UNEP, (2012), Basel Convention - Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns, accessed on 11 Aug 2025

[118] UNCTAD, (2025), Ship recycling, by country, annual (analytical), on 10 Jun 2025, available at: https://unctadstat.unctad.org/datacentre/dataviewer/US.ShipScrapping, accessed on 31 Jul 2025

[119] Watkinson, R. (2012). Sustainable ship recycling: A global perspective. International Maritime Organization.

[120] Eolog, (2024) https://eolog.com/en/bangladesh-could-lose-top-

position-in-the-global-shipbreaking-market/#, 12 Jan 2025
[121] YPSA, (2024), The Challenges to be Green Ship Recycling Yard in Bangladesh: YPSA Round Table Meeting, available at: https://ypsa.org/2024/02/the-challenges-to-be-green-ship-recycling-yard-in-bangladesh-ypsa-bsbrs-round-table-meeting/#, 16 Feb 2024, accessed on 31 Jul 2025