SHIP RECYCLING PROCESS AND MATERIAL DISTRIBUTION CHANNEL MODEL FOR BANGLADESH SHIP RECYCLING INDUSTRY

Commodore K Akhter Hossain, (E), NUP, psc, BN

Abstract

Ship recycling is a reverse engineering process of dismantling End of Life (EOL) ship to recover reusable materials in a safe and environmental friendly way. As per International Maritime Organization's (IMO) guidelines, ship recycling means all associated operations including mooring or beaching, dismantling, recovery of materials and reprocessing. Bangladesh possesses the largest ship recycling industry in the world. South Asia is undoubtedly the global center for ship breaking and recycling of EOL ships. In Bangladesh, average 200 different types and size of obsolete ships with 2000000 LDT are recycled annually in different local yards. The actual problem of this sector is the restrictive nature of mentality of the owners of local yards, as well as lack of ground information. However, very few studies have been done but most were based on limited preliminary baseline studies. An extensive study is necessary to develop a ship recycling process model and a distribution channel model for viable and sustainable recycling process which depicts the actual distribution channel of reusable and waste material produced from local recycling industry of Bangladesh. It has been depicted that, recycling practice and process of local recycling yards of Bangladesh will be sustainable at future if proper guidance and professionalism can be enforced. This promising industry needs uninterrupted monitoring, balanced leadership, financing, guiding, motivation and whole hearted support from every corner from home and abroad.

Keywords: Ship recycling, reusable and waste material, asbestos, incineration

Introduction

Ships are normally removed from the fleet after EOL through a process known as ship scrapping; decommissioning of ship; abandonment of ship; ship breaking; ship dismantling or (recent practice) ship recycling. Ship recycling habitually considered as the best means to dispose of a ship either at the end of her operational life or at any time as decided by the owner, regulatory bodies or law

enforcement authority. Actually, ship recycling is an engineering process[1] and more particularly a reverse engineering process of dismantling obsolete ship to recover reusable materials in a safe and environmental friendly way.[2] As per International Maritime Organization's (IMO) guidelines, ship recycling means all associated operations including, mooring or beaching, dismantling, recovery of materials and reprocessing (IMO Resolution A.951). Again, ship dismantling, also commonly referred to as ship "recycling", is an inherently sustainable activity, the benefits of which are felt at the global level. Until the 1960s, ship breaking activity was concentrated in industrialized countries; mainly USA, UK, Germany etc.[3] During the 1960s and 70s, ship breaking activities migrated to semi-industrialized countries like Spain, Turkey and Taiwan, mainly due to the availability of cheap labor and the existence of re-rolling steel market. But from the early 1980s, to maximize profits, ship owner's sent their EOL ship to the scrap-yards of India, China, Pakistan, Bangladesh, Philippines and Vietnam, where safety health and environment (SHE) standards are minimal and workers are desperate for work.

There are more than hundred registered ship recycling yards located along the coastal belt of Chattogram, of which, only a few dozen are active. This industry provides the country's leading source of steel, create huge (around half million) employment and generates large amounts of revenues for the government.[4] It is also contributing to the local shipbuilding industry extensively.[5]

Bangladesh has the largest ship recycling industry in the world. Local shipbreaking yards are the prime source of raw materials including steel plates, pipes, engines/ generators, auxiliary machinery and other ships' components for local private shipyards. About half of the domestic steel production of Bangladesh comes from the ship recycle industry. The people of this area have pride on

1 K. A. Hossain, "Overview of Ship Recycling Industry of Bangladesh", Journal of Environmental and Analytical Toxicology, Vol 5, Issue 5, 2015a.

2 K. A. Hossain, and M. N. G. Zakaria, "Underlying Problems of the ship-recycling industry in Bangladesh and way forward", 6th International Mechanical Engineering Conference & 14th Annual Paper Meet 2012, 2012, P. 28-29.

3 K.P. Jain, J.F.J Pruyn and J.J. Hopman, "Influence of ship design on ship recycling", Maritime Technology and Engineering, CRC Press, 2014, pp. 269–276.

4 K. A. Hossain, K. S. Iqbal, and N. M. G. Zakaria, "A Study of Socio-Economic and Ecological Impact of Ship Recycling in Bangladesh", The Journal of NOAMI, Vol 27-1, 2010a, pp. 35-47.

5 K. A. Hossain, "SWOT Analysis of China Shipbuilding Industry in the Third Eyes", Journal of recent advancement of petrochemical science, Volume 4, Issue 2, 2018a.

shipbuilding since the early stage of its civilizations. Bangladesh has a population of 163.04 million, which is predicted to reach the figure of 242.8 million by the year 2050. The area of the country is only 147570 square kilometers.[6] Unemployment is the main problem in this country. Ship recycling is the main earning source for millions of people of South Asia, particularly in Bangladesh, Pakistan and India. It should be ensured that local ship recycling yards are maintaining a minimum standard in respect these issues. It does not necessarily imply that we have to follow dry docking instead of beaching; rather keeping the beaching intact, we can improve the situation by providing some common facilities and training, which we somehow lack now.[7]

Recycling and reusing materials and items have become an important requirement. As a result, the shipbreaking method has also witnessed the recycling of the parts of the vessel. On the other hand, with the rise in consciousness towards the marine environment, there have been numerous changes in the process, which have given rise to a new term, green ship recycling and that became very popular in the maritime arena.[8] For safe and environmentally sound recycling of ships, HKC 2009 also strictly directed that vessels that are being recycled after their service lives should not pose any unnecessary risks to human health, safety and to the environment as a whole.[9] Green ship recycling has been introduced across the world as a viable alternative to other methods of shipbreaking that make negative effects on the environment.[10] As a way of responsible ship recycling, this method reduces the amount of waste and also keeps the waste materials from ship breaking out of the beaches, reducing its impact on the environment. However, there are several reasons which have made the concept of green ship recycling popular and meaningful. The main relevant benefits are: segregate those parts of the ship which

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[6] K.A. Hossain and M.N.G. Zakaria, 2012, op. cit.; K.A. Hossain, "Future of Energy Resources", International Journal of Renewable Energy Technology Research (IJRETR); Vol. 4, No. 5, 2015b.; World Bank, "Population-Total, Bangladesh", 2019, Available at: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=BD, accessed on 5th April, 2021.

[7] K. A. Hossain, "Material Flow Analysis Technique for Material Assessment of Ship Recycling Industry", Bangladesh Maritime Journal, Vol 3, Issue 1, 2019.

[8] Basel Convention, "Basel Convention on the Control of the Trans-boundary Movements of Hazardous Wastes and their Disposal", 1989.

[9] HKC Convention, "Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships", 2009.

[10] K. A. Hossain, "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, 2017.

are detrimental and unsafe to both marine and human lives; preserve marine environment by proper disposal of ship dismantling waste; reusing the parts which can be effectively reused while making new ships as well as saving resources in most environment friendly way.

On the other side of the coin, the perfect green ship recycling is a costly affair. But, viable green ship recycling with the merging of present usual practice (beaching method) in Asian countries is very much possible. The valuable components of a ship that are reused include steel, aluminum, copper, silver and brass, among others. Since a major part of a ship's weight is steel, the steel scrap from the vessel are converted into bars and rods for several other uses. However, in addition to the metal that can be recycled, there are a number of the toxic components inside a vessel.[11] These harmful substances include lead, asbestos, mercury and oil sludge, etc. The inefficient ship breaking methods, especially those carried out on beaches in a unprofessional way than the dry-dock ship recycling facilities; allow these toxic and hazardous waste to be disposed of unsafely. But shipbreaking on beaches in a professional way may reduce hazardous waste dispose-off up to 98% and it is achievable.[12]

The main problem of this sector is the lack of actual information. Again very few studies have been done but most were based on limited preliminary baseline studies. The major limitations of those studies were, the inventory of reusable and hazardous wastes from the ship recycling industry was derived on the basis of benchmarks from other countries. As a result, any assessment of the local industry is questionable, and any policy-making decision based on the studies are not technically sound. However, Because of the changing socio-economic scenarios of the world, it is necessary to develop the industry in such a way that it would be sustainable in the long run. So, an extensive study is necessary to develop a ship recycling process model and a distribution channel model for viable and sustainable recycling process which depicts the actual distribution channel of reusable and waste material produced from the local industry of Bangladesh.

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[11] K.A. Hossain, 2018a, op. cit.

[12] A.M. Hiremath, Anand M., Atit K. Tilwankar, and Shyam R. Asolekar. “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, 2015, P. 520-532. ; K. A. Hossain, “Calculation of Yearly output of reusable material of Ship Recycling Industry of Bangladesh”, Journal of Recent Advancement of Petrochemical Science, Vol 5, Issue 3, 2018b.

It is a research work to develop a ship recycling process model and a distribution channel model for viable and sustainable recycling process which depicts the actual distribution channel of reusable and waste material produced from the local industry of Bangladesh by analyzing on-ground data; which have been collected by physical involvement of the author since last eight years.[13] Data of the ship recycling activity were collected from actual ship recycling industry located in Chattogram and provided by the different stakeholders as well as the Bangladesh Ship Breakers Association (BSBA). The inventory of reusable and hazardous wastes materials from recycled ships was derived and compiled based on collected data by the author. Results are based on original on ground data and take considerable help/guideline from the methodology followed in the available literature and research paper. Primary and basic data about the output of material/component and hazardous material of different types of recycled ships has collected from the industry by physical involvement of the author.[14] However, nuclear waste and other releases, such as emissions to atmospheric pollutants and diffuse emissions of pollutants to the water, have not been included in the scope of this research work.[15] Total 26 different types/categories and sizes of recycled ships have been considered as a sample to calculate the average annual amount of reusable materials output. For this research work, five bulk ships, five tankers, six container carriers, five cargo ships and five other types of ships have been selected. For a single ship, it takes six to eleven month to complete an inventory of different materials and item output. The fact and figure of those 26 sample EOL ships have been shown in table 1. This is the first time in Bangladesh such broad data sampling analysis has been taken place.

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

[13] M. Stopford, "Maritime Economics. Routledge", New York, USA, 2009.

[14] K.A. Hossain and M.N.G. Zakaria, 2012, op. cit.

[15] A.M. Hiremath et. al., 2015, op. cit.

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: Summarize Facts and Figures of 26 Sample EOL Ships

Development of Ship Recycling Process Model for Local Recycling Yards

Ship recycling process consists of various engineering operations and managerial activities to dismantle and segregate the reusable and waste material from EOL ships as well as their storage, transportation and disposal. This is essential for understanding the entire process. There are few important commercials and technical operations are to be carried out well in advance to facilitate the objectives of recycling of EOL ships. Precise knowledge regarding these specific activities is vital for understanding and realizing the ship recycling processes so that this can handle as a modern industrial business. In figure 1, the typical life of a new ship has been shown and which is usually from 15 to 25 years. In figure 2, typical steps required to be accomplished to place an EOL ship at the site of dismantling yards in Chattogram has been shown and which usually takes 2 to 11 weeks. In figure 3, a model for ship recycling process for local ship recycling yards has been shown and completion time for the process is usually 5.5 to 10.5 months.

Ship classification societies are very active in merchant shipping technical operations and take a lead role in various decision-making activities.[16] However, there are no specific international rules or regulations regarding obsolete or decommissioning of a ship from service. Besides, they have little role to play in the decommissioning process. Usually there are no classification society rules which recommend dismantling of an EOL ship.[17] But, classification societies can declass a ship according to their rules and regulations.[18] This decision does not mean that

[16] K. Sivaprasad, "Development of best practices for ship recycling processes", Thesis Submitted to the Department of Ship Technology, Cochin University of Science and Technology, India, 2010.; K. A Hossain, N. M. G. Zakaria and K. S. Iqbal, "Ship Recycling Prospects in Bangladesh", Proceeding of MARTEC 2010, 8th International Conference of Marine Technology, BUET, Dhaka, 2010b.

[17] Ibid.

[18] K. A. Hossain, 2019, op. cit.

the ship declassed by any classification society will go under the recycling process immediately. The owner can change the flag or can move toward another classification society, not affiliated to International Association of Classification Societies (IACS) which may be ready to register any such vessel under them. Actually, the decision of decommissioning an EOL ship from service fully depends on the owner of the vessel. Here few factors play a pivotal role to decide the fate of the EOL ship. Those factors are EOL ship's value in the scraped market, the life of the ship, ship's hull and machinery condition, freight market status, economic life of the ship, demand of such ship's size and category etc.

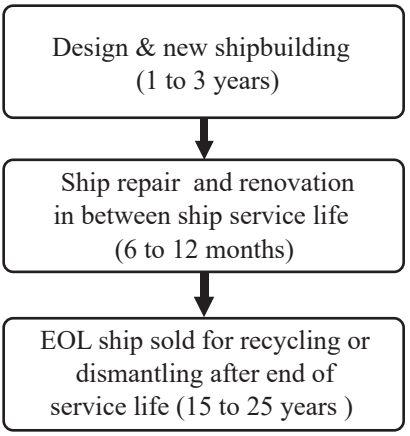

Figure 1: Typical Life of a New Ship

The EOL ship usually passes through different intermediate owners, before reaching the last owner, who is responsible for towing the ship to the positioning site or close to yard for dismantling. As per Basel regulation, owners of decommissioned ships can no longer remain as ship owners if the ship ceases to be operational and becomes scrap.[19] Intermediate owners of such EOL ships are called as ship recycling brokers. Whenever the ship owners decide to decommission their vessels, information regarding this, is made available to global information platforms such as internet websites and maritime publications.[20] Concerned ship recycling brokers approach the owners and transfer the ownership by paying advance amount. Then the broker invites quotation from possible buyers based on the highest bid offer from the dismantling site and other basics. A ship surveyor as representative of the buyer will thoroughly inspect the vessel and give

[19] Basel Convention, 1989.

[20] K. Sivaprasad, 2010, op. cit.; K. A. Hossain et. al., 2010b, op. cit.

a report. The buyer pays the price to the owner based on surveyor's report.[21] All these activities including arranging relevant certificates for transferring the vessel from a foreign owner to the end buyer treating the EOL ship as an imported commodity (or import) is the responsibility of the broker, and he will arrange everything.

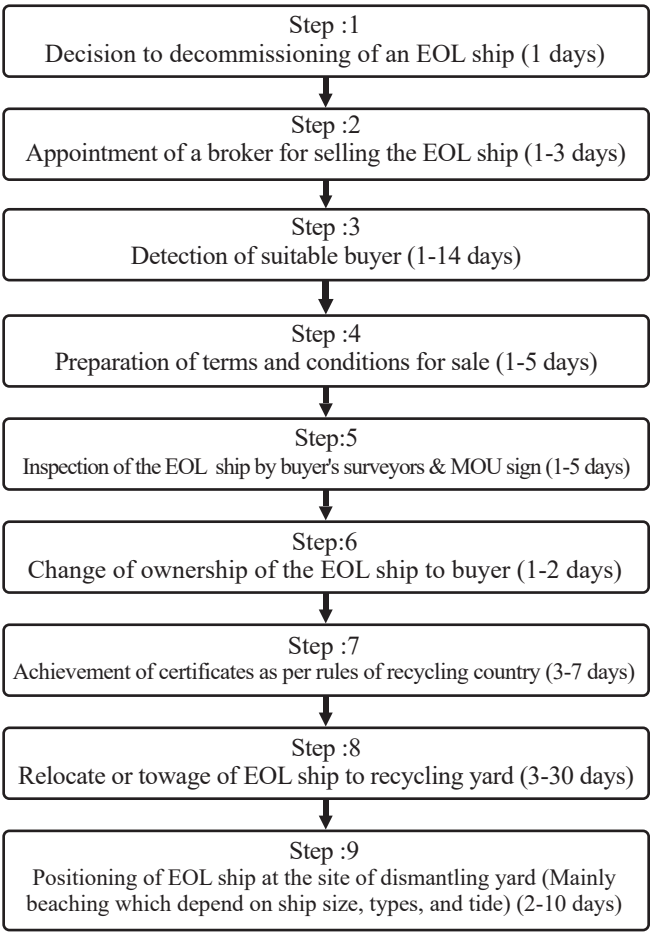

Figure 2: Typical Steps Required to be Accomplished to Place an EOL Ship at the Site of Dismantling Yards at Chattogram.

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

There are four commonly used positioning methods, and from where, beach method is employed at shallow basins with long shelf bed where high tidal variations exist. Always beaching is done during high tide. The beached EOL ship gradually slides up, to the recycling yard during successive high tides.[22] Entire separation and recycling operations are done in the beach area available in the waterfront of the recycling yard. Beach method has been employed at all yards located in East Asian Countries.[23] The main difference between dry-docking method and beach method is the presence of a concrete barrier between the dismantled vessel and seawater. Progressive sliding for transporting the vessel within the yard premises is absent in the dry docking method. European countries and the United States practice dry docking method.

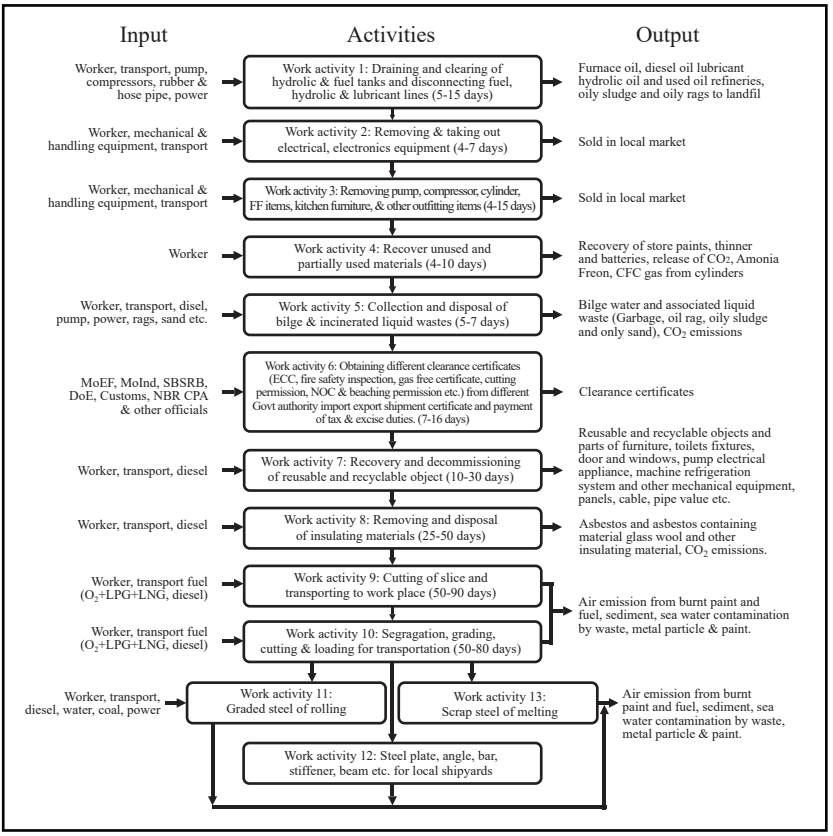

Figure 3: Developed Ship Recycling Process Flow Diagram for Local Ship Recycling Yards.

[22] K. Sivaprasad, 2010, op. cit.

[23] K.A. Hossain, 2015a, op. cit.; K.A. Hossain, 2018b, op. cit.

After arrival at the outer port, brokers of the ship-owner inform the recycling yard and port authorities regarding positioning and placing of vessels at the anchorage area. In Bangladesh, outer anchorage area of Chittagong Port Authority (CPA) dedicated for placing of such EOL ships. The assessment and inspection team of the recycling yard makes a systematic check of various mandatory certificates regarding the import and export shipment and payment of taxes and excise duties to be produced by the owner before beaching the EOL ship. As per existing practice, one deck officer, one certified marine engineer and the master of the vessel must be present during the inspection and examination by the yard and the port authorities. A detailed inventory of communication and navigation equipment used by the EOL is prepared. These are to be handed over to the wireless board or respecting law enforcing agency of the recycler state immediately after completion of beaching. In Bangladesh, Bangladesh Navy (BN) acts as this authority and the custodian of those items. A comprehensive list of marine supplies and safety measures implemented on board are prepared by the yard and port authorities. After this, permission is granted and the ship will be allowed to enter the beach either by towing or by its own propulsion. The grounding for dismantling begins with the submission of man entry certificate and hot work certificate from the explosive department to the statutory recycling authority operating from the recycling yard. All kinds of petroleum oils including inflammable gas in the fuel tank of the vessel have to be emptied and evacuated before starting of the cutting operations.[24] The actual cutting is started after taking written permission from the local port authority.

There are a few important steps involved in the ship recycling practices in the beaching method. It involves different engineering activities that are performed prior to ship breaking and during dismantling, buffering, lifting, transporting, storing, inventory of reusable and waste material and disposal or landfilling of hazardous material. After beaching of EOL ship and completion of all formalities, yard workers use gas cutting torches (mainly) to dismantle the ship from the end facing the beach to the end facing the sea. The usual cutting operation sequence is staring for top to bottom and bow to stern of the EOL ship. Conventionally large blocks are cut and allowed to fall down freely. Further dismantling of flat-lying block is done by using gas cutting again.[25] The cutting and transportation activities

[24] K. Sivaprasad, 2010, op. cit.

[25] K. A. Hossain, "Material Flow Analysis (MFA) is A Better Tool to Calculating Reusable Material For Ship Recycling", 11th International Conference of Marine Technology, UTM, Malaysia, 13-14, 2018c.

continue till the dismantled item can be handled by worker mainly manually and sometimes by a small crane to nearby stack location. The handling and stockpiling are done mainly manually and sometimes by mechanical lifting procedures. With little exception, usually, no weight lifting calculation or lifting analysis is done prior to lifting. The dismantle hull steel and other machinery, equipment and items for the EOL ship is towed further inland by teams of men using winches simultaneously.[26] Dismantled metal and items are sorted as per material type and size. Steel plates are mainly sold to re-rolling mills and some extent to the local shipbuilding industry. Various machinery items are sorted and kept separately under the warehouse.[27] If knowledge-based reverse engineering method adopted in all dismantling activities such as segregation of hull, deck, frame, outfit and machinery of EOL ship, it is possible to improve the overall performance of the ship recycling process. Again, there are ample scopes to improve some places such as optimum yard layout, infrastructure development, worker well-being improvement, flowing scientific procedures, using proper PPE, proper handling and management of waste materials etc. in recycling yards of Bangladesh.[28] Local yards need to follow the national and international rule, regulation and guideline to improve the overall ship recycling process.

Around ninety percent of global ship recycling activities are done by South East Asia countries. India, Bangladesh, China, Pakistan and Turkey are the main ship recycling destinations in the world. Besides Turkey in Asia, ship recycling activities are reported in isolated locations of Europe, including in the UK. The UK has only recently joined the ship recycling nation group. Very stringent ship recycling regulations based on the principle of sound management are implemented in the UK. During the shipbuilding boom in the year 2005 onwards, China had less focus on ship recycling industry and hence went down in recycling output. Cooperation between stakeholders of ship recycling is identified by the government as key to clean and efficient ship recycling in China. Advanced dismantling facilities, futuristic vision-based recycling policy, stringent laws and regulations and stakeholders' cooperative working model are reported to be the four pillars of the enterprising ship recycling industry in China. The recycling yards of Pakistan need distinct development, and they are using a combination of a manual and mechanical method for dismantling activities. The beaching is done by experienced hands in this field and minimum statutory inspection is carried out

[26] K. A. Hossain, 2015b, op. cit.

[27] K. A. Hossain, 2019, op. cit.

[28] K.A. Hossain et. al., 2010b, op. cit.

during beaching. The yards use deck lift winch and minor concrete flooring for cutting and removal TBT based paints.[29] The modes of operation remains the same as other neighbouring countries like Pakistan and Bangladesh.[30] Gujarat Maritime Board has an exclusive wing for monitoring ship recycling in Gujarat region, whereas other states do not have any such administrative or technical mechanism to manage ship recycling activities.[31] Bangladesh with very low labor price, somehow relaxes regulation and favorable government policy on the industry is flourishing subsequently.[32] Due to high tidal difference, local yards of Bangladesh are suitable for the dismantling of big tankers and bulk carriers.[33] European Union has taken some initiatives to develop sustainable ship recycling facilities in European Countries (EC).[34] Ship recycling facilities in Turkey is getting the maximum benefit out of these attempts undertaken by the European Union. Environmental and occupational controls are being exercised rigorously by the concerned government authorities.

Reusable Material Output from Local Recycling Yards

There are thousands of line items found in a recycled ship. Data and information about those items need to be collected daily to complete excellent research work. So, to compile and prepare a detailed inventory of materials and items of 26 sample EOL ships is a time-consuming task. Again to collect such a huge volume of data from such restrictive nature industry is a challenging and ambitious task. The researcher has employed six dedicated data entry workers and a manager for that purpose. The reusable material comes out from local recycling yards has been divided into four categories based on HKC 2009 guideline for easy compilation, estimation and weight calculation.[35] During dividing such groups, researcher has taken help from ship design and construction concept as a naval architect and also taken considerable help from few available pieces of literature.

[29] K.P. Jain et. al. 2017, op. cit.; K.A. Hossain, 2018a, op. cit.

[30] K.A. Hossain, 2018c, op. cit.

[31] K. Sivaprasad, 2010, op. cit.

[32] K.A. Hossain, 2018b, op. cit.

[33] K. Sivaprasad, K. K. Dileep and C. G. Nandakumar, "Sustainable development index for ship recycling", Proceedings of the Second International Conference on Dismantling of Obsolete Vessels, Glasgow September, Session 6, 2008.

[34] K.A. Hossain, "Analysis of important steering factors which give Success to Global Shipbuilding Leaders", Journal of recent advancement of petrochemical science, Volume 4, Issue 5, 2018d.

[35] Basel Convention, 1989, op. cit.; HKC Convention, 2009, op. cit.

The researcher has used separate tally register and Excel Broadsheet to collect and enter the relevant data of sample EOL ships. Division of reusable materials produced from EOL ships has given below:

a. Metal Items: Plate (Heavy), Plate (Light), Brass, Copper, MS Pipe, Nickel, G.I./Bar, SS Sheet, Aluminum, Zinc, Hose pipe, Hatch Cover Plate, Tank Cover, Nut, Bolt, Washer, Anchor, Bar & Angle, Cast Iron, Shaft Plate, Chain & Cable, SS Scrap, Welding Rod, Other Ferrous material including scraps, Other Non-ferrous material including scraps etc.

b. Machinery Equipment and Accessories: Main Engine, Generator, Gear Box, Shaft, Propeller Shaft, Rudder, Air Compressor, CNG Bottle, CO_2 Bottle, Pump, Bearing, Carburetor, Condenser, Radiator, Water Heater, Heat Exchanger, AC Plant and Unit, Evaporator, Oil Separator, Reduction Gear, Engine Head, Mechanical Tools, Machinery Spare Parts, Life Boat, Lifebuoy, Life Raft, Life Jacket, Fire Extinguisher, Kitchen Accessories, Personal Safety and Protection Equipment etc.

c. Electrical Item: Electric Cable, Switchgear, Transformer, Motor, Computer, Electric Goods, Kitchen Item, Socket, Plug, DVD/Movie Player, Camera, Communication Set, Navigation Item/Equipment (Radar, GPS, Eco-sounder, etc.), Washing Machine, Electric Oven, TV, Fan, Electrode, Pad/Tab/Mobile set, Electrical & Electronic Spare Parts, Electrical & Electronics Tools etc.

d. Outfit and Other Reusable Items: Door/Hatch, Window/Port Hole, Ladder, Capstan/ Windless, Crane, Davit, Trolley, Winch, Starting air bottle, Gate valve, Seawater line valve, Freshwater line valve, Fuel line valve, Lubricant & Hydraulic oil line valve, Furniture, Glass, Toilet and Sanitary Equipment etc.

Summarize Fact and Figure of Reusable Material Output

The researcher has determined that there are average 1833461 MT (minimum) and 1989252 MT (maximum) reusable materials have been collected annually from ship recycling industry of Bangladesh. For calculating and determining the amount of reusable materials and factor, the researcher has been taken help from free commercial software like Microsoft Excel and Material Flow Analysis (MFA) software STAN in addition with manual calculation.[36] The researcher has found that manually calculated result of reusable material vary up

[36] O. Cencic and H. Rechberger, "Material Flow Analysis with Software STAN", Journal Environment Engineering Management, Vol 18, 2008.

to 0.4% with STAN software result, whereas no variation has found with MS Excel Broadsheet result.[37] In table 2, the average reusable material factor and amount of materials output per year in MT for different types of recycled ships in Bangladeshi yards has been shown. In figure 4, average annual LDT against average annual reusable material output in MT for different types of recycled ships in local yards has been shown. The detail compilation, analysis, result, graphs and output of reusable material of 26 EOL sample ships has been done by using MS Excel Broadsheets and programming.[38]

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 Per Year in MT for Different Types and Sizes of Recycled Ships in Bangladesh.

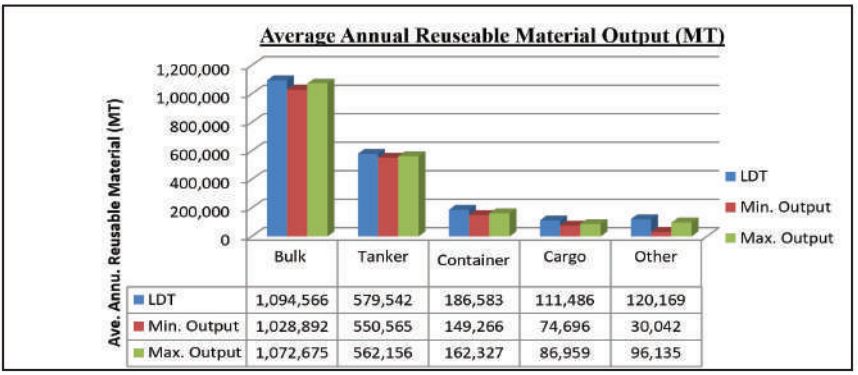

Figure 4: Average Annual LDT against Average Annual Reusable Material Output in MT for Different Types and Sizes of Recycled Ships in Local Yards.

[37] Stephen Bullen, Rob Bovey and John Green, Professional Excel Development (2nd ed.). Addison-Wesley. ISBN 0-321-508793, 2009.

[38] Ibid.

Waste Output from Local Recycling Yards

As per Bangladesh Environment Conservation Act 1995, hazardous waste is defined as any waste which, due to its natural or its physical, chemical, reactive, toxic, flammable, corrosive nature, on its own or when it comes into contact with other substances, may create harm to the environment or human health. Hazardous waste can be categorized into two broad categories: organic material, e.g. polymers, and minerals (inert material), such as heavy metals or asbestos. Hazardous waste that is organic in nature can be destroyed, i.e. the toxic compounds can chemically be altered and transformed into harmless products.

The waste material and substances from local recycling yards have been divided into six categories based on HKC 2009 guideline and for easy compilation, estimation and weight calculation.[39] During dividing such groups, the researcher has taken help from ship design and construction concept as a naval architect and also taken considerable help from few literatures. Division of waste material and substances produced from EOL ships are summarized below:

a. Group A: Asbestos and asbestos-containing waste, insulation material etc. (including glass wool, ceramic wool, damping and other insulation materials etc.).

b. Group B: Cementing material, ceramic rust and dust, iron rust, dust and scales, fire ash, incinerator ash, glass waste from cathode ray tube, glass dust and particle, waste zinc residues, and other land-filled wastes etc.

c. Group C: Combustion/burning waste, paint, coatings, hexavalent chromium compounds, pharmaceutical waste (like medicine), incinerated waste etc. (which include polyvinyl chlorinated or PVC, polychlorinated biphenyl or PCB, polychlorinated terphenyl or PCT, polybrominated biphenyl or PBB, other polybrominated analogues, oil rags, sludge, plastic, rubber, textile, TBT, polyurethane foam or PUF, welding fumes, arsenic compound etc.).

d. Group D: Bilgewater, fuel oil, lubricants, hydraulic oil, organic solvents (both halogenated and non-halogenated, volatile organic compound, thinner), other mineral oil, microorganism and sediments, outdated chemical and other liquid waste, pesticides & insecticide sprays etc.

[39] HKC Convention, 2009, op. cit.

e. Group E: Heavy metal, toxic metal etc. (Lead, Mercury, Cadmium, Radioactive materials, etc.) which usually found in the battery, anodes, nut & bolt, connector, light fitting, thermometer, level indicator, coupling, bearing, fire detector sensor, communication & navigation equipment, alloys, soldering machine, cable insulation, motor & transformer components, computer screen, fire alarm etc.

f. Group F: Ozone-depleting substances (ODS), compressed gas cylinder, fire fighting liquid, other explosive nature waste etc. (which include CFCs, halon, Aqueous Film Forming Foam or AFFF etc.).

In the above paragraph Group A refers to asbestos and asbestos-containing waste; whereas Group B refers as land fillable waste. On the other hand, Group C is known as incinerated waste and Group D refers to bilge waste. On the other hand, weight and amount of waste in Group E and F are very negligible.

Summarize Fact and Figure of Waste Material Output

For calculating and determining the amount of waste materials and factor, researcher has taken help from free commercial software like Microsoft Excel and Material Flow Analysis (MFA) software STAN in addition with manual calculation. Researcher has found that manually calculated result of reusable material vary up to 0.4% with STAN software result, whereas no variation has found with MS Excel Broadsheet result.[40] The total average annual amount of waste produced in MT from different categories and size of EOL ships from local yards of Bangladesh has been shown in figure 5. In table 3, the average annual amount of different categories of waste products from different EOL ships recycled in local yards of Bangladesh has been shown. The detail data, compilation, analysis, result, graph and output of reusable material of sample EOL ships has been done by using MS Excel broadsheets and programming.[41]

[40] Stephen et al, 2009, op. cit.; K.A. Hossain, 2019, op. cit.

[41] Ibid.

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 3: Annual Average Amount of Waste Produced in MT from Different Categories and Size of EOL Ships.

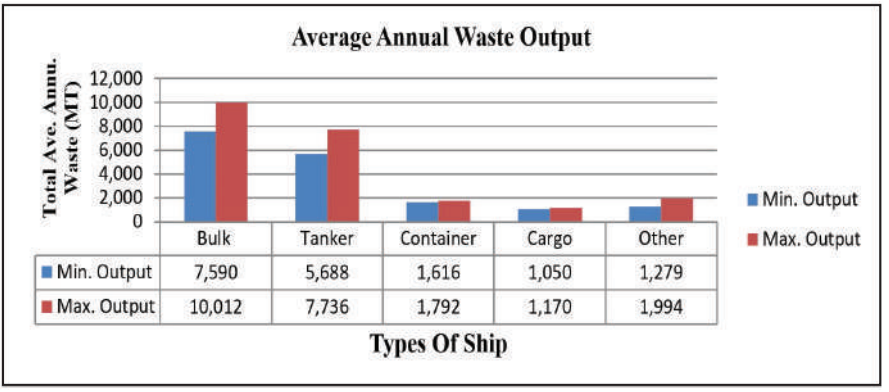

Figure 5: Total Average Annual HazMat or Waste Produced in MT from Different Types and Sizes of EOL Ships Recycled in Bangladeshi Local Yards.

Disposal and Management of Waste

During several visits to the local yards, realistic investigation, and in-depth field work, it has been found that around 97% of the glass wool and insulation materials are recycled by contractors who sell it as insulation in various

local industries such as: shipbuilding, ship repair, house building, small industry, cold storage industry etc. Therefore, it seems reasonable to assume that only 3% of the glass wool and insulation materials are sent to the Treatment, Storage and Disposal Facility (TSDF), while 97% is recovered and recycled, because it is found in a useable condition and has demand in the local market. It is interesting that bilgewater, slugs, old chemical, solvent, broken furniture, all sort oil are sold to the local market and used in brick filled, house and some other local small industries.

Interesting information about the cost of reusable material sold in the South Asian Countries is: an average rate of USD 100 per ton of glass wool insulation in the second-hand market in India and the rate is USD 110 per ton in Bangladesh.[42] There might be no EVS coming out of removal of insulation, flooring and tiling. The sub process of the precutting process depends on the demand of reusable insulation in the market and the possibility of removing insulation in good condition at a reasonable cost. For example, in India, intact glass wool insulation panels are purchased by resellers to cater the needs of cold storage firms and other industries requiring insulation material.[43] Also, there is a strong demand of all the materials and products recovered from EOL ships by the network of secondary processing firms located around the ship recycling yards in Bangladesh.[44] Endless scenarios and possibilities of material flows exist depending on the recycling process employed.

The MFA can be used as a tool to visualize, plan and compare different scenarios that can arise as a result of recycling an EOL ship.[45] As an example, electrical cables (USD 1-2 per kg), electric motors (USD 1 per kg), glass wool insulation sheets (USD .02 per kg), sludge (USD .02 per kg), waste oil (USD 8-15 per barrel), scrap machinery (USD 1 per kg), etc. were being legally sold in the second-hand market at Alang, India at the prices mentioned in the brackets. On the other hand, electrical cables (USD 1.2-2.2 per kg), electric motors (USD 1.2 per kg), glass wool insulation sheets (USD .2 per kg), sludge (USD .2 per kg), waste oil (USD 10-16 per barrel), scrap machinery (USD 1.2 per kg), etc. were being

[42] K.A. Hossain, 2018b, op. cit.

[43] K.A. Hossain, 2015a, 2018a, 2018c, op. cit.

[44] K.A. Hossain et. al., 2010a, pp. 35-47.

[45] K.A. Hossain, 2019, op. cit.

legally sold in the second-hand market at Chattogram, Bangladesh at the prices mentioned in the brackets.[46]

The researcher has always visited local yards from time to time in last seven years. He has found that record-keeping and documentation of reusable and waste material have been improved substantially in recent years. Earlier, these are reported and compiled without weighing and control and are only based on visual estimation.[47] But at present, improvements have been observed in some important aspects/fields of recycling process and practice in Bangladeshi few recycling yards. Those aspects/fields are: handling of hazardous wastes/materials, working in confined spaces and at heights, fire prevention and control, use of Personal Protective Equipment (PPE), cutting and removing paint from a plate on the hard standing floor, adequate and safe rest recreation shower and accommodation facility for the worker, emergency evacuations and rescue plans, safe handling, entry process in confined spaces, asbestos handling and management, inventory and storing of hazardous waste, preventive environmental practices through environmental awareness in a regular basis, making a viable plan for worker's health, welfare and future, employ a naval architect and technical personal in most of the recycling yards, ensure regular training and updated worker knowledge about modern technology and regulations etc. As a result, few Bangladeshi yards are at the door to achieve the standard of Statements of Compliance (SoC) with the Hong Kong Convention. One of the yards, PHP Recycling and Industry Ltd, has already achieved the SoC certificate.

Analysis of Result Derived from MFA for Reusable Material

MFA can be successfully used to compile, analyze and determine the amount of reusable and waste materials produced from an EOL ship recycled in a yard. Usually and logically, the recycling process can be divided into three main phases: precutting, cutting and post-cutting. All material streams originating from each process are categorized into two major streams: economic value stream (EVS) and non-economic value stream (NEVS). EVS stream is the stream of the products which can either be sold for reuse or recycling, resulting in cash in-flow for the recycling yard. NEVS stream is the stream of the products which needs to be disposed of either at a waste treatment facility or landfill sites resulting in cash

[46] K.A. Hossain et al. 2012, op. cit.; K.A. Hossain, 2018a, op. cit.

[47] Maria Sarraf, "The Ship Breaking and Recycling Industry in Bangladesh and Pakistan", World Bank, Washington, DC, 2010.

out-flow for the recycling yard. The distribution of material streams into the EVS and NEVS can differ for yards depending on the factors such as location, recycling practices, and demand in the second-hand market, present of forwarding and backward linkage industries, regulations and time. The EVS and NEVS originating from precutting and cutting process is an input for post cutting, where further separation and sorting takes place.[48] Researcher has estimated and calculated using MFA that about 1% to 2% and 2% to 4% of LDT of the sample ships usually originate as NEVS and EVS respectively from the precutting process. The cutting process is the process where actual cutting of steel hull and machinery into small pieces takes place.[49] The cutting process is divided into two sub-processes: primary cutting and secondary cutting. The primary cutting is the process where a ship's hull is cut into ferrous blocks and non-ferrous items, which are extracted from the hull. Researcher has calculated and estimated using the MFA that average 72% to 93% and 1.5% to 5.5% of LDT of the sample ships (in average), usually originate as EVS and NEVS respectively from the cutting process.

Distribution Channel Model of Reusable and Waste Items for Local Yards

A model of distribution channel has been developed for a clear understanding of the fate of recycled and waste material output from the EOL ships, which has been dismantled at Chottogram recycling yards. A model of distribution channel with a percentage of different recycled and waste material produced from typical EOL ships, dismantle in Chottogram area has been shown. During preparing of this model, help and guideline has been taken Professor Md Maruf Hossain of Chittagong university.[50] In the developed model, in the first layer marked pink, is the main output which has been shown in percentage in the distribution channel model. It has been observed that steel and machinery cover

[48] K.P. Jain, J. F. J. Pruyn and, J.J. Hopman, "Improving ship design process to enhance ship recycling", In: Soares, C. G. & TA, S., eds. In: Proceedings of the 3rd International Conference on Maritime Technology and Engineering (MARTECH 2016), Lisbon, Portugal. London, U.K.: CRC Press: Taylor and Francis Group, 2016a, P.663–671.; K.P. Jain, J. F. J. Pruyn and, J.J. Hopman, "Quantitative assessment of the material composition of end-of-life ships using onboard documentation", Resour., Conserv. Recycle. 107, 2016b, P.1–9.

[49] K.A. Hossain, 2019, op. cit.

[50] M. Hossain, "Shipbreaking Activities: Threats to Coastal Environment, Biodiversity and Fishermen Community", A book published by Young Power Social Action (YPSA), 2010, p.120.

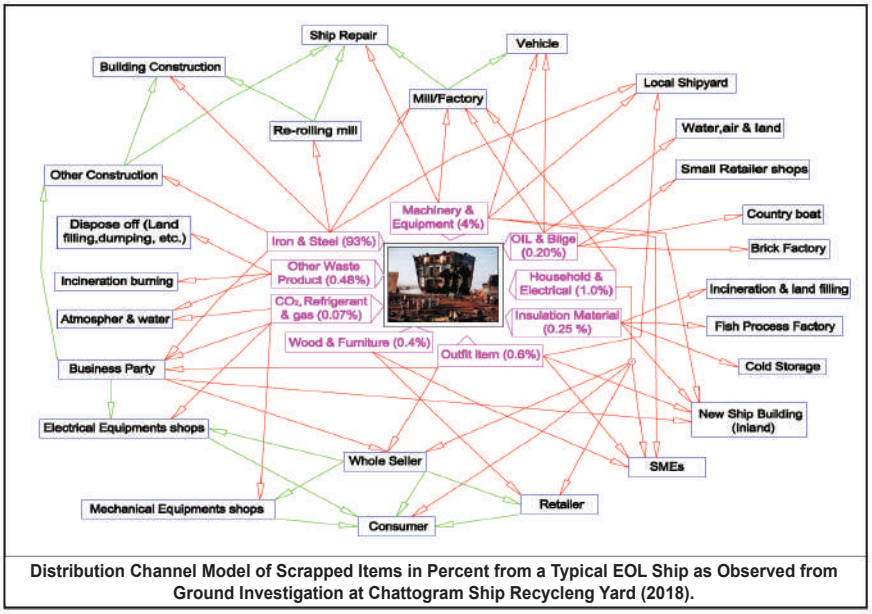

Figure 6: Model of Distribution Channel of Reusable and Waste Material of a Typical Ship from a Local Ship Recycling Yard of Bangladesh.

almost 98%. Primary and secondary market distribution has also been shown in the model in different colors. In the distribution channel model, it has been shown that there are nine main recycled and waste items which produced from a typical EOL ship in Chottogram area and those items are distributed around twenty-one consumers end, in more than fifty different channels has been shown in figure 6.

The post cutting process comprises of three sub process: collection and storage, separation and segregation, and transportation. The NEVS and EVS originating from the subprocess separation and segregation are fed into the subprocess transportation, where the EVS is transported either for reuse or recycling, and the NEVS is transported either to landfill sites or to disposal sites. The researcher has calculated and estimated by means of MFA that 1% to 3.5% of LDT of the sample ships (in average), usually be sent for waste disposal or considered as NEVS and 73% to 95% of LDT of the EOL ships can either be reused or recycled in the local market or considered as EVS. Around 20% to 30% of the weight of the NEVS usually extracted as EVS during the separation sub process of the post cutting process.[51]

[51] K.P. Jain et al. 2016a, 2016b, op. cit.

For this research work, all the available research papers and technical reports on material quantification of EOL ships have been reviewed. Unfortunately, unlike the car or aircraft industry, the number is limited (around a dozen). In order to develop the material flow diagrams using STAN,[52] data for the input and output flow of each process must be fed by the user as far as practicable.[53] An input flow to a process can be divided into two or more output flows based on the defined ratios. Such data can be generated by reconciling the material composition data of the ship. Based on such data, STAN calculates the value of each flow.[54] The author of this research work has explained that MFA has been carried out on 26 different types, categories and sizes of EOL ships which dismantled and recycled in local yards in Bangladesh. Researcher has also found that, the MFA can be used as a tool to visualize, compile, estimate, plan and compare different scenarios that can arise as a result of breaking and recycling of any EOL ships. Reusable material output in percentage with respect to LDT of sample 26 EOL ships and average reusable material output of sample 26 EOL ships has been shown in figure 7 and 8 respectively.

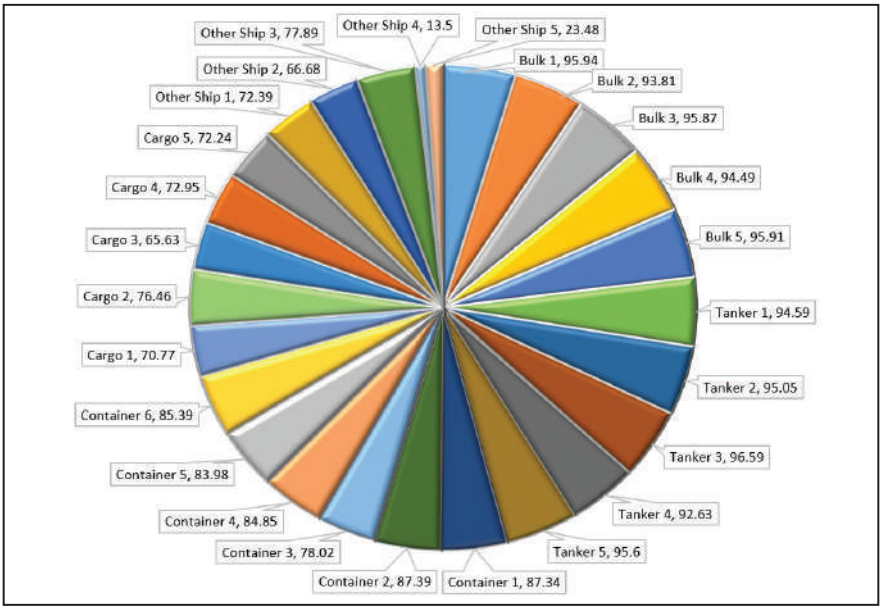

Figure 7: Reusable Material Output in the Percentage of Sample 26 EOL Ships

[52] K.P. Jain et al. 2017, op. cit.; K.A. Hossain, 2019, op. cit.

[53] K. P. Jain et. al., 2016b, op. cit.; K.A. Hossain, 2015b, op. cit.

[54] K.P. Jain et al, 2015, 2017, op. cit.

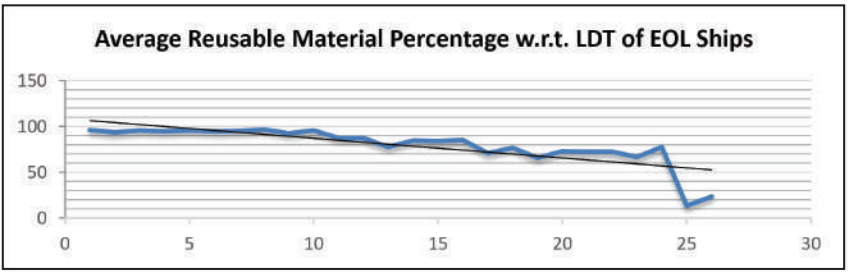

Figure 8: Average Reusable Material Output of Sample 26 EOL Ships

Analysis of Result Derived from MFA for Waste Material

For calculating and determining the amount of waste materials, free commercial softwares like Microsoft Excel and STAN have been used in addition with manual calculation.[55] It has been found that manually calculated result of waste material vary up to 0.4% with STAN software result, whereas no variation has found with MS Excel Broadsheet result. Waste material output in percentage with respect to LDT of sample 26 EOL ships and average waste material output of sample 26 EOL ships has been shown in figure 9 and 10 respectively.

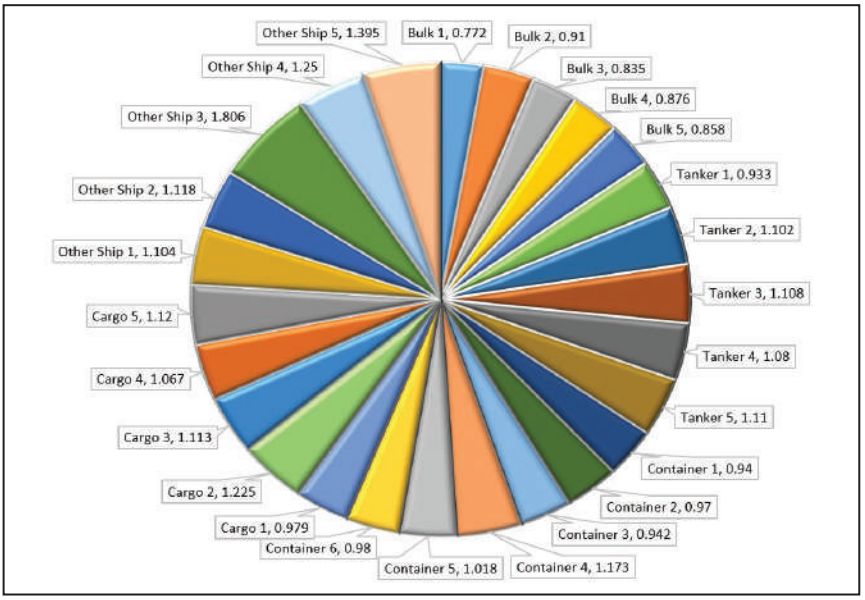

Figure 9: Waste Material Output in Percentage from Sample 26 EOL Ships

[55] K.A. Hossain, 2019, op. cit.

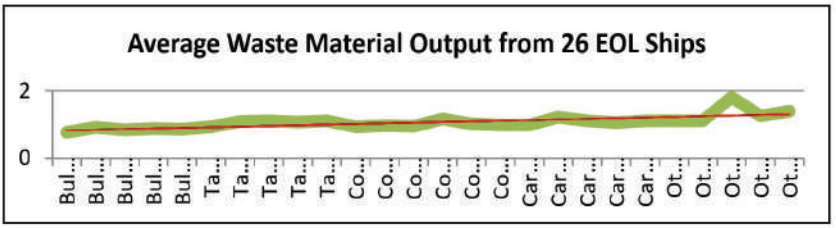

Figure 10: Average Waste Material Output From Sample 26 EOL Ships

Conclusion

The global ship recycling industry dismantles and recycles around 1,000 large ocean-going vessels per year. At present, South Asia is undoubtedly the global center for ship breaking and recycling. In Bangladesh, average 200 different types and size of obsolete ships with 2000000 LDT are recycled annually in different local yards. The author collected and made an inventory of materials, equipment, machinery, items and hazardous material on different types and sizes of EOL ships recycled in local recycling yards of Bangladesh in last seven years. Total 26 of different types and sizes of recycled ships has been considered as a sample to calculate the average annual amount of reusable materials and waste output. There are average 1833461 MT (minimum), and 1989252 MT (maximum) reusable materials have been collected annually from ship recycling industry of Bangladesh. Again, there are on average 17215 MT (minimum) and 22702 MT (maximum) hazardous waste products annually produced from local recycling yards of Bangladesh. However, future ships will be safer and more environment friendly. So the quantity of different HazMat or waste will be reduced at the future. At the same time, it can be hoped that amount of reusable material comes out from the future EOL ships will be increased and refined as well as will be environment friendly. As Bangladeshi recycling yards are working towards becoming compliant with the convention and regulations, it can be hoped that the number of EOL ships comes to this country will increase in future.

Perfect green ship recycling is a costly affair. On the other hand, sustainable or viable green ship recycling with the merging of present usual practice (beaching method) in Asian Countries is certainly possible. Ultimately those countries are doing a excellent job as they are in fact doing the recycling of obsolete old ships end of their life with good efficiency, but with less professional manner. It is, however, possible to comply HKC in the modified name of Statements of Compliance (SoC) and achieve approved standard by EU regulation

by adopting viable and sustainable ship recycling process keeping beaching method intake. At present, few improvements have been observed in some important aspect/field of recycling process and practice in a few Bangladeshi yards. As a result, those Bangladeshi yards are going to achieve the SoC certificate with the Hong Kong Convention. So it can be hoped that recycling practice and process of local recycling yards of Bangladesh will be sustainable in future. This promising industry needs continuous monitoring, balanced leadership, financing, guiding, motivation and wholehearted support from every corner from home and abroad. Bangladesh has a dazzling opportunity in ship recycling in the global market as a leader by utilizing skilled and low wage workforces and handling the matter more professionally. This model for recycling process and distribution channel of reusable and waste material will guide the yard owner, decision-maker and stake holder to develop a sustainable ship recycling industry in Bangladesh in an effective and efficient way.

About Author: Commodore Khandakar Akhter Hossain, (E), NUP, psc, BN is currently serving as the Managing Director of Dockyard and Engineering Works Ltd, Narayangonj. He did his B.Sc and M.Sc in Naval Architecture and Marine Engineering from Bangladesh University of Engineering and Technology (BUET). He pursued his first PhD from American World University, California, USA and second PhD from BUET. He also served in Chittagong Port Authority as a Board Member (Member Engineering). His several writings have been published in international journals. He is a lifetime fellow of Royal Institute of Naval Architect (RINA), UK; International Association of Marine Shipping Professionals (IAMSP), USA and Institute of Engineers (IEB), Bangladesh. He can be reached at hossaindrakhter@gmail.com.