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A Review on Assessment and Management of Occupational and Health Risks in the Shipbuilding Sector of Bangladesh

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ABSTRACT

Bangladesh's shipbuilding sector makes a significant contribution to the country's economy. However, it is also associated with occupational risks for its workforce. This paper aims to review and explore existing literature on assessing and managing these risks within the context of Bangladesh shipbuilding industry. The review delved into different types of hazards encountered by shipyard workers, including physical, chemical, and biological dangers, by analyzing incident reports, safety audits, and exposure data elaborated in the literature. Furthermore, the review also examines established methods applied to the international and local shipbuilding industry for risk assessment and management and makes a comparison to find the gap in the literature. The study reveals a significant amount of literature covering various focus areas within the global shipbuilding sector. However, only a limited number of these works are relevant to Bangladesh shipbuilding industry, and among them, only very few papers deal with the Occupational Health and Safety assessment technique. This highlights a huge gap in the literature and suggests a need for more studies regarding Occupational Health and Safety management in Bangladesh shipbuilding.

1. INTRODUCTION

Bangladesh, known for its extensive river network, is home to approximately 700 rivers, including tributaries, with a total length of around 24,140 km. The country's strategic position, skilled labor force, and vast river system have contributed to the growth of its shipbuilding industry, which has seen significant development in the past decade. Several shipyards in Bangladesh can now construct a variety of vessels, such as ocean-going ships, inland cargo vessels, and passenger ships, all meeting both local and international standards.

Over 120 registered shipyards and 100 shipbuilders of various sizes are located largely along riverbanks in divisions such as Chattogram, Khulna, Barisal, and Dhaka (BIDA Website). Chattogram serves as a major shipbuilding center due to its proximity to the Bay of Bengal. Economic growth, infrastructure projects, and increased trade activities have contributed to a rise in the number of registered vessels in the country, with an annual growth rate exceeding 6% (Raju, 2023). The local shipbuilding industry is currently valued at approximately USD 1 billion annually, and future demand is expected to align with continued economic progress. The industry's export capacity is estimated at 20 vessels per year, while domestically produced ships, such as multipurpose vessels, container ships, bulk carriers, tankers, dredgers, tugs, and passenger ferries, typically ranging from 1,000 dwt to 20,000 dwt (BIDA Website).

Provisional data from the Export Promotion Bureau (EPB Website) indicate that exports of ships, boats, and floating structures totaled USD 5.33 million for the fiscal year 2022-2023. The target for 2023-2024 has been set at USD 6.00 million, signaling growth expectations in the maritime export sector. The industry benefits from low labor costs, a skilled workforce, and a strategic position along major shipping route. Bangladesh's workforce is not only professional but also willing to work for wages lower than those in other countries. For instance, a study by Zakaria, Iqbal, and Hossain (2010) highlighted that, in 2010, shipyard workers in the United States earned about $18 per hour, while their counterparts in countries like China, Italy, and South Korea, earned around $5, $8, and $16 per hour, respectively. Japanese workers had the highest rate at $25 per hour. In comparison, the average labor wage in Bangladesh for 2010, was collected from field data.

Zakaria, Ali, and Hossain (Zakaria et al., 2011) explained in their research paper that Bangladesh offered a competitive advantage due to its lower cost of human inputs and average labor rate. The competitive price advantage may play a significant role in the lifecycle development of the shipbuilding industry as per historical trends; hence it was anticipated that the possibility of phasing in the shipbuilding industry in the foreseeable future in South Asian region including Bangladesh was found very bright.

The shipbuilding industry falls under the industrial sector consisting of various industries, including steel, machinery manufacturing, electrical-electronics, paint, and rubber plastics, ensuring a systematic and scientifically disciplined process in shipyards, with the ship being the product of this industry (Storch et al., 1988). However, the shipbuilding process involves various risks and dangers while building a ship in a yard. The use of heavy machinery, cranes, and other equipment may pose significant risks of accidents, such as crushing injuries, falls, and being struck by objects. Working in confined spaces like tanks and hulls may lead to suffocation, poisoning from fumes, or difficulty in evacuation during emergencies. Shipbuilding workers may frequently be exposed to hazardous materials, including paints, solvents, welding fumes, and even asbestos, which can lead to long-term health issues such as respiratory diseases and cancer. Also, the presence of flammable materials and the use of welding and cutting equipment increase the risk of fires and explosions. Shipyards often have multiple levels and scaffolding, leading to a high risk of falls from heights, which can cause serious injuries or fatalities. Manual handling of heavy materials and components can cause musculoskeletal injuries, such as back injuries and repetitive strain injuries. Prolonged exposure to high levels of noise and vibration from tools and machinery can result in hearing loss and other related health issues. Exposure to chemicals used in shipbuilding, such as solvents and cleaning agents, can cause skin irritation, respiratory problems, and other health issues. The use of electrical gears and welding equipment can lead to electrical shocks and burns. Due to these numerous risks, stringent safety protocols, personal protective equipment (PPE), and regular training are essential to mitigate hazards and protect workers in the shipbuilding industry.

Furthermore, shipbuilding can pose various health risks to workers due to exposure to hazardous materials, physical strain, and environmental factors. Long-term exposure to welding fumes, paint fumes, and other airborne contaminants may cause Chronic Obstructive Pulmonary Disease (COPD), silicosis may be caused by inhaling silica dust during sandblasting operations, contact with hazardous chemicals, solvents, and oils can lead to skin irritation and allergic reactions, Chemical burns resulting from direct contact with corrosive substances, musculoskeletal disorders/ back injuries may be caused by heavy lifting, awkward postures, and repetitive movements., noise-induced hearing loss (NIHL) may result from exposure to high noise levels from machinery, tools, and shipbuilding operations. The portal crane is essential for shipbuilding due to its high lifting capacity and efficiency, making it a critical tool in the industry.

It is widely acknowledged that Bangladesh has a high chance of succeeding as a shipbuilding nation. One of the major problems that was faced by the shipyard for exporting ships was delay in delivery (Zakaria, 2012). There may be various reasons for this delay in delivery, such as lower productivity and frequent disturbance of production due to worker injuries, etc. For example, Irene and Michael (2015) reported a significant number of worker injuries in local export-oriented shipyards and highlighted the benefit of adopting Occupational Health and Safety measures for shipyards.

Therefore, identifying risks in shipbuilding in Bangladesh is crucial for ensuring worker safety and minimizing accidents as well as maintaining a healthy working environment. However, addressing these occupational risks requires a comprehensive safety management system, including regular risk assessments, safety training, use of personal protective equipment (PPE), and implementation of safe work practices.

This study aims to review the present scenario of occupational and health risk assessment and management practices within the Bangladeshi shipbuilding industry. To achieve this objective, the review will delve into:

- Research conducted in Bangladesh focusing on prevalent hazards encountered by shipyard workers encompassing physical, chemical, and biological dangers with their management.
- Examining established methods in the global and local shipbuilding sector by analyzing frameworks and tools used to identify, categorize, evaluate, and manage potential hazards.
- Finding gaps in research and suggesting future direction of research for shipbuilding in Bangladesh.

2. METHODOLOGY

This study has been conducted using a systematic review of local and global shipbuilding with a focus on the assessment and management of occupational and health risks in the shipbuilding sector. For carrying out the systematic literature review, a scoping review approach has been used. A set of keywords were put in specifically to carry out the systematic review. The search strategy included the ScienceDirect and ResearchGate databases. The search terms included the terms, “Shipbuilding”, “Hazards”, “Safety”, “Accidents”, “Occupational Accidents”, and "risk assessment". The period for searching the research article was mostly considered from 2010 to Sept 2024.

Research papers were included in the review if they met the following criteria:

- Focus on occupational and health risks specifically within the shipbuilding sector.
- Present empirical research findings, including quantitative, qualitative, or mixed-methods studies, reviews, and meta-analyses.
- Publication in peer-reviewed journals, conference proceedings, or reputable academic sources.

It is to be mentioned that despite efforts to conduct a comprehensive search, some relevant studies may have been

inadvertently omitted from the review as the search strategy primarily focused on English-language publications, which may have resulted in the exclusion of relevant research published in other languages. Moreover, considering the dynamic nature of the shipbuilding industry, the literature review has more papers on countries such as Turkey, Indonesia, Singapore, and Korea.

3. OVERVIEW OF OCCUPATIONAL AND HEALTH RISKS IN SHIPBUILDING INDUSTRY

In the shipbuilding process, various activities expose workers to a multitude of occupational and health hazards which have the potential to harm them and the risk may be calculated when the likelihood of a hazard causing harm is known. A breakdown of the key hazards in the shipbuilding industry in Bangladesh is given in Table 1.

Table 1: Key Hazards in the Shipbuilding Industry

Key factors	Hazards
Physical Hazards	• Cuts, lacerations, and punctures: From sharp edges, tools, falling objects, and improper handling of heavy materials. • Crush injuries and amputations: From machinery entanglement, falling objects, and improper use of lifting equipment. • Burns: From welding, cutting, grinding, hot surfaces, and chemical exposure. • Slips, trips, and falls: Due to uneven surfaces, clutter, improper lighting, and loose materials. • Electrical shock: From faulty equipment, improper grounding, and working with live wires.
Health Hazards	• Respiratory problems: From exposure to dust, fumes, chemicals, paints, solvents, and welding gases. • Skin irritation and burns: From chemicals, paints, solvents, and lubricants. • Hearing loss: From loud machinery, noise from cutting, grinding, and hammering. • Eye injuries: From flying debris, sparks, UV radiation, and chemical splashes. • Musculoskeletal disorders: From heavy lifting, awkward postures, and repetitive motions. • Poisoning: From lead paint, exposure to chemicals, and gas leaks. • Drowning and hypothermia: During launching, undocking, and working near water.
Environmental Hazards	• Air pollution: From dust, emissions from machinery, and paint fumes. • Water pollution: From spills, leaks, improper waste disposal, and contaminated runoff. • Soil pollution: From spills, leaks, and improper waste disposal.
Additional Hazards	• Fire and explosions: Flammable materials, improper storage of chemicals and gas cylinders, and welding sparks. • Falling objects: From improper securing of loads, working at heights, and material handling.

4. RESEARCH LANDSCAPE OF BANGLADESH ON OCCUPATIONAL HEALTH AND SAFETY

Research conducted in Bangladesh itself is crucial for addressing the specific challenges and needs of the shipbuilding sector in the country. Although the volume of research focusing on health and safety issues may be comparatively less, it is valuable in providing insights into the unique circumstances and context of Bangladesh's shipbuilding industry.

Iqbal, Zakaria, and Hossain (Iqbal et al., 2010) conducted research on shipbuilding issues in Bangladesh and analyzed obstacles to industry development. The research highlighted problems in shipyards and discussed the impact of the economic recession on Bangladeshi shipbuilding and global market trends. The authors also addressed management, human resource, and quality control challenges in shipyards while describing Bangladesh's shipbuilding history, international exposure, and shipyard capabilities. The paper highlighted that the safety, health, and environmental (SHE) aspects of shipbuilding materials in shipyards are overlooked, with only a few shipyards being aware of these issues as they are focusing on technology, financing, and marketing, but not the long-term effects. Proper awareness, training, and government regulations are needed to improve SHE aspects, especially in Bangladesh's export-oriented shipbuilding industry. Environmental issues, such as pollution from shot blasting, plate preparation, welding, and painting, were identified as a major concern.

Islam and Fatema (2015) focused on shipyard working conditions from a sample of 187 workers from the Meghnaghat and Keranigonj areas. It was found that a significant number of workers in shipbuilding companies suffer from Myopia, with painters being the most affected. Additionally, many workers experience Body aches and Back Pain. Only a small portion of workers report Irritation in the Eye Site and Bronchitis respectively. The survey also revealed that a notable number had experienced accidents while working in the shipyard. The percentage of different consequences of problems for workers is shown in Figure 1. This study signifies that it is of paramount importance to comprehensively evaluate these hazards along with giving expectations of the workers of shipyards shown in Figure 2, and develop an understanding of the challenges faced by the shipbuilding sector in Bangladesh.

A study conducted by Irene and Michael (2015) provided a Cost-benefit Analysis of occupational health and safety interventions and evaluated the Occupational Health and Safety (OHS) measures and certification in Bangladesh one shipbuilding company named Western Marine Shipyard Ltd. (WMShL). It aimed to fill a gap in the scientific literature by evaluating how and if OHS measures and international OHS certification processes benefit those involved in the construction and shipping industries in economically developing countries. This study was claimed as the first to quantify OHS costs in Bangladesh and one of the few studies to investigate the bottom-line costs and benefits of OHS measures in

countries. The shipyard implemented OHS measures, including comprehensive PPE, employee training, and the establishment of the PHCC, resulting in a significant reduction in worker injury rates from over 500 to nearly zero within a few months as shown in Figure 3. These measures have had a lasting impact on employee and contractor safety, resulting in cost savings and potential damage to equipment and property shown in Figure 4.

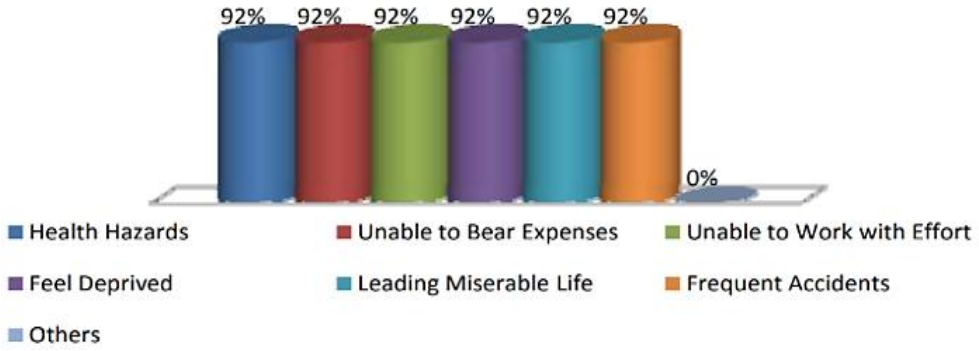

Figure 1: Consequences of Problems for Workers (Islam and Fatema, 2015)

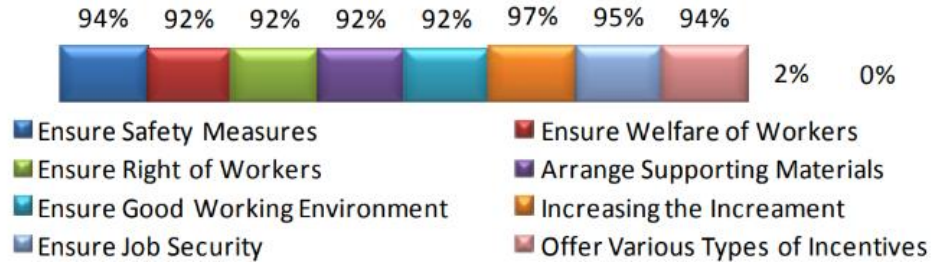

Figure 2: Expectations of The Workers of Shipyards (Islam and Fatema, 2015)

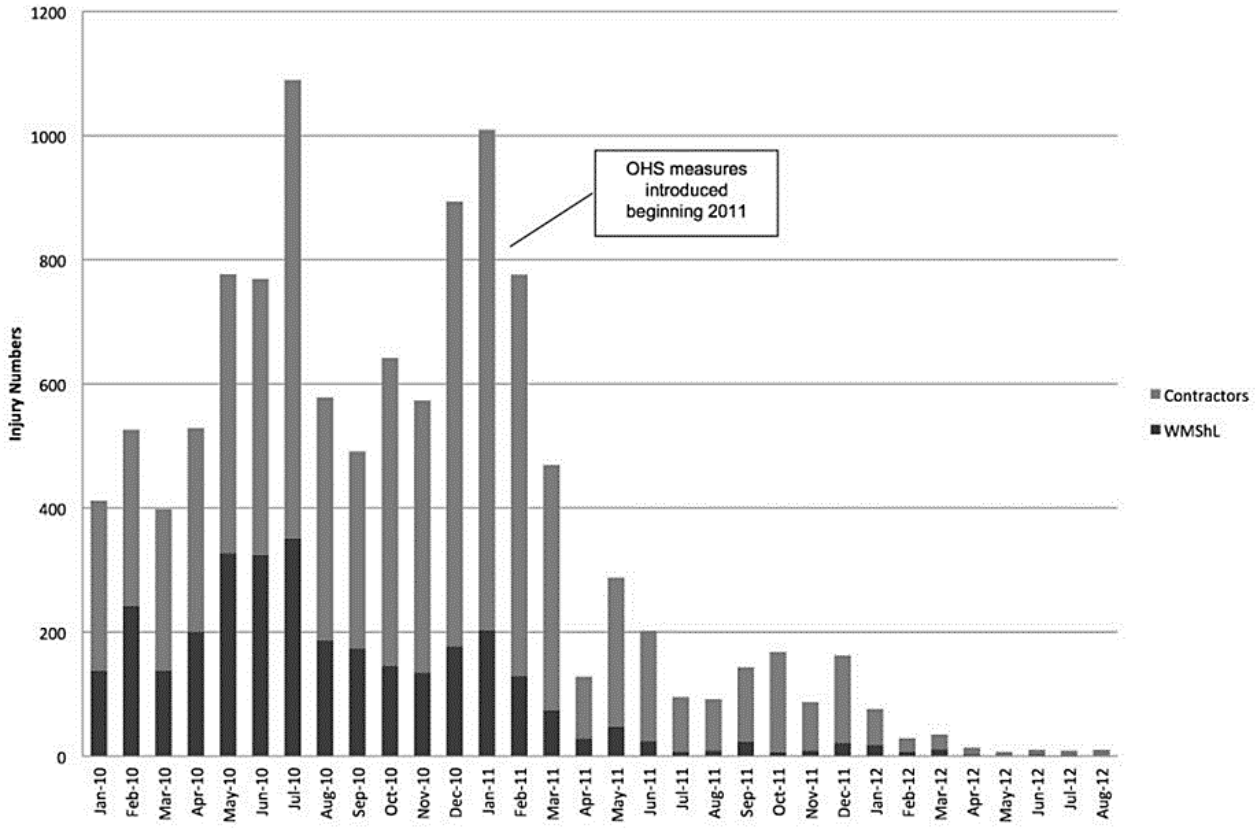

Figure 3: Total injuries per month at WMShL January 2010–August 2012 (source: WMShL 2012) (Irene and Michael, 2015)

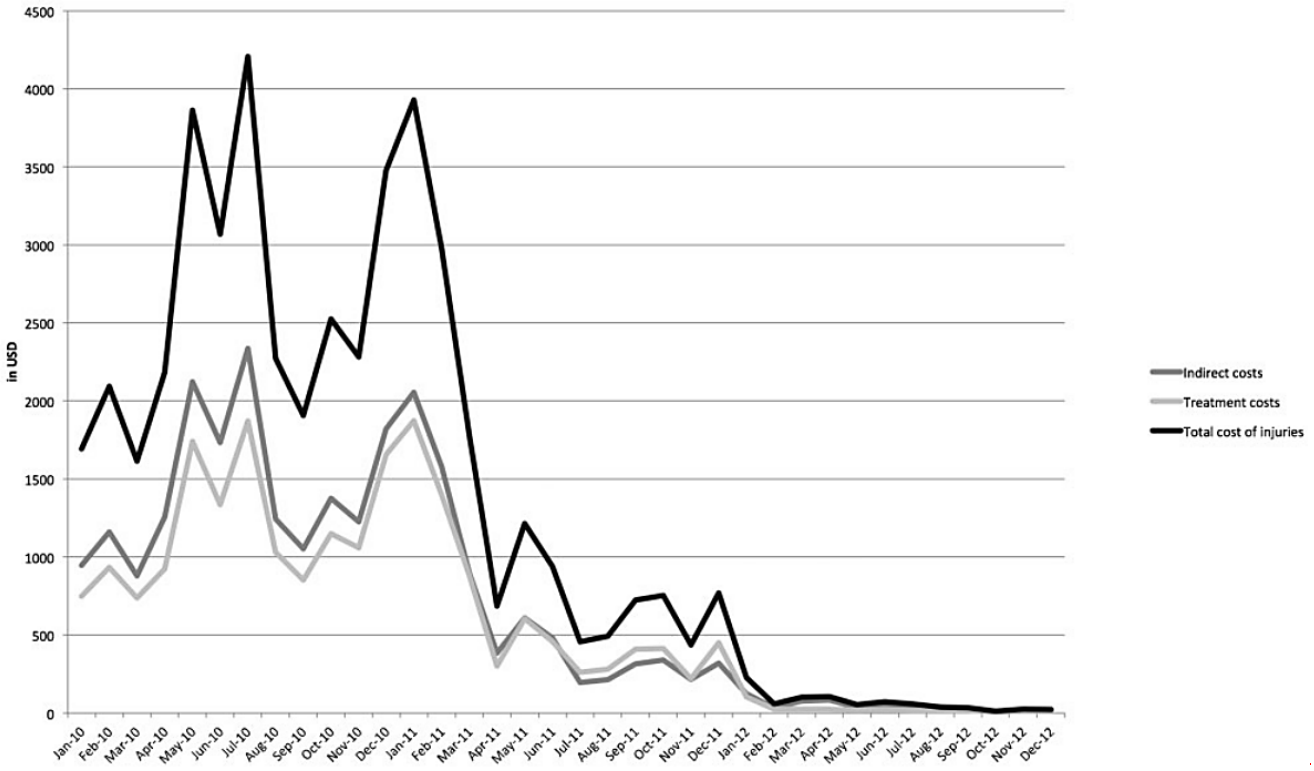

Figure 4: Total monthly worker injury treatment costs at WMShL, January 2010–November 2012 (USD) (Irene and Michael, 2015).

The study by Zahan Tasnima (2016) discussed the shipbuilding industry in Bangladesh, emphasizing the need to address worker safety, health, and environmental factors in the shipbuilding industry through design and awareness.

Another study by Hossain, Nur, and Jaradat (Hossain et al., 2016) identified and evaluated workplace hazards in the shipbuilding industry and developed a Preliminary Hazard Analysis (PHA) and hazard evaluation worksheet for risk control and mitigation. The study was based on limited data using a semi-quantitative analysis and did not clarify the relationship of shipbuilding process flow with the hazards.

Parveen and Kabir (Parveen and Kabir, 2021) in their research paper investigated the shipbuilding industry in Bangladesh for economic growth potentials and challenges and highlighted the industry advantages, challenges, and recommendations for stakeholders.

A study by Haq (2022) examined determinants of occupational hazards in the shipbuilding industry using Descriptive statistics and a Multiple regression model giving significance to Personal protective equipment and health status to reduce hazards. However, the study was based on limited data from one shipyard.

A study by Haldar, Mehtaj, and Zakaria (Halder et al., 2023) focused on the SWOT analysis to identify prospects and challenges in the shipbuilding industry of Bangladesh, assessed for IR4.0 adoption resulting in scopes and obstacles of implementing IR 4.0 technologies and strategies to overcome hindrances in the shipbuilding industry.

5. REVIEW OF INTERNATIONAL RESEARCH STUDIES

The influence of global research in the shipbuilding sector has enhanced the sector's information base, encouraged the trade of best practices, and contributed to the worldwide discussion on upgrading security, natural supportability, and innovative headway.

The potential respiratory hazards associated with welding and flame-cutting processes carried out in shipyards possess severity of the health risks highlighted by Steel J, (1968). Studies concerning the health and safety concerns of shipyard employees have grown significantly in the last few years. While some research (Coggon & Palmer, 2016; Selikoff & Hammond, 1980; Kilburn, Warshaw & Thornton, 1985) examined the negative effects of process outcomes (asbestos, fumes, sparks) on the health of shipyard workers, other studies (Cherniack, Brammer, Lundstrom, Meyer, Morse, Nealy, & Fu 2004; Gillibrand, Ntani & Coggon, 2016; Malharbe & Mandin, 2007) concentrated on the effects of environmental factors (vibration, noise, dust and VOC) on the workers in shipyards.

More research highlighted that common causes of occupational accidents are high elevation, toxic, flammable, and explosive materials, fire, moving machinery, dangerous gases, work on/close to haphazard established heavy structures, misuse or failure of equipment, poor ergonomics, untidiness, poor illumination, exposure to general hazards including electricity, and inadequate protective clothing (Krstev et al., 2007; Barlas, 2012).

Additionally, Shin In Jae, (2013) analyzed that subcontracting in the shipbuilding industry is highly

hazardous, and Risk assessment is needed to prevent accidents.

Lokhande's (Lokhande, 2014) research concentrated on the health profile of workers in the shipbuilding sector, which involved numerous risky activities such as working at heights and being exposed to chemicals and metal exhausts. The study was carried out on 100 randomly selected workers in a shipbuilding yard in Mumbai. The research revealed that 7% of workers sustained fractures from workplace accidents that necessitated hospitalization. Most of these injuries involved forearm fractures, while others included fractures of the ribs, spine, or metatarsal bones. Around 25% of welders reported suffering burn injuries from welding activities, and 5% experienced asthma linked to their work. Similarly, 5% of painters dealt with skin reactions resulting from paint exposure. Additionally, one worker had a previous case of hearing loss. Dermatitis was observed in 25% of fabricators, 5% of painters, and 3% of electricians, while bronchospasm affected 11% of painters and 13% of welders. The Personal Protective Equipment (PPE) used among various worker groups is shown in Figure 5, and the prevalence rates of hypertension among workers are shown in Figure 6.

Several descriptive and analytical methods, including statistical techniques and regression analysis, have been used to study and categorize occupational injuries. Numerous studies focus on detailing the patterns of injuries, such as incidence rates, frequency, and distribution, based on factors like individual characteristics, location, and workplace conditions. These insights help in identifying high-risk industries, job roles, and hazardous work environments (Yorio and Wachter, 2014; Salminen, 2005; Seokho et al., 2013; Trontin and Bejean, 2004).

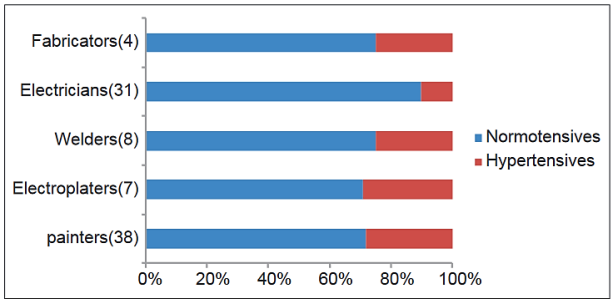

Figure 5: Relevant Personal Protective Equipment (PPE) used among various worker groups (Lokhande, 2014).

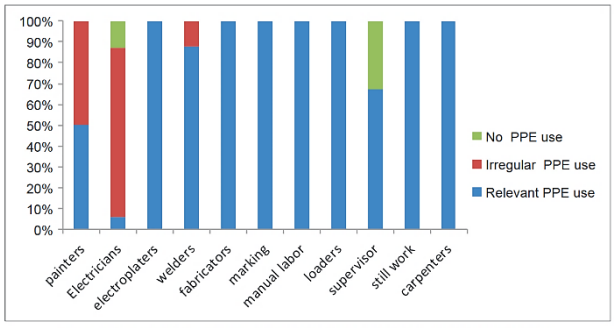

Figure 6: Prevalence rates of Hypertension among various worker groups (Lokhande, 2014).

A study by Tsoukalas and Fragiadakis (Tsoukalas and Fragiadakis, 2016) identified key risk factors for occupational accidents in the shipbuilding industry, including carelessness, inadequate training, and hazardous working conditions. The study employed a multivariable linear regression (MVLR) model combined with genetic algorithms (GA) to optimize occupational risk parameters by accumulating data from 294 occupational accident reports, focusing on various parameters such as worker specialty, type of incident, and injury severity.

A study by Huang, Tong, Ren, and Ouyang (Huang et al., 2021) used Fault tree analysis as the primary method for identifying hazards in portal cranes, based on expert consultations and iterative exploration. The analysis identified both direct causes of accidents and potential underlying causes including human, machine, management, environment, and use, allowing for a comprehensive understanding of safety hazards.

The shipbuilding industry has hazardous working conditions and materials affecting the respiratory system and worker mortality. Hazard risk management by Ibrahim and Aris, (2022) in the Phinisi shipbuilding process identified the physical, chemical, mechanical, and physiological hazards using the Hazop approach recommending occupational safety measures in the shipbuilding industry. The paper discussed the need for planning and risk assessment models for component availability in shipbuilding in Indonesia.

A study by Sari, Ilasabilirrosyad, Tanjov, and Rahayu (Sari et al., 2023) aimed to provide insights for creating a safer work environment at PT Blambangan Bahari Shipyard to ultimately enhance productivity and worker health by employing interviews to identify hazards at various stages of shipbuilding, utilizing the Hazard and Operability Study (HAZOP) method for systematic risk analysis. The study highlighted the significant risks to workers, including mold creation, coating and gel coat application, and lamination. The study emphasizes the need for strict safety protocols and the mandatory use of personal protective equipment.

FMEA (Failure Modes and Effects Analysis), a widely embraced method for risk analysis, finds extensive application in the global realm of shipbuilding risk assessment. Numerous authors have employed this method to delve into various aspects of risk analysis. Burak Efe (Efe, 2019) proposed a novel risk assessment approach using intuitionistic fuzzy numbers-based quality function deployment (QFD) and VIKOR approach and examined occupational accident-related failure modes in shipbuilding. This study aimed to examine the relationship between occupational accidents (OA) and FM in shipbuilding.

Liu, Guo, and Zhang (Liu et al., 2019) proposed an improved FMEA method using fuzzy logic and DEMATEL theory to enhance reliability and prioritize risk levels for shipboard-integrated electric propulsion systems, aiding in accident prevention in shipbuilding.

Shi, Wang, Li, and Liu (Shi et al., 2020) proposed a novel FMEA method using fuzzy evidential reasoning and fuzzy Petri nets to enhance risk assessment in ship fire-safety systems, improving the reliability of failure mode ranking.

This method improved traditional FMEA by addressing deficiencies in assessment and weighting.

The paper by Ariany, Pitana, and Vanany (Ariany et al., 2022) proposed the use of the Failure Mode and Effect Analysis (FMEA) and Bayesian Network (BN) approaches for risk assessment and evaluation in the procurement of shipbuilding materials. The study also discussed the risk management in the shipbuilding process thus reviewing methods for risk assessment in shipbuilding.

Shi, Hu, and Yan (Shi et al., 2023) proposed a new FMEA method using the probabilistic linguistic best-worst method and TOPSIS applied to a marine diesel fuel injection system. This method enhances risk analysis in shipbuilding and helps identify critical failures.

Doganay, Çaşoğlu, and Güler (Doganay et al., 2023) identified bunkering operation hazards using FMEA and conducted Hazard identification for operational risk reduction.

Researchers, Rakhman and Naufal, (2023) at Daehan Shipbuilding Company used FMEA to identify and analyze work accidents. The research calculated the Risk Priority Number (RPN) for each accident form, with pinched accidents having the highest RPN. The critical value suggests that pinched, fall from height, and slipped work accidents should be promptly addressed and identified through Job Safety Analysis for improved accident prevention.

Numerous studies have been conducted in shipyards across Turkey. A study conducted by Celebi, Ekinci, Alarcin, and Unsalan (Celebi et al., 2010) in the aspect of Turkey Investigated the shipbuilding industry processes and waste and analyzed accidents and illnesses in Turkish shipyards. The research emphasized that prolonged exposure to base metal fumes, volatile organic compounds (VOCs), and the considerable generation of NOx gases during welding and cutting activities can lead to serious and long-lasting health problems.

Seker, Recal, and Basligil (Seker et al., 2017) used a combined DEMATEL and grey system theory approach to analyze occupational risks in the Turkish shipbuilding industry, aiming to prevent fatal accidents and enhance safety measures.

Izci, Gökyay, and Barlas (Izci et al., 2024) identified common risk factors in non-fatal occupational accidents in Turkish shipyards, emphasizing inadequate safety equipment, improper tool use, and non-compliance. This study used the Analytical Hierarchy Process (AHP) method to prioritize preventive measures for the shipbuilding industry. Additionally, several other studies explored similar topics such as studies by Yilmaz et al., (2017), Menteşe et al., (2017), Acuner et al., (2016), Aydin et al., (2015), Barhad et al., (1975), Buerke et al., (2002) and so on.

6. GAP ANALYSIS

The shipbuilding sector's occupational and health risks have been assessed based on the research studies conducted at both international and local (Bangladesh-centric) levels.

The analysis of the reviewed papers shown in Figure 7 indicates a diverse range of focus areas within the shipbuilding sector. Specifically, 9.09% of the research papers concentrated on hazards inherent to shipbuilding, highlighting the various risks and dangerous conditions workers may encounter. A significant portion, 25.00%, was dedicated to examining occupational risks, emphasizing the broad spectrum of dangers associated with the working environment and practices in the industry. Meanwhile, 29.55% of the studies addressed the health and safety of workers, exploring both the physical and mental well-being of those employed in shipbuilding. Additionally, 25.00% of the papers focused on shipbuilding in general, covering aspects such as industry trends, technological advancements, and economic impacts. Finally, 11.36% of the research investigated accidents during shipbuilding, offering insights into the frequency, causes, and consequences of such incidents within the sector. Although the analysis of the review papers showed a diverse range of focus areas, only few is found relevant to the Bangladeshi shipbuilding industry. This highlights a gap in the literature and suggests a need for more studies specifically targeting the conditions and challenges in Bangladeshi shipbuilding.

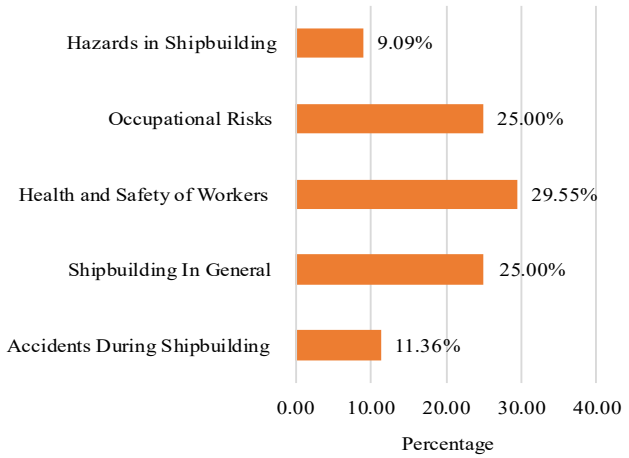

Figure 7: Representation of the Distribution of Research Focus Areas in the Shipbuilding Sector.

The comparison and contrast findings from research conducted in Bangladesh with those from international studies and identification of common trends, gaps, and areas of divergence have been summarized and shown in Table 2. From Table 2, it is found that there are noticeable gaps in the adoption of advanced risk assessment methodologies and global best practices with no comprehensive management guides or scholarly papers that cover the entire process of risk assessment in Bangladesh-centric research. As the shipbuilding industry in Bangladesh is expanding rapidly, it's important to address and manage the hazards to ensure the safety and health of workers.

7. RECOMMENDATIONS AND ACTION PLAN

The authors propose some risk control measures tailored to the findings of the risk assessment and develops a comprehensive action plan for shipyards. By addressing the

critical hazards identified in Bangladeshi shipyards, the measures and action plans aim to enhance occupational health and safety practices. Below is a detailed outline of the management strategies, emphasizing practical implementation for risk reduction and fostering a culture of safety.

Table 2: Comparison of the literatures reviewed

	International Research Studies	Dynamic Research Landscape of Bangladesh
Methodologies Employed	• International studies primarily utilize advanced risk assessment methodologies such as Failure Mode and Effect Analysis (FMEA) and its variants like fuzzy logic, Bayesian Network (BN) approaches, and intuitionistic fuzzy numbers-based approaches.	• Research in Bangladesh predominantly utilizes descriptive statistics, thematic mapping, participatory appraisal, Preliminary Hazard Analysis (PHA) and SWOT analysis. Also, the research is based on limited no. of data without following comprehensive approach.
Focus Areas	• These studies extensively cover various aspects of risks in shipbuilding, including machinery failures, operational hazards, occupational accidents, and environmental impacts.	• Studies in Bangladesh primarily focus on identifying determinants of occupational hazards, evaluating workplace hazards.
Key Findings	• International research emphasizes the importance of advanced risk assessment methods to identify critical failures, enhance reliability, prioritize risk levels, and prevent accidents effectively. • Additionally, these studies highlight the significance of global collaboration and knowledge exchange in improving safety practices and technological advancements in the shipbuilding sector.	• Bangladesh-centric research highlights the specific challenges and needs of the shipbuilding industry in the country, including inadequate safety measures, healthcare facilities, occupational hazards, and workplace accidents. • Performing comprehensive risk analysis studies in Bangladesh, especially in shipbuilding is rarely found due to various factors, including limited resources, expertise, and data availability. No study is found where relationship is established between ship building process flow and hazard identification which are inherent in different methods practiced in shipbuilding industry in Bangladesh.

7.1. Proposed Risk Control Measures

- Welding and Gas Cutting Hazards
  - Dedicated gas storage areas with enhanced fire prevention systems.
  - Worker's biannual training in fire safety and gas leak protocols.
  - Mandatory use of flame-retardant PPE.
  - Isolated welding zones with barriers to minimize risks.
- Heavy Material Handling and Storage
  - Equipping stability locks in handling zones with forklifts.
  - Implementing guidelines for stacking height and stability checks.
  - Segregating pedestrian and machinery pathways.
  - Installing anti-slip flooring and enhance area lighting.
- Confined Space Entry Hazards
  - Introducing confined space entry permits and supervision protocols.
  - Providing portable gas detectors and oxygen meters.
  - Ventilating spaces thoroughly before entry.
  - Equipping workers with two-way radios for emergency communication.
- Block Erection and Heavy Equipment Hazards
  - Mandating operator certification and regular competency tests.
  - Using load-bearing monitors for structural stability checks.
  - Defining clear zones around block erection sites for unauthorized personnel.
- Noise, Vibration, and Ergonomic Hazards
  - Providing hearing protection and rotate tasks to minimize exposure.
  - Offering ergonomic tools and adjustable workstations.
  - Conducting regular health checks for hearing and musculoskeletal issues.

7.2. Development of a Comprehensive Action Plan

The action plan ensures a phased approach to implementing risk management practices, categorized into immediate, urgent, and medium-term actions.

- Immediate Actions (0–6 Months)
  - Distributing specialized PPE for welding and confined space tasks.
  - Installing fire suppression systems and leak detectors.
  - Conducting mandatory training on safety protocols.
- Urgent Actions (6–12 Months)
  - Scheduling biannual safety inspections.
  - Initiating routine noise and vibration assessments.
  - Establishing a maintenance log for heavy machinery.
- Medium-Term Actions (12–24 Months)
  - Investing in digital monitoring systems for confined spaces.
  - Forming a safety oversight committee to continuously update practices.

- Upgrading facilities, including structural reinforcements and soundproofing.

7.3. Implementation Strategies for Safety Management Teams

- Assigning officers to monitor compliance, conduct spot checks, and maintain safety logs.
- Creating anonymous reporting channels and encouraging active feedback from workers.
- Fostering a proactive safety culture through rewards for exemplary practices.
- Simulating emergencies, such as gas leaks or fires, to prepare workers for real-life scenarios.
- Conducting biannual audits by third-party consultants to incorporate global best practices.

8. FUTURE RESEARCH DIRECTION

Based on the gaps and unresolved questions identified in the reviewed literature, as well as opportunities for advancing knowledge and improving risk assessment and management practices, the following areas for future research are suggested:

- Conducting in-depth studies using advanced techniques on human factors and ergonomics in shipyard operations, focusing on aspects such as worker behavior, workload management, fatigue, and cognitive workload.
- Exploring the implementation of proactive health surveillance programs to monitor and manage occupational health risks among shipyard workers.
- Conducting comparative analysis of regulatory frameworks and policy interventions in different countries to identify best practices, regulatory gaps, and areas for harmonization.
- Integration of Advanced Technologies such as artificial intelligence, Internet of Things (IoT), and predictive analytics into risk assessment and management processes in the shipbuilding sector.
- Incorporating global practices in the shipbuilding sector to address emerging challenges, leverage technological advancements, and promote interdisciplinary collaboration to foster a safer, healthier, and more sustainable working environment for shipyard workers which will ensure higher productivity and the long-term viability of the industry.

9. CONCLUSION

The shipbuilding industry in Bangladesh has witnessed remarkable growth in recent years, establishing itself as a significant player in the global market. This growth is attributed to various factors such as competitive labour costs, a skilled workforce, and a strategic location. This review paper has comprehensively studied shipbuilding practices, particularly in Bangladeshi facilities, focusing on the critical perspectives of occupational safety and health risks assessment with management. The following conclusions can be drawn from the study.

- The shipbuilding industry in Bangladesh encompasses a wide range of hazards including chemical, physical, and safety concerns, and hence it necessitates effective risk assessment and management practices to ensure a safe working environment for the sustainability of the industry.
- While the industry experiences rapid growth, the research gap analysis suggests a critical gap in risk assessment practices in Bangladesh. This highlights the need for more advanced studies specifically targeting the conditions and mitigating the challenges in terms of Occupational Health and Safety risks in Bangladeshi shipbuilding.
- Also, studies have highlighted the high incidence of occupational hazards among shipyard workers, including respiratory issues, musculoskeletal injuries, and accidents. This needs a more comprehensive approach to risk assessment in Bangladeshi shipyards.

By prioritizing research, implementing robust risk management strategies, and fostering a culture of safety and collaboration, a safer and healthier working environment for shipyard workers can be ensured which will contribute to the long-term sustainability of the shipbuilding industry in Bangladesh.

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AUTHOR DECLARATION

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