Proceedings of the American Society for Engineering Management 2016 International Annual Conference
S. Long, E-H. Ng, C. Downing, & B. Nepal eds.

AN ANALYTICAL STUDY OF HAZARDS AND RISKS IN THE SHIPBUILDING INDUSTRY

Niamat Ullah Ibne Hossain*, Ph.D. Student
Farjana Nur, Ph.D. Student
Raed M. Jaradat, Ph.D.
Mississippi State University

*** Email address: ni78@msstate.edu**

Abstract
The shipbuilding industry is one of the heavy production industries, and because of the kinds of materials, equipment, actions, processes, and conditions shipbuilding involves, there is a heightened probability for the occurrence of accidents. Shipbuilding is associated with numerous risks and hazardous wastes that have the potential to negatively affect environmental safety and health. The purpose of this paper is to identify and evaluate workplace hazards in the shipbuilding industry using Khulna Shipyard as a case study. Khulna Shipyard, located in Bangladesh, is considered as a heavy ship construction and repair yard. In an effort to improve the decision making process relevant to risk control and mitigation, a Preliminary Hazard Analysis (PHA) will be used to develop an initial listing of potential hazards and hazardous events that affect workers' health and safety. Following the initial listing of the hazards, the paper presents a hazard evaluation worksheet (PHA worksheet), based on a systematic approach, which is designed to help the shipyard take corrective actions.

Keywords
Hazard Evaluation Checklist, PHA Worksheet, Risk Score, Workers, and Safety Issue

Introduction
Bangladesh is a well-known maritime nation, entitled to 12 nautical miles of territorial sea and 700 rivers that flow from the adjacent countries constituting inland waterways of 15000 miles. Due to congenial topographical position, water transports play a significant role for Bangladeshi trade and commerce. According to present statistics, more than 10,000 inland and coastal ships have been plying all over the country, which transport around 90% of total oil product, 70% of cargo and 35% of passengers (Iqbal, Zakaria & Hossain, 2011). Owing to favorable facilities, all inland ships are manufactured and renovated in local shipyards. For instance, local shipyards can design and manufacture ship up to 3500 deadweight (DWT) that fulfill the demand of local market and lately, few local shipyards achieved the competence to fabricate the ships of 10000 DWT (Iqbal, Zakaria & Hossain, 2011). Bangladesh also exporting ships to Denmark, Mozambique, Germany, the Netherlands and Finland for more than a decade and in 2008, was declared to be a shipbuilding nation with high international standards. With more than 200 shipyards & marine workshops in Bangladesh, a large workforce is required to work in production areas under difficult conditions while handling hazardous materials. Most of these production areas, which include welding, painting, blasting, and fiberglass production have a direct effect on workers' health. For example, exposure to volatile organic compounds (VOCs) and fumes generating from burning base metal, as well as a substantial generation of NO_x gases during the welding and cutting processes can cause severe and chronic health problems (Celebi & Alarcin, 2010)**.** In recent years, research pertaining to health and safety issues of shipyard workers has been flourished. While some studies (Coggon & Palmer, 2016; Selikoff & Hammond, 1978; Kilburn, Warshaw & Thorton, 1985) were conducted on how process outcomes (fumes, spark, asbestos) adversely impact on the health of the shipyard workers, others (Cherniack, Brammer, Lundstrom, Meyer, Morse, Nealy, & Fu 2004; Gillibrand, Ntani & Coggon, 2016; Malharbe & Mandin, 2007) focused on the consequences of environmental factors (dust, noise, vibration, VOC) on the shipyard workforce.

The shipyard environment demands constant caution to control or mitigate the hazards inherent in the production processes. Thus, it is necessary to identify and manage any potential hazards, hazardous situations using

risk analysis tools and techniques. Using preliminary hazard analysis, a checklist of conceivable hazards, and hazardous situations, related to Khulna Shipyard were identified. The data collected for analysis was generated through interviews and a survey. Preliminary hazard analysis (PHA) is a semi-quantitative analysis that is widely used to detect all potential hazards that may lead to an accident and prioritize them based on their severity and recommend the supplementary initiatives in order to alleviate the hazards (Rausand, 2004). PHA helps to generate a hazard log which assists the incessant observation of a hazard to ensure that it is under control or eliminated (Pinto, Magpili & Jaradat, 2015).

This paper is organized into three main sections that describe the methodology used. Following the introduction, section 2 examines the research methodology with a focus on the data collection procedure and the research instrument. Section 3 describes the steps taken to conduct the PHA. The paper concludes with results, recommendations, and preventive measures/mitigation in order to plummeting the risks associated with the production process at Khulna Shipyard.

Research Methodology

To assess and identify a list of common hazards and hazardous events for Khulna Shipyard, interview sessions were followed with a survey questionnaire containing demographical questions such as age, gender, occupation, and education level. Open ended questions were developed to collect data germane to hazardous situations at Khulna Shipyard. Besides the survey, focus group discussions were arranged to cross-check the data collected through the prescribed questionnaires. The following subsections describe the steps taken to build the research methodology.

Research Instrument and Data Collection

Prior to using the Preliminary Hazard Analysis, interview questions were prepared to determine the primary hazard types in Khulna Shipyard. After conducting the interviews, three main hazards were identified namely working conditions, physical hazards, and fire and explosion (see Exhibit 1). A survey was designed to measure the three main hazardous events which consists of two types of questions:

- Four open-ended questions that measure each hazard type including what sources cause the hazard(s), what are the consequences and what are the safeguards or suggestions to mitigate that particular hazard(s)
- A multiple choice question asking the frequency of that particular hazard weekly, monthly, or quarterly.

After obtaining the dataset, a preliminary hazard analysis worksheet was prepared to assess the three types of identified hazards and their corresponding accidents in the system. Results and recommendations are provided in the results section.

Sample Size and Technique

A total of 42 employees participated in the interview session. More than 115 employees, with different backgrounds and experience, participated in the survey to identify the list of conceivable hazards. After data collection, it was feed into a tabular format and then analyzed and categorized into subsections namely, causes of hazards, exposure, and frequency. After analyzing the dataset obtained from the survey, a list of hazards and potential accidents were identified. The study sample included employees from different categories, based on the industries hierarchical structure, such as (1) ship-in-charge, (2) yard supervisor, (3) foreman, (4) cutter, (5) fitter, (6) cutter helper, (7) fitter helper, (8) wire group personnel, (9) loader, and (10) cleaner. Participants within these categories were first interviewed and then considered for the survey questionnaire. It is important to note that other categories were not selected for the research study due to time and resources constraints.

Data Analysis and Results

Data analysis and results are discussed below:

Identifying Hazards and their Potential Causes

As mentioned earlier, three main types of hazards and their root causes were identified based on the results obtained from the questionnaire. Exhibit 1 below provides a tabulated summary of the types of hazards and their potential causes.

Exhibit 1. Hazard Identification Check-list.

Types of Hazards	**Potential Causes**
1. Working Conditions	1.1. Cramped spaces for working 1.2. Lack of comfortable environment 1.3. Excessive trip hazards and potential for falls 1.4. Gloomy and dirty work area
2.Physical Hazards: 2.1 Physical injury to limbs 2.2 Suffocation 2.3 Hearing problem (eardrum rupture etc.)	 2.1 Cramped spaces 2.2 Cramped spaces 2.3 -Working near abrasive blasting or jack hammer operations -Heavy equipment or machinery -Fuel-powered hand tools and power actuated tools -Compressed air
2.4 Extreme temperatures	2.4 -Slag, weld splatter, or sparks -Combustible material closer than thirty-five feet (10.7 m) to the hot work
2.5 Vibration	2.5 -Heavy equipment or machinery -Power actuated tools
2.6 Radiation	2.6 -X-ray machines and radioactive sources (radiography) used to test pipe welds, bore-holes
3. Fires and Explosions 3.1.Fire explosion	 3.1 - Generating excessive heat near lubricants or flammable materials -Naked flames -Lack of sufficient fire extinguishers -Lack of maintenance
3.2. Electrical explosion	3.2 - Improper maintenance of electrical machinery - Excessive heat generation
3.3.Short circuits	3.3 - Improper circuit design & maintenance
3.4. Electric shocks	3.4 - Lack of awareness while using electrical equipment or machines - Placing conducting materials near electric machines and circuits - Lack of personal protective equipment (PPE)
3.5. Burns	3.5 - Exposure to fire/ flame/ electric shocks

Preparation of the Hazard Evaluation Worksheet

After identifying the three main types of hazards, PHA was used to answer the following questions: what are the accidents and the possible causes of each type of hazard, what is the likelihood of a particular cause to trigger an accident, and what the severity of the consequences if the accident occurs. Exhibits 2 **(**Pinto, C., Magpili, L., & Jaradat, R., (2015) *Operational Risk Management*: Momentum Press, U.S. Pg.: 23) and Exhibit 3 **(**Ref: Pinto, C., Magpili, L., & Jaradat, R., (2015) 'Operational Risk Management' Momentum Press, U.S. Pg.: 22) respectively, present a likelihood and severity scales that have been used in PHA. The 8 columns in Exhibit 4 **(**Pinto, C., Magpili,

L., & Jaradat, R.,(2015) 'Operational Risk Management' Momentum Press, U.S. Pg:34) show in a tabular format the steps taken to conduct the PHA for Khulna Shipyard. Risk score, column 7, is calculated based on the likelihood information entered in column 5 and the severity information in column 6. Column 8 provides some control measures to address the hazards and their corresponding causes and consequences.

Exhibit 2. Likelihood Scale.

Likelihood of Cause	Criteria: Occurrence of Cause	Rating
Very Likely	Once per month or more often	5
Likely	Once per year	4
Moderately Possible	Once per 10 years	3
Unlikely	Once per 100 years	2
Very Unlikely	Once per 1000 years	1

Exhibit 3. Severity Scale.

Severity Class	Criteria: Occurrence of Cause	Rating
Catastrophic	Failure results in major injury or death	5
Significant	Failure results in minor injury	4
Major	Failure results in medium or high level of exposure but does not cause injury	3
Minor	Failure results in low-level exposure but does not cause injury	2
Negligible	Failure results in negligible exposure	1

Exhibit 4. Hazard Analysis Worksheet.

Preliminary Hazard Analysis (PHA) Worksheet							
Activity No	**Hazardous Events (Type of Hazard)**	**Accidents**	**Possible Causes**	**Likelihood (L)**	**Severity (S)**	**Risk Score (L*S)**	**Control Measures**
1	Type I: Poor working conditions	1. Damage to physical and mental health and discomfort leads to injury	1. - Cramped spaces for working - Lack of comfortable environment - Fumes from residual materials in tanks - Gloomy and dirty work area	4	4	**16**	
		2. Fire hazards	2. - Cramped spaces for working - Fumes from residual materials in tanks - Gloomy and dirty work area	3	5	**15**	1. Ventilation in confined spaces must be supplied mechanically. 2. Supplied-air respirators must be used. 3. Adequate source of lighting should be provided.
		3.Falls and slips	3. - Excessive source of falls	5	4	**20**	
		4. Long term diseases	4. - Gloomy and dirty work area - Extreme concentrations of fibers - Fumes	3	3	**09**	

2.1	Type II: Physical injury to limbs	Permanent disability	- Cramped spaces - Dangerous working environment	2	4	**08**	1.Ventilation in confined spaces must be supplied mechanically. 2. Supplied-air respirators must be used.
2.2	Suffocation, asphyxiation, pressure	Permanent disability and delayed effects	- Cramped spaces - Extreme concentrations of fibers - Welding in confined spaces can yield high concentrations of toxic airborne contaminants - Painting operation generates toxic fumes	5	4	**20**	1.Potentially dangerous spaces must be tested, inspected, and determined as safe for entry by a marine chemist, industrial hygienist, or other qualified person.
2.3	Hearing problem (eardrum rupture etc.)	1. Permanent disability 2.Damage to health	1. - Working near abrasive blasting or jack hammering operations - Working near heavy equipment or machinery - Working near fuel-powered hand tools and power actuated tools -Compressed air 2. All above causes (1)	3 4	4 2	**12** **08**	1. Proper ear protection should be taken.
2.4	Extreme temperatures	Burns	- Slag, weld splatter, or sparks - Combustible material closer than thirty-five feet to the hot work - Insufficient ventilation	3	4	**12**	1. Proper coolant, ventilation system should be used. 2.Workplace should be organized in such a way that it should keep combustive material apart from heat generating sources.
2.5	Vibration	Loss of concentration and musculoskeletal disorders	- Working with heavy equipment or machinery - Working with power actuated tools	2	2	**04**	1. Machinery should be provided with proper maintenance. 2. Hydraulic powered tools can be used.
2.6	Radiation	1. Permanent disability/ Irreversible disease 2.Include delayed effects	1. - X-ray machines and radioactive sources (radiography) used to test pipe welds, bore-holes - Toxic rays emitted during various operations 2. All above causes	3 2	4 2	**12** **04**	1. Radiation affected areas should be kept apart from work areas. 2. Safety sign should be used 3. PPE should be properly designed in case of those areas.
3.1	Type III: Fire explosion	1.Burns due to explosion 2.Death / catastrophe due to fire explosion	1. - Generating excessive heat near lubricant or flammable materials - Naked flames - Lack of sufficient fire extinguisher - Lack of maintenance 2. All above causes	4 4	4 5	**08** **20**	1. Keeping lubricant or flammable materials apart from excessive heat generating sources. 2. Naked flames should be in secured place. 3. Providing sufficient fire extinguisher. 4. Maintenance.

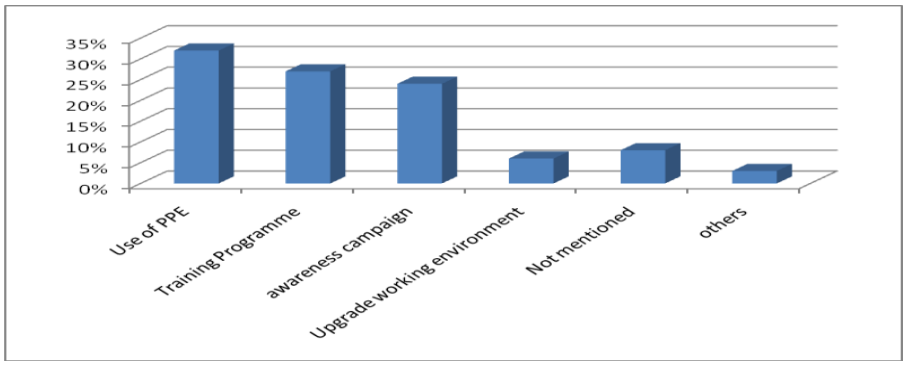
3.2	Electrical explosion	1.Burns/ shocks	1. - Improper maintenance of electrical machinery - Excessive heat generation	4	4	**16**	1. Maintenance of circuits and electrical equipment. 2. Providing sufficient fire extinguishers. 3. Using non conducting material in PPE. 4. Only skilled operators should be allowed.
		2.Death / catastrophe	2. All above causes	4	5	**20**	
3.3	Short circuits	Catastrophe	- Improper circuit design and maintenance	4	5	**20**	As activity 3.2
3.4	Electric shocks	1.Burns	1. -Lack of awareness -Placing conducting materials near the electricity driven machines and circuits -Lack of PPE	4	4	**16**	As activity 3.2
		2.Major and Minor shocks	2. All of the above	4	3	**12**	
		3.Death	3. All of the above	2	5	**10**	
3.5	Burns	Burns	- Exposure to fire/ flame/ electric shocks	4	4	**16**	As activity 3.1 & 3.2

Results, Risk Reduction Measures and Recommendations

Using a PHA technique, a total of 21 types of accidents are generated from Khulna Shipyard with risk scores ranging from 4 to 20. The results from the analysis illustrate that 15 types of accidents possess risk scores greater than or equal to 10. The higher the risk score, the worse the consequences. Many of the accidents result in death or permanent loss of limbs. On the basis of the results, necessary risk reduction measures are analyzed and recommendations are made in order to heighten workplace safety.

The accidents or hazardous events along with their risk scores (L*S) and control measures are presented in Exhibit 4. By practicing these common measures, the probability of accidents can be minimized. Exhibit 4 column 7 indicates that the majority of hazardous events possess high risk scores with a high frequency. Based on the results and interview sessions, we found that approximately 32% of the workers believe that the accidents can be minimized by ensuring the use of personal protective equipment (PPE) whereas 27% respondents suggested that training could play a vital role to minimize accidents (Exhibit 5). Twenty-three percent of the respondents stated that an awareness campaign on occupational safety and health issues might be useful in minimizing undesirable events. Only around 5% of the respondents recommended upgrading and maintaining the working environment.

Exhibit 5. Measures of Hazard Prevention (By Interview & Questionnaire).



Below are 7 recommendations that should be taken into consideration in any shipyard environment. Some precautions are mandatory.

1. Implementing safety rules and conducting primary safety training is very necessary in reducing workplace accidents.
2. Personal protective equipment should be provided and should be 'declared' as mandatory in the workplace.
3. Safety signage is a must in hazardous areas.
4. Routes of escape should be kept clear at all times.
5. Roadways, quays, and yards where individuals and vehicles move or are stationed should be constructed and maintained on a regular basis.
6. Sufficient secure storage areas should be provided for flammable liquids, solids and gases such as LPG.
7. "No smoking" signs should be prominently displayed in all places with combustible or inflammable material.

Discussion and Conclusion

Workplace safety is one of the major concern nowadays in workplace of any kind. With a view to finding major and serious issues related to workplace safety in an active shipyard, relevant well organized surveys were undertaken and proper data analysis techniques were used. At the end of the paper, recommendations were drawn on the basis of analyzed results. From this study, it can be easily noticed that both the frequent and severe hazards are responsible for the accidents. Adopting proper preventive measures is imperative to avoid accidents as well as accidental loss in shipyard. Results also depict that the use of personal protective equipment and proper training are the two main measure to avoid accidents. Moreover, consciousness and efforts of all level of the workforce is necessary to well develop a safe working environment. This research was done by using PHA technique. Researchers can also use other hazard analysis tools for this data set and find the discrepancy of the results if any. Alternatively, researchers can use the same PHA technique for analyzing the hazards of other workplaces. In fine it can be said that, the shipyard is one of the most important sectors in the economy of Bangladesh. Care must be given to improve its overall safety to save precious lives as well as money.

References

Celebi, U. B., Ekinci, S. E. R. K. A. N., Alarcin, F. U. A. T., & Unsalan, D. (2010). The risk of occupational safety and health in shipbuilding industry in Turkey. *In Proceedings of the 3rd Int. Conf. Maritime and Naval Science and Engineering* (pp. 178-184).

Cherniack, M., Brammer, A. J., Lundstrom, R., Meyer, J., Morse, T. F., Nealy, G., & Fu, R. W. (2004). Segmental nerve conduction velocity in vibration-exposed shipyard workers. *International archives of occupational and environmental health*, 77(3), 159-176.

Coggon, D., & Palmer, K. T. (2016). Are welders more at risk of respiratory infections? *Thorax*, thoraxjnl-2016.

Gillibrand, S., Ntani, G., & Coggon, D. (2016). Do exposure limits for hand-transmitted vibration prevent carpal tunnel syndrome? *Occupational Medicine*, kqw025.

Haltiwanger, G., Landaeta, R. E., Pinto, C. A., & Tolk, A. (2010). Understanding the relationship between Risk Management and Knowledge Management: a literature review and extension. *International Journal of Knowledge Management Studies*, 4(3), 281-300.

Iqbal, K. S., Zakaria, N. G., & Hossain, K. A. (2011). Identifying and Analysing Underlying Problems of Shipbuilding Industries in Bangladesh. *Journal of Mechanical Engineering*, 41(2), 147-158.

Kilburn, K. H., Warshaw, R., & Thornton, J. C. (1985). Asbestosis, pulmonary symptoms and functional impairment in shipyard workers. *Chest*, 88(2), 254-259.

Malherbe, L., & Mandin, C. (2007). VOC emissions during outdoor ship painting and health-risk assessment. *Atmospheric environment*, 41(30), 6322-6330.

Pinto, C., Magpili, L., & Jaradat, R.,(2015) *Operational Risk Management*: Momentum Press, USA.

Puntoni, R., Merlo, F., Borsa, L., Reggiardo, G., Garrone, E., & Ceppi, M. (2001). A historical cohort mortality study among shipyard workers in Genoa, Italy. *American journal of industrial medicine*, 40(4), 363-370.

Rausand, M. (2004). Preliminary hazard analysis. *Norwegian University of Science and Technology*

Selikoff, I. J., & Hammond, E. C. (1978). Asbestos-associated disease in United States shipyards. CA: *a cancer journal for clinicians*, 28(2), 87-99.

Vincoli, J. W. (2006). Preliminary Hazard Analysis. *Basic Guide to System Safety*, Third Edition, 71-90.
Zakaria, N. M. G., Hossain, K. A., & Islam, M. S. (2010). SWOT analysis of shipbuilding industries in Bangladesh and its challenges to become potential ship-exporting nation. *Journal of Ship Technology*, 6(2), 45-57.

About the Author(s)

Niamat Ullah Ibne Hossain is a doctoral student in the Department of Industrial and Systems Engineering at Mississippi State University. His research interest includes system of systems engineering, complex system and risk management. He received his BS in Mechanical Engineering from Khulna University of Engineering & Technology, Bangladesh and MBA in Management Information Systems from Dhaka University, Bangladesh.

Farjana Nur is a doctoral student in the Department of Industrial and Systems Engineering with a concentration in Human Factors and Ergonomics at Mississippi State University. She received her BS in Industrial Engineering from Khulna University of Engineering & Technology, Bangladesh.

Raed M Jaradat is an Assistant Professor of Industrial and Systems Engineering department at Mississippi State University. His main research interests include engineering management, systems engineering and management systems, systems thinking and complex system exploration, systems simulation, risk and vulnerability in critical infrastructures with applications to diverse fields ranging from the military to industry. He is a past proceedings chair of the American Society for Engineering Management. He holds a PhD in Engineering Management from Old Dominion University in 2014.