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Ship Recycling in South Asia: Evaluating Current Practices and Addressing Future Challenges

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Abstract

This study gives a detailed comparative analysis of three ship recycling countries in South Asia, namely Bangladesh, India, and Pakistan. It assesses health risks and hazards to workers and harmful effects to the environment by the ship recycling industry in these countries. Additionally, it explores the economic significance of the industry in these countries and the legal frameworks that govern its activities. It also considers the status, living conditions, and health and safety challenges of workers at ship recycling yards. A detailed risk assessment matrix is utilised in this study to identify risky activities throughout the ship recycling process and evaluate the safety measures across the industry, identifying key hazards and their mitigation strategies. The study also reflects the environmental effects of ship recycling activities, especially the pollution caused by hazardous waste products such as oil, asbestos, and heavy metals. It can be observed from the literature that in legal framework and administrative policy aspects, India seemed to be established. In contrast, Pakistan and Bangladesh lacked proper rules and enforcement. Despite this, all three countries face serious challenges in providing a safe and healthy work environment for workers and effective environmental regulation. By addressing these challenges, the paper aims to fill the knowledge gap on ship recycling practice in the region and advocate for practical steps towards making the industry more sustainable. These recommendations involve reducing government bureaucracy, investing in modern recycling yards, and improving safety regulations to protect labourers' health. The article also advocates for more efficient hazardous materials management to reduce the negative impacts of ship recy-

cling activities on the environment.

Keywords

Risk Assessment, Ship Recycling, South Asia, Comparative Analysis

1. Introduction

Shipping has been the most cost-effective means of conveyance worldwide over the last several centuries. Being one of the most favoured modes of transportation in global trade, ships are observed to last for up to 25 years. Upon reaching the end of their working life, these obsolete ships must be disposed of and replaced by new vessels, as it would be very costly to maintain and/or repair them. In common practice, ship disposal is also referred to as ship recycling, a process of dismantling ship parts and reutilising its valuable components (particularly steel components) for other practical purposes [1].

In the early 1970s, the ship recycling industry was centralised in several developed countries and regions: the EU, the USA, Japan, and Taiwan region. These countries and regions implemented a "mechanised" process, using high levels of mechanisation and advanced technology to dismantle obsolete ships effectively. However, due to continuously increasing oil prices, the industry had gradually shifted its activities from the "mechanised" to a "non-mechanised" process. The latter method has been proven to be much more cost-effective as a low-salaried labour force performs the whole operation instead of automated machines/robots. Therefore, since the 1990s, the ship recycling industry has moved its "hub" to South Asian countries (Bangladesh, India and Pakistan), as illustrated in **Figure 1** [2].

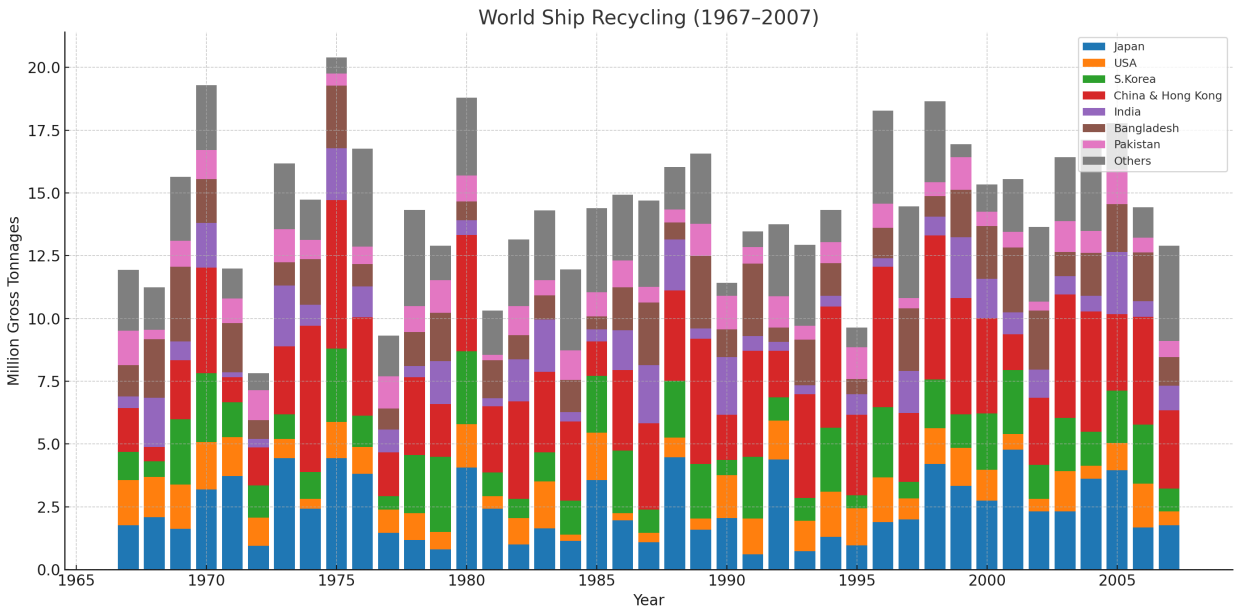

Figure 1. The world's ship disposal movement.

The non-mechanised ship recycling process adopted in Bangladesh, India, and Pakistan uses the "beaching" method illustrated in Figure 2 [1]. The general idea of this method is to provide a systematic procedure for dismantling ships economically and efficiently. However, this process has not been performed sustainably in all three countries.

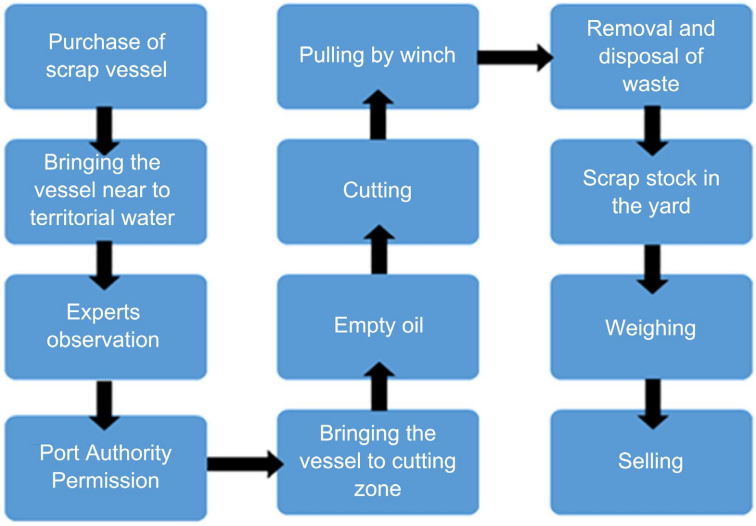

Figure 2. Beaching method workflow.

1.1. Aim and Objectives

The project aims to reassess the current practice of ship recycling in South Asia (Bangladesh, India, and Pakistan).

The objectives of the project are as follows:

1) To conduct a comparative study across three ship recycling countries in South Asia (Bangladesh, India and Pakistan).

2) To assess the significant health hazards and risks to workers due to ship recycling activities in South Asia.

3) To study the harmful effects on the environment brought by ship recycling in South Asia.

4) To draw an objective conclusion and suggest possible solutions for more sustainable ship recycling activities in South Asia.

1.2. Background

In 2010, Demaria [3] conducted a qualitative study to observe the waste disposal activities of the ship recycling industry in the Indian subcontinent countries. He found that waste (by-products) from the ship-breaking process was very harmful to the environment and not well treated. The main substances contaminating the environment are also identified in his study: oil, asbestos, heavy metals and other toxic materials (PAH, PVC, and PCB). Furthermore, a quantitative analysis to evaluate the environmental impact of the ship recycling industry performed by [1] also produced similar results. By collecting water samples from a yard in Chittagong,

Bangladesh, and testing them in a research lab, they discovered that metals and oil polluted the water.

Apart from the environment, ship recycling activities in Bangladesh, India, and Pakistan also jeopardise the workers' health. In 2001, Andersen [4] identified that the industry's practices in those countries harmed the workers working on the site (health and safety issues). Various risky tasks include removing oil and fuel from ships, disposing of paint waste, and cutting metal components (ships' bodies). These activities are indeed deadly and were classified as sources of potential hazards related to health and safety problems by Mishra and Mukherjee in 2009 [5]. Moreover, Andersen [4] also listed four main factors which lead to an unsafe working environment: insufficient training for workers, lack of proper technical protocol, lack of personal protection equipment, and inadequate resources.

In 2012, the investigation examining workers' health and safety in the ship recycling industry was further developed by Zakaria *et al.* [6] through a statistical study, as shown in **Figure 3** [6].

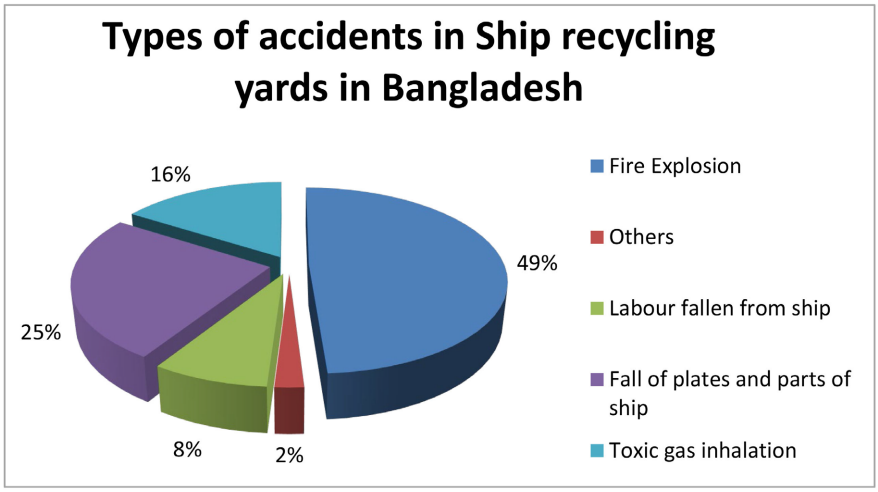

Figure 3. Accident data in Bangladesh's recycling yards.

Later on, in 2023, Mannan *et al.* [7] examined recent developments in key ship recycling nations, highlighting both opportunities and challenges faced by this industry. A strategic analysis using SWOT (Strengths, Weaknesses, Opportunities, Threats) methodology was also employed to analyse the ship recycling industry in South Asian countries.

In 2024, Malek [8] identified the primary sources of risks associated with ship breaking and recycling in Chittagong, Bangladesh. The provisions of existing laws and conventions about occupational safety were also compiled, and mechanisms for workers' safety were suggested.

In the same year, using SWOT analysis, Günes *et al.* [9] performed a comparative study of the ship recycling process between Türkiye, Bangladesh, and India. This study compared and evaluated the present dismantling procedures and identified the best practices and areas that need development in these countries.

2. Literature Review

Moving towards globalisation, ship recycling has been recognised as a sustainable activity in the maritime industry. However, the practice adopted by the Indian subcontinent in the ship recycling industry does not reflect the "green" ideology, as it produces substantial negative impacts on human lives and the environment. Hence, in this chapter, several articles related to environmental impact and the health and safety of workers in the ship recycling industry are reviewed.

Also, a few comparative studies about ship recycling practices in various countries worldwide are examined. In this review, more attention has been given to the countries in the Indian subcontinent.

2.1. Environmental Impact

As described in the introduction, ship recycling activities generally can produce various hazardous waste materials that are dangerous to the environment if they are not treated well. In 2010, Demaria [3] identified that there are three treatment methods of waste disposal:

1) Decontamination before export: The ship owners will remove all hazardous materials before sending the ships to the breaking site.

2) Environmental sound management on site: After the "beaching" process, the hazardous materials are safely removed and discharged.

3) Dumping: The dangerous materials are freely disposed of into the surrounding environment.

Among those three items, dumping is the most dangerous method. In fact, this method has been widely used as a common practice in the yards of the Indian subcontinent. Demaria's [3] study about shipbreaking in India and Hossain and Islam's [10] research on the environmental impact of ship-breaking industries in Bangladesh supported this fact.

In his study, Demaria [3] reported that several kinds of freely discharged hazardous substances contaminate the environment: oil, bacteria, asbestos, heavy metals, and persistent organic pollutants. The same information is also specified in Hossain and Islam's [10] research, in which a more detailed explanation is offered as follows:

1) Oil (composed of hydrocarbons and sulphur). Oil is spilled into the water during the ship-cutting process, harming the aquatic ecosystem.

2) Asbestos (a group of minerals naturally occurring as masses of long, silky fibres) is commonly used as an insulating, fireproof, soundproof, and thermal insulating material on ships. However, this mineral can pollute the air and potentially cause cancer in the workers who breathe it in.

3) Heavy metals (lead—Pb, mercury—Hg, cadmium—Cd, iron—Fe, Aluminium—Al, and Zinc—Zn). The above-listed heavy metals are toxic to humans and can cause various diseases, including vision and hearing impairment and damage to the kidneys, heart, and reproductive system.

4) Other toxic materials (PAH, PVC, and PCB). All of these materials can pol-

lute the water and air and have the potential to cause diverse, deadly effects on human health, such as various cancers, respiratory problems, reproductive impairment, and nervous attacks.

Demaria [3] has indeed provided important information about the environmental hazards caused by ship recycling activities. However, the study only offers qualitative data, which makes it unsuitable for comparative analysis (either across countries or across time). This limitation has driven Pasha *et al.* [1] and Talukder *et al.* [11] to conduct quantitative experimental research.

Pasha *et al.* [1] investigated the physicochemical properties of the water at the SRS Ship Breaking Yard (Chittagong, Bangladesh) to evaluate the environmental impact of the ship recycling industry. They collected water samples and analysed them in a laboratory. The results are summarised in **Table 1** [1].

Table 1. Results of the water samples test [1].

Parameters	Sample Data	Standard Limits
pH	8.4	6.5 - 9.0
EC	2230 µc/cm	1200 µc/cm
TDS	3220 mg/l	2100 mg/l
Chloride	890 mg/l	600 mg/l
DO	6.4 mg/l	4.5 - 8 mg/l
BOD	1.0 mg/l	50 mg/l
COD	6.5 mg/l	200 mg/l
Oil & Grease	378 mg/l	10 mg/l
NH_3	0.17 mg/l	5 mg/l
Turbidity	14.9 FTU	-

In the same research, Pasha *et al.* [1] also carried out an environmental impact assessment based on a simple methodology called the Environment Evaluation System (EES). In this approach, the environmental impact was analysed using a numerical score that represents the effect of the ship recycling industry towards the environment. Positive and negative scores refer to the favourable and unfavourable impact, respectively. This score was computed via Equation (1) [1].

$$\text{EIV} = \sum_{i=1}^{n} V_1 W_1 \tag{1}$$

where V_1 is the relative change in the value of the environmental quality of the parameter, W_1 is the relative importance or weight of the parameter, n is the total number of environmental parameters related to the project, and EIV is the Environmental Impact Value. This assessment was performed based on several aspects, including physical, ecological, human interest, and quality of life. A calculation sample in the evaluation is illustrated in **Table 2** [1].

The total score obtained from the evaluation was found to be unfavourable.

This result is aligned with the most recent study about environmental impacts conducted by Talukder *et al.* [11] in 2015. An identical approach to Pasha *et al.* [1] was adopted in his research. Experiments were conducted to test the water quality (turbidity, salinity, dissolved oxygen, electric conductivity, pH, total dissolved solids, temperature, Ammonia-Nitrogen, Nitrate-Nitrogen, and Phosphate concentration) around the ship-breaking yard in Chittagong, Bangladesh. The results obtained in both studies are similar. In conclusion, both studies agreed that the ship recycling industry generates adverse effects on the environment.

Table 2. Environmental impact assessment [1].

Parameter	Relative Importance Value	Degree of Impact	Relative Impact	
1. Physical			Positive	Negative
Regional Hydrology and Flooding	4	−1		−4
Soil fertility	2	0	0	
Water Pollution	2	−1		−2
Air Pollution	2	−1		−2
Noise Pollution	2	−7		−14
			EIV=	−22

2.2. Health and Safety of the Workers

Ship recycling activities harm not only the environment but also the workers' health. Through these activities, common pollutants (asbestos, oil, PVC, and PCB) described in Section 2.1 are eventually exposed to the workers through their work surroundings, thus endangering their health. Andersen [4] singled out seven activities that potentially lead to contact with hazardous pollutants.

1) Removal and disposal of asbestos—Workers are exposed to the inhalation of asbestos fibres, which could cause cancer or asbestosis (**Figure 4**) [4].

Figure 4. Workers handling the asbestos (mask given by the photographer).

2) Removal and disposal of PCB—Workers are exposed to PCB through consumption and absorption through the skin, which can cause adverse health issues.

3) Removal of bilge and ballast water—Bilge and ballast water contain harmful organics, and their release can cause dangerous diseases.

4) Removal of oil and fuel—Oil and fuel contain toxic properties that can affect health. Workers are exposed to oil and affected by breathing in the toxic air, as shown in **Figure 5** [12].

Figure 5. Workers are exposed to oil.

5) Removal and disposal of paint—Paint contains harmful substances and chemicals. Breathing in these releases could cause serious health problems or even cancer.

6) Cutting and disposal of metal—Torch cutting produces hazardous fumes that can cause a negative health impact.

7) Removal and discarding of various ship machinery—When dealing with machinery, workers are unprotected from the toxins (oil, fuel and asbestos).

Mishra and Mukherjee [5] also identified these activities as hazards associated with health issues. To tackle the problems, several control plans are mentioned, such as providing coverage, storage space for hazardous materials, and covered work areas.

Apart from evaluating the joint activities in the ship recycling industries, several factors affecting health and safety in the ship recycling industry in Bangladesh, India and Pakistan were identified and listed in **Table 3** [13] [14].

Table 3. Health and safety factors.

Parameters	Bangladesh	India	Pakistan
Providing of PPE	Not compulsory	Yes, compulsory	No
Fire-fighting facilities	No	Minimal	No data
Waste disposal	No	Few landfills	No
Medical check-up	No	Once in a month	No data

Muhibbullah M. [15] categorised the hazards and risks of ship breaking activities in Bangladesh in five different areas: Serious accident-related hazards, Physical hazards, Mechanical hazards, Biological hazards, Economic and physiological hazards. He also studied the problems and limitations associated with human rights and found that workers often perform the loading activities manually, leaving them vulnerable to accidents such as gas explosions, toxic gases, iron plates and sheets falling, etc. [15] [16].

According to Andersen [4], another important aspect concerning the workers is safety. The current practices adopted by the ship recycling companies in the Indian subcontinent are not aligned with the international and national standards of the Occupational Health and Safety Administration (OHSA). Furthermore, he listed four primary factors that endangered the operational safety of the workers.

1) Lack of proper training—Workers have inadequate skills to perform complex tasks.

2) No general working principle—Task is being carried out arbitrarily without proper sequence.

3) Inadequate personal protection equipment—Workers are exposed to hazardous fumes and chemicals that are inhaled and exposed (**Figure 6**) [4]. It can cause health deterioration.

Figure 6. Cutting work being done without protective equipment.

4) Less equipped with facilities and safety tools—Most heavy work is carried out manually without suitable machinery.

These factors are responsible for accidents that occur in the ship recycling yard. For example, without proper assessment and protocol, cutting works take place in the cargo tank, which contains explosive gases that could lead to an explosion.

3. Methodology

The non-experimental study was carried out by critically reviewing and analysing data across the available literature. The detailed methodology and procedures are described as follows.

3.1. Data Collection

This study began by collecting data on ship recycling activities in India, Bangladesh, and Pakistan, covering methods, technologies, facilities, and their impacts on the environment and workers, including socio-economic effects, health, and safety issues. It systematically analyzes studies published between 2009 and 2025 on current practices in the South Asian ship recycling industry, focusing on environmental hazards, risks to workers' health and safety, and accident frequency. Data were sourced from published books, peer-reviewed journal articles, conference proceedings, and reports from reputable online platforms and international organizations, accessed through Google Scholar, ResearchGate, SpringerLink, ScienceDirect, and Taylor & Francis Online, as well as official organizational websites such as YPSA, Transparency International, World Bank, IMF, SAJ, and Shipbreaking Platform. Additional materials, including conference proceedings and statistical reports, were obtained from conference archives and institutional repositories. The search employed keywords such as "ship recycling", "shipbreaking", "South Asia", "Bangladesh", "India", "Pakistan", "health risks", "environmental impact", and "legal frameworks", while excluding non-English papers, studies without specific data, publications before 2009, and works not focused on South Asia.

3.2. Data Analysis

The accumulated data from each source was analysed using statistical methods to verify the results across literature. In section 5, the verified results are represented in bar charts and tables to conduct a comparative analysis among the three countries. The comparison analysis mainly focuses on several critical issues related to ship recycling: its role in the countries' economy, legal status, workers' status, and living conditions. Data about the ship recycling industry's health and safety issues and environmental impact were also gathered and discussed in sections 6 and 7, respectively.

3.3. Risk Assessment Matrix

In Section 5, a risk assessment matrix/table is utilised as a tool to assess all activities that are deemed to be dangerous in the ship recycling process.

The following sequential steps were performed in carrying out the risk assessment: firstly, various types of activities accompanied by their sub-activities (if applicable) in ship recycling operations were listed. Furthermore, the potential hazards associated with each sub-activity, as well as their possible harmful effects on the workers, were also recorded. Every potential hazard and impact was subsequently evaluated based on how likely (probability of occurrence) and how severe (degree of impact) they might be, using the criteria specified in **Table 4** and **Table 5**. The probability and impact scales presented in **Tables 4** and **Table 5** follow standard qualitative–quantitative risk assessment practices recommended by ISO 31010:2019, ensuring consistency with internationally accepted methodologies.

Table 4. Degree of probability.

Probability	Rating (%)
Rare	10 - 20
Unlikely	21 - 40
Moderate	41 - 60
Likely	61 - 80
Very likely	81 - 100

Table 5. Impact of activity.

Impact	Rating
Very low	1 - 2
Low	3 - 4
Medium	5 - 6
High	7 - 8
Very high	9 - 10

After determining the probability and severity of all hazards, the level of risk for each activity was determined (Table 3). The impact of activity is calculated via Equation (2).

$$\text{Risk} = \text{Probability (in decimal)} \times \text{Impact} \tag{2}$$

Lastly, the numerical value obtained from Equation (2) was then translated into three risk zones (low, medium, and high risk) using the Risk Matrix shown in Figure 7 [17].

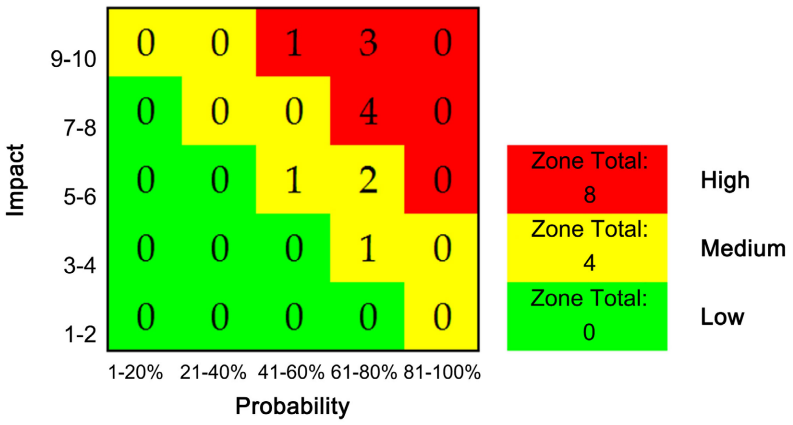

Figure 7. Risk matrix.

When a particular activity is found to be a medium or high-risk zone, mitigation actions are recommended to minimise the possibility. A summary of the step-by-step procedure of the risk assessment is illustrated in Figure 8 [17].

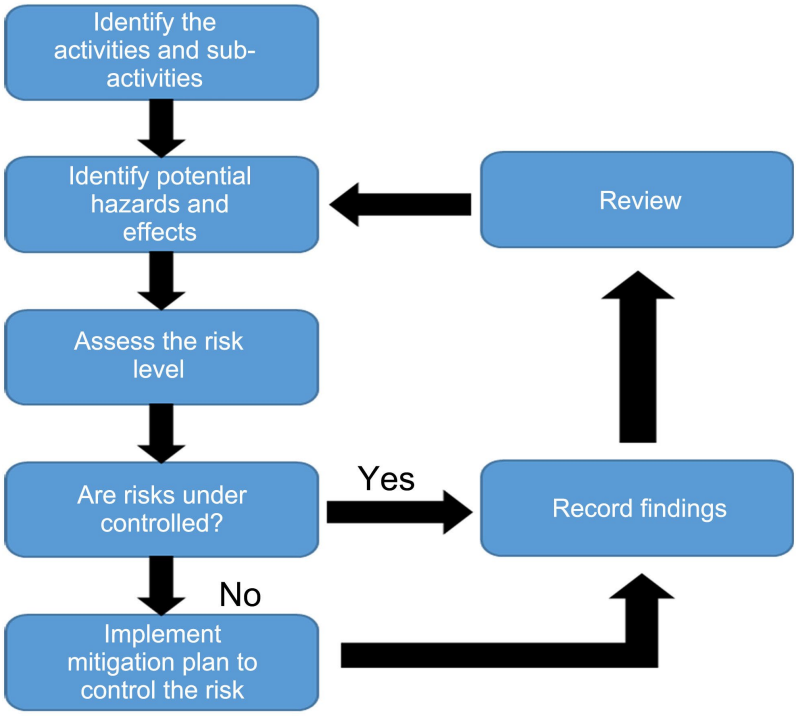

Figure 8. Typical flow of risk assessment process.

4. Comparative Study

As mentioned in Section 1, Bangladesh, India, and Pakistan are the three countries in the Indian subcontinent that are actively involved in the ship recycling industry. In general, they have similar methods and approaches in breaking up ship bodies. There are also not many differences in the quality and safety of the whole ship recycling activities between these countries. However, despite these general similarities, few studies have been carried out to collate and compare ship recycling activities/industries across the three countries in more detail.

4.1. Role in the Economy

Over the past three decades, the ship recycling industry in South Asia, particularly in Bangladesh, India, and Pakistan, has significantly contributed to the respective countries' economies. The sector in these areas has been rapidly growing since 2000, outperforming Europe, Taiwan region, and Korea. To date, approximately 70% to 80% of the worldwide ship recycling market is dominated by these three countries.

The performance of the ship recycling industry in a particular place/country is quantified mainly by the number of gross steel tonnage produced from the recycling activities. This value is often even used as the industry's key performance indicator (KPI), as the revenue is mainly generated from the sales of recycled steel. Thus, an analysis has been done to compare the financial performance of SBRI between Bangladesh, India and Pakistan based on the weight of steel produced annually by each country. The analysis result is illustrated in **Figure 9** [18].

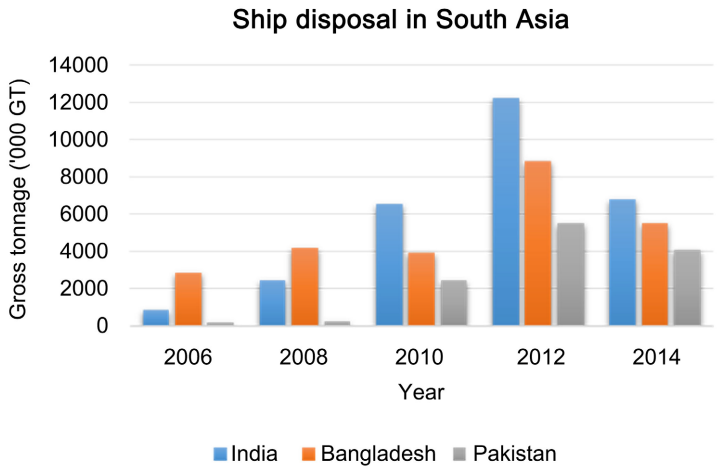

Figure 9. The weight of steel produced annually.

Apart from contributing to the global steel market, the ship recycling industry in the three countries has also played a prominent role in their domestic economy. In Bangladesh, about 50,000 workers are directly employed by ship-breaking and recycling firms to work full-time at the Chittagong yard. This large workforce is a valuable asset for Bangladesh's steel production. On average, 50% of the national steel contribution comes from the ship recycling industry, which generates an annual revenue of USD 118 - 132 million for the government through taxes. On the other hand, the number of labourers recruited in the Gadani ship breaking yard in Pakistan nowadays is not as large as that in Bangladesh. Approximately only 15,000 workers are actively involved in the ship recycling process, which is only about half of the number of employees recruited in the 1980s during the peak of the industry.

The role of the ship recycling industry in India's economy is significant. By exploiting 30,000 workers, more than 400 ships are scrapped yearly, generating an average of about 6 million gross tonnages of steel. However, although this contribution appears similar to a global steel contribution, it only accounts for 6% of the domestic steel production. The economic contributions of the ship recycling industry in the three countries are summarised in **Table 6** [19].

Table 6. Number of employees and steel contribution generated by SBRI South Asia (2014) [19].

Parameters	Bangladesh	India	Pakistan
No. of direct employees	50,000 workers	30,000 workers	15,000 workers
Steel contribution	50%	6%	15%

4.2. Legal Status in Bangladesh, India, and Pakistan

Despite more than 30 years of operation, there is no proper legal framework regulating the ship recycling industry in either Bangladesh or Pakistan. The lack of enforcement by the government is one of the main reasons why ship recycling

firms neglect the importance of legal obligations in their business. On the contrary, proper legal frameworks and administrative regulations have been well established in India. A wide range of regulations and standards prevail in the industry, including the provision of labour insurance, waste removal facilities, as well as cargo movement across countries. Through this framework, the government benefits through various taxes imposed. Legal status in Bangladesh, India, and Pakistan is listed in **Table 7** [13].

Table 7. Status of current regulations and rules in ship breaking yards in the Indian subcontinent (2009) [13].

Parameters	Bangladesh	India	Pakistan
Labour Insurance	No	Yes	No
Waste Removal Facility	No	Yes	No
Gas Free Certificate	No	Yes	No
Cargo Free Certificate	Yes	Yes	Yes
Specific Rules for Shipbreaking	No	Yes	No

4.3. Workers' Status

There is no written work agreement for semi-trained and untrained labourers in Bangladesh and Pakistan. They can be dismissed at any time without prior notice or justifiable reasons. Likewise, in India, the non-existence of job security due to the deficiency of official contracts has often frightened workers from carrying out their duties. In the ship recycling industry, the issue is more evident and critical. Being afraid of losing their jobs, the ship-breaking labourers in Bangladesh, India, and Pakistan deliberately give up their right to seek a safe environment in performing their work.

However, the lack of proper administration and written employment contracts does not always discourage potential employees in all of the abovementioned countries. It is found to be beneficial for villagers as they can get a job quite easily in the ship recycling industry without a qualification/education. According to a global survey across the Indian subcontinent countries, about 40% of the labourers in the industry have no previous education. This eventually leads to low salaries for workers, ranging from US$2.85 to US$4.15 per day. The status of the workers in the ship recycling industry in the Indian subcontinent is summarised in **Table 8** [20]-[22].

Table 8. Status of workers in SBRI South Asia (Data gathered from different years: 2006, 2010, 2014) [20]-[22].

Parameters	Bangladesh	India	Pakistan
Average wages (US$/day)	2.85	4.15	3.34
Working hours	12	8	12
Education level	46% no education	36% no education	40.2% no education
Training program status	No	Yes	No

4.4. Living Conditions

The living conditions of labourers working in the shipyards in Gadani (Pakistan) are relatively poor. The lack of advanced technology, decent infrastructure, and facilities (hospital, housing, proper toilets) creates an unpleasant and unhealthy environment for them. Similarly, in Alang (India), ship recycling workers live in a miserable and harsh environment. Many workers suffer from the absence of appropriate sanitation facilities and accommodations. Also, only a small hospital in the area cannot accommodate the thousands of labourers.

In Bangladesh, the workers staying in the Chittagong shipyard face a similar situation. Apart from the absence of necessary facilities and housing, the poor waste management in the ship recycling process poses serious health problems for the workers. Air and water resources are highly polluted in the area. The comparison of living conditions among the workers in Bangladesh, India, and Pakistan is summarised in **Table 9** [13] [14] [22].

Table 9. Living conditions in SBRI South Asia (Data gathered from different years: 2009, 2010, 2014) [13] [14] [22].

Parameters	Bangladesh	India	Pakistan
Availability of drinking water	Limited	Tap supply in yards	No
Housing	No	No	No
Hospital	No	Small Hospital	No
Sanitation Facility	No	No	No

5. Results and Discussions

After identifying the everyday hazardous activities (Section 2.2), the abovementioned risk assessment process was applied to predict the activity with the highest risk. Form **Table 10**, it can be seen that "Working at height, especially near deck openings and edges", initially had the highest risk due to an 80% probability of fatal injuries, but after implementing safety measures such as safety belts, harnesses, and regular inspections, the risk significantly decreased to a low level with a reduced probability of 35%.

Table 10. Result of the highest risk activity.

S/N	Types of activities	Sub-activities	Potential Hazards	Possible effects	Probability % (Before)	Impacts (Before)	Risk (Before)	Zone (Before)	Mitigation procedure	Probability (After)	Impacts (After)	Risk (After)	Zone (After)
3	Working at height especially near deck openings and edges	N.A	Free fall from height	Fatal /major injury	**80%**	**9**	**7.2**	High	Ensure the use of safety belts and harness. Provide necessary training. Provide scaffoldings and conduct regular check on it to ensure stability.	35%	4	1.4	Low

Upon analysing the risk assessment results, it is observed that the mitigation procedures have substantially reduced risks across nearly all activities. For exam-

ple, the activity "Entry into enclosed space" saw a significant reduction in risk, with the risk score dropping from 5.6 (High) to 0.7 (Low) after the implementation of safety measures. The common mitigation strategies that contributed to these improvements include using proper PPE, installing ventilation systems, regular safety inspections, training, establishing waste treatment facilities and improved housekeeping practices. Overall, the risk levels for most activities have shifted from "High" and "Medium" to "Low", demonstrating the effectiveness of these safety protocols in minimising the potential hazards associated with ship recycling.

5.1. Lack of Good Governance

All three countries have experienced numerous political upheavals. Although the governments in these countries intend to be economically productive and raise their GDP (Gross Domestic Product), some challenges remain, such as poor planning and inefficient bureaucracy.

The extent of political instability differs in severity in these three countries. The Corruption Perception Index scorecard and the score of the involved countries are shown in **Figure 10** and **Table 11**, respectively [23]. India ranks lowest among the three countries. This relates to the legal status prevailing in each country. All three countries are striving to improve their governance. India has shown better improvements than Bangladesh and Pakistan. It has consistently allocated resources and capital in the ship recycling industry, trying to upgrade the workforce and facilities. Moreover, India has established essential rules and regulations involving different authorities (see **Table 7**). Therefore, this makes India more competitive when vying for ship disposal contracts. To add, it can be interpreted that India is more reliable among the three countries due to better governance and structure. However, involving several politically affiliated institutions in the ship recycling industry can be a serious issue. Obtaining permission for ship recycling works would be time-consuming. This will eventually encourage the shipbreakers to circumvent the laws altogether.

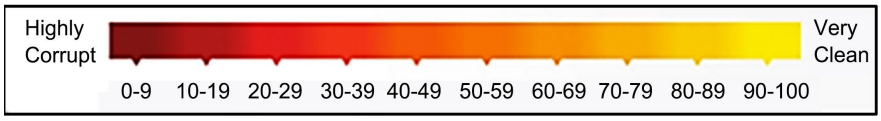

Figure 10. Corruption Perception Index scorecard [23].

Table 11. Corruption perceptions index [23].

Country	Corruption Perceptions Index (CPI) 2015	World Ranking
Bangladesh	25	139
India	38	76
Pakistan	30	117

5.2. Workers' Safety Status

There are still insufficient considerations regarding the coverage of workers' well-being and safety on handling hazardous materials. Workers in both Bangladesh and Pakistan's ship recycling yards still face the absence of appropriate PPE. Moreover, the lack of training programmes in both countries also hinders the safety measures. Workers have inadequate knowledge of handling and identifying the potential hazards and dangerous materials. However, despite vigorous enforcement in equipping workers with PPE and training in India, the importance of incorporating fire-fighting facilities in the yard might have been overlooked (see **Table 8**). Also, without such a feature, common potential dangers such as fire outbreaks, oil spills, and chemical spills could not be efficiently dealt with and contained. This would pose severe risks to the workers and the environment. All three countries' safety measures still lack the basis to ensure workers' protection in the recycling yards.

5.3. Poor Facilities and Management

The harmful materials in the ship recycling process, such as metals, asbestos, PCBs, PAH, oil, dioxins, and furan (as described in Section 2.1), are excessively generated during the following activities: metal cutting, oil tank drainage, and waste removal. In Bangladesh and Pakistan, these activities are currently not managed well, as there is no proper legal framework that binds ship recycling firms to adhere to their business practices. On the other hand, in India, an appropriate legal framework and governmental regulations have fundamentally controlled the ship recycling industry. A step-by-step supervision and administrative procedure has to be completed before all ship recycling activities can be performed. However, despite the existing legal frameworks, India's ship recycling industry is still highly polluting to the environment. This could be mainly caused by the lack of facilities and/or irresponsible management in handling waste. Thus, the current performance of the ship recycling industry in the three Indian subcontinent countries is still substandard and can be improved regarding the following aspects:

- Hazardous waste management facilities.
- Emergency handling capabilities.
- Standard working procedures.

5.4. Limitations

This study is based entirely on secondary data from published literature and official reports. While efforts were made to select credible and up-to-date sources, the accuracy and completeness of the findings may be affected by regional differences in reporting standards, data availability, and potential biases in the original sources.

6. Recommendations

Based on the analysis and discussions, the following possible solutions are suggested

to improve the current ship recycling process by applying the good practices of European counterparts and the author's critical assessment.

6.1. Reduce Government Bureaucracy

The issue of bureaucracy exists in all governments; the difference is in its extent. The lack of governmental initiatives to "free up" the ship recycling industry and make it more open regarding logistics and operations has proven to be the leading cause of an unfavourable environment. Therefore, eliminating some unnecessary administration would enhance the ship recycling industry. In addition, reducing the government bureaucracy may provide fewer opportunities for dishonesty and unauthorised activities by ship owners and breakers. Moreover, with simpler measures involved, ship recycling activities can be done more efficiently in terms of time and cost. This solution would improve the overall industry in the long term.

6.2. Investment in the Recycling Yards

The current recycling yards were judged unsatisfactory and poor. Indeed, a serious improvement in the recycling yard is required in these countries, which involves government participation through investment. One possible investment might focus on establishing a dry dock recycling yard following the European counterparts, as shown in Figure 11. This initiative will enable the recycling process in the involved countries to be carried out in an orderly manner that does not jeopardise workers' health and safety conditions.

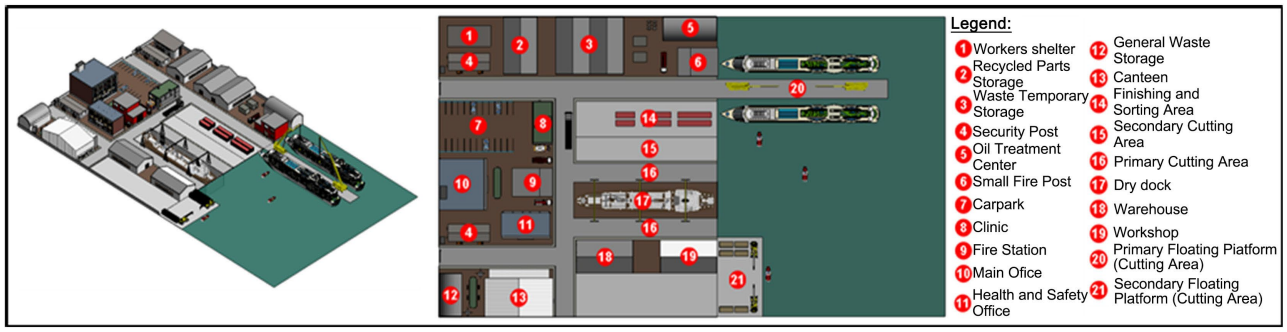

Figure 11. Authors' perspective of the government yard.

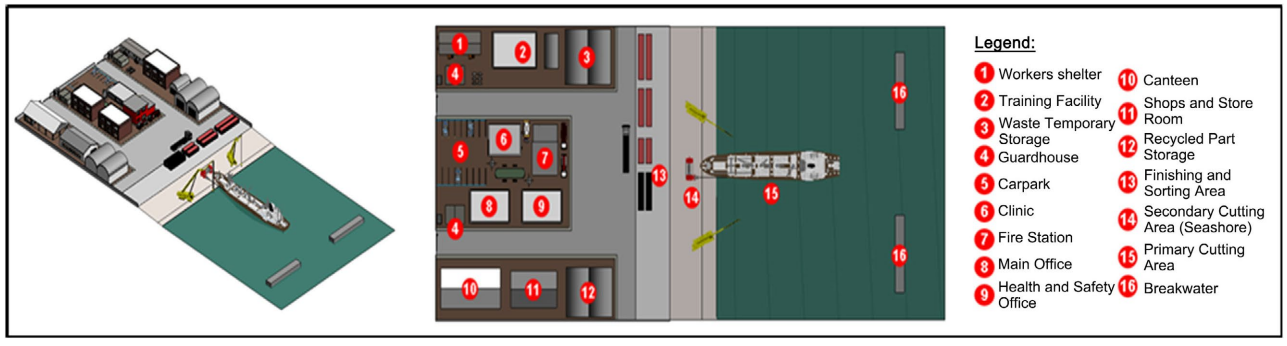

Figure 12. Authors' perspective of the privatised yard.

Additionally, considering the involvement of the wide beaches in the current practice, the government could establish at least three dry docking yards along the beaches. These yards could also be rented out to private companies, which would then become a possible source of income for the government.

Besides the government, private companies can also step up their initiatives to upgrade their current yards. With a much simpler layout, as shown in Figure 12, these small upgrades could improve the industry's current situation and attract potential contracts.

7. Conclusions

Looking closely at the ship recycling industry in the Indian subcontinent countries (Bangladesh, India and Pakistan), several common issues keep hindering their progress. These issues are critical as they not only affect the performance of the ship recycling industry in the said countries but also contaminate the environment as well as threaten workers' health and safety.

No proper legal frameworks have been established to regulate the ship recycling industry. Moving forward, the government needs to improve the situation without compromising too many complex bureaucracies.

Basic human rights are being contravened. The government's concerns should concentrate on social policies such as minimum wages and proper housing that are for the future. Also, private companies should be more responsible in ensuring a safe and sound working environment for all workers.

The current conditions of ship recycling yards are poor and unacceptable. With the collaboration of international organisations and governments of the respective countries, a sustainable recycling yard can be designed and made a reality through various investments.

In general, the ship recycling industry produces a significant amount of hazardous substances or by-products that could damage the environment. The issue can be mitigated by establishing a proper and efficient treatment method before discharging any toxic materials. To achieve this, the Indian subcontinent countries could tap into the resources of developed countries to improve their technical knowledge and technology.

Overall, there are still many improvements that have to be made in the ship recycling industry, especially in the countries of the Indian subcontinent. A further study could be developed based on the possible solutions recommended in this article, particularly on the arrangement of the ship recycling yard. It shall focus on the costing, revenues, as well as the safety and environmental aspects of the intended yard. The plans proposed should be implemented responsibly to ensure sustainability in the industry's overall performance.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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