

Occupational Safety Risk Analysis Using FMEA and JSA Methods at PT. Kodja Bahari Dock and Shipyard 1 Jakarta

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Abstract—Workplace accidents pose major challenges in the shipyard industry due to high-risk activities like welding, blasting, and heavy lifting. This descriptive observational study aimed to identify, evaluate, and control safety risks at PT. Kodja Bahari Dock and Shipyard I Jakarta, specifically within the Blasting & Painting and Hull Replating sections. Utilizing purposive sampling, data were collected via field observations, safety records, and worker interviews. Data analysis integrated Failure Mode and Effect Analysis (FMEA) to determine Risk Priority Numbers (RPN) alongside Job Safety Analysis (JSA). The process identified 12 potential risks in Blasting & Painting and 10 in Hull Replating, with critical hazards including high-pressure exposure and electrical shocks. Based on RPN calculations, risks were categorized into high, medium, and low levels. Control strategies were formulated using the hierarchy of hazard control, incorporating engineering, administrative protocols, and mandatory PPE. In conclusion, integrating FMEA and JSA successfully categorized operational hazards and established targeted control measures, enhancing the company's safety management system.

Keywords—Occupational Safety, FMEA, JSA, Shipyard, Risk Priority Number, K3.

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I. INTRODUCTION

Shipyards play an important role in the maritime industry because they are responsible for building, repairing, and dismantling ships. All of these activities involve various high-risk jobs, such as welding, cutting materials, lifting large components, and operating heavy equipment. The complexity of the production process, along with the interaction between people, equipment, and the work environment, makes the potential for workplace accidents in shipyards relatively higher compared to other industrial sectors [1]. If these risks aren't managed systematically, the impact can go beyond injuries or occupational diseases—it can also lower productivity, increase operational costs, and disrupt the production process. That's why implementing Occupational Health and Safety (OHS) is crucial to creating a safe and productive work environment [2].

The high level of risk at shipyards is influenced by job characteristics that involve activities in confined spaces, working at heights, exposure to heat and sparks from welding, the use of chemicals during painting processes, and operating heavy equipment [3]. This condition is reinforced by findings that ship repair activities are characterized by complex and dynamic work environments, with high levels of physical, chemical, and ergonomic hazards [4]. In addition, the

dynamic work environment means that potential hazards can change at every stage of the job. Various studies show that activities like welding, cutting, painting, as well as inspection and maintenance work, have the highest accident risk [5]. This situation shows that hazard identification and risk assessment need to be done in detail at each stage of the job so that the control measures applied really match the sources of danger.

Various methods have been used to analyze occupational health and safety risks in the shipbuilding industry. Research at PT. Kodja Bahari Dock and Shipyard I Jakarta used the Failure Mode and Effects Analysis (FMEA) method combined with the Analytic Hierarchy Process (AHP) in the Landing Craft Tank (LCT) shipbuilding project. That study was able to determine risk priorities but recommended developing the method to improve the accuracy of determining the Risk Priority Number (RPN) values. Meanwhile, another study on the implementation of occupational health and safety risk management in welding activities at PT. Kodja Bahari Dock and Shipyard III Jakarta applied the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method. The results of that study recommended using the Job Safety Analysis (JSA) method to get a more detailed hazard identification at each stage of the work.

Based on the suggestions and recommendations from previous researchers, this study aims to combine the JSA and FMEA methods. The integration of these two methods is highly complementary. The JSA method excels at identifying hazards at each work step [6] [7] [8]. However, it struggles to compare and prioritize which hazards are the most critical. Combining these two methods makes the risk analysis process superior to analyzing risks using the JSA method alone. By integrating the FMEA method, which provides a deeper risk assessment through failure mode analysis and RPN

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calculations, researchers can prioritize the most critical hazards and determine more effective control measures.

Failure Mode and Effect Analysis (FMEA) is a risk management tool capable of identifying potential failure modes and analyzing their causes and effects [9]. Along with updates in the production process, there is a possibility of new error modes emerging [10]. One way to prevent workplace accidents is by developing correct work procedures through Job Safety Analysis (JSA) to minimize risks and analyze potential hazards.

This research focuses on the KMP Kumala during its docking, maintenance, and hull repair processes. This

research is expected to provide a significant contribution to the company. The results of the risk analysis using FMEA and JSA will yield potential hazard identifications, failure modes, and concrete, measurable mitigation recommendations. The implementation of these recommendations is expected to help reduce workplace accident risks, prioritize the most critical hazards, determine more effective control measures, create a safer and more productive work environment at PT. Kodja Bahari Dock and Shipyard I Jakarta.



Figure 1. KMP Kumala
(Source: Author Documentation, 2026)

TABLE 1
SHIP PARTICULAR KUMALA (SOURCE : SHIP KMP. KUMALA)

Ship Name	KUMALA
Type	Ro-ro Ferry
LPP	94.70
LOA	104.20
Breath	19.20
Draft	6.30
GT	5874
Years	1959

II. METHOD

This study uses a semi-quantitative approach by converting workers' subjective assessments, gathered through interviews and questionnaires, into structured numerical data based on FMEA evaluation parameters. The subjects of this study are workers in the blasting & painting section and the hull replating section. The research was conducted at PT. Kodja Bahari Dock and Shipyard I Jakarta, located in North Jakarta, from January to February 2026. The variables in this study

include hazard identification, risk assessment, and risk control (residual risk).

The main data was obtained through direct field observations and interviews with workers in the blasting & painting section as well as hull coating replacement, covering various types of common risks, their severity levels, and the likelihood of occurrence. This secondary data was obtained from literature studies, such as books or journals on occupational safety and health risk management [11] [12].



Figure 2. Research Flowchart

1. FMEA

Failure Mode and Effects Analysis (FMEA) is a systematic method used to identify the root causes of defects or failures that may occur during a production process. As an engineering reliability tool, FMEA is designed to evaluate potential failure modes and their effects, enabling organizations to improve system reliability and operational performance [13]. With the growing emphasis on risk management across various industrial sectors, both qualitative and quantitative risk assessment methods have been widely adopted in research and industrial practice. These methods are generally applied to identify potential hazards, assess their impacts, and support the implementation of effective risk control measures [14]. Among these approaches, FMEA is widely used because it provides a structured framework for prioritizing risks based on three assessment parameters: Severity (S), which represents the consequences of a failure; Occurrence (O), which indicates the likelihood of the failure occurring; and Detection (D), which reflects the probability of detecting the failure before it results in adverse effects [15]. Each parameter is rated on a ten-point scale, and the three scores are multiplied to calculate the Risk Priority Number (RPN), which is subsequently used to rank and prioritize risks requiring corrective actions.

2. JSA

Job Safety Analysis (JSA) is a systematic approach used to identify and evaluate potential hazards that may arise in the workplace [16]. The primary objective of JSA is to enhance occupational safety and health by identifying hazards associated with each step of a work activity before incidents occur. By analyzing individual job tasks, JSA facilitates the implementation of preventive measures to minimize the likelihood of accidents and occupational injuries. In this study, the JSA method was employed to develop risk control recommendations based on the hierarchy of hazard controls, including engineering controls, administrative

controls, and the mandatory use of personal protective equipment (PPE). These control measures provide a structured framework for reducing workplace risks and improving the overall effectiveness of occupational safety management.

3. Risk

Risk is the possibility of negative impact or loss that comes from an activity or work process being carried out. Risk prevention can be done by identifying potential hazards [17]

4. Risk Control

Risk control is the act of eliminating or reducing hazards in a certain way so that they don't pose a risk to workers. Risk control activities are carried out in a sequential and systematic manner with the aim of gradually reducing existing risks [18].

5. Data Collection Technique

a. Observation

Observations were performed directly on the ship during maintenance operations, including scraping, hull washing, painting, and hull repair, to analyze work activities, workplace conditions, and potential occupational safety hazards

b. Interviews

Interviews with related personnel were used to obtain information regarding work processes, hazard causes, and existing control measures that could not be fully identified through observation and questionnaires.

c. Questionnaire

The questionnaires were administered to 30 respondents from the blasting & painting and hull replating sections to assess the Severity, Occurrence, and Detection ratings for every identified hazard.

6. Data Analysis Technique

The identified hazards were analyzed using the *Failure Mode and Effect Analysis* (FMEA) method. This assessment utilizes the FMEA method analysis with three parameters: severity, occurrence, and detection [19]. Each of these three parameters uses a 10-point scale, which is then calculated into a Risk Priority Number (RPN):

$$\text{RPN} = \text{S} \times \text{O} \times \text{D} \quad (1)$$

These results can then be used to calculate the risk priority number and will be categorized based on low, medium, and high levels as shown in Table 2. Below : [20]

TABLE 2.
RPN VALUES & PRIORITY CATEGORY.

RPN	Criticality Category
277-1000	High
93-276	Moderath
1-92	Low

FMEA is a method for analyzing the potential impact of a failure. It can also reduce the risk of danger, especially risks with the highest risk priority [21] [22]. Adapted from the FMEA reference, are based on the

SMK3 (Occupational Health and Safety Management System) hierarchy of controls, which includes engineering controls, administrative protocols, and the mandatory use of personal protective equipment (PPE).

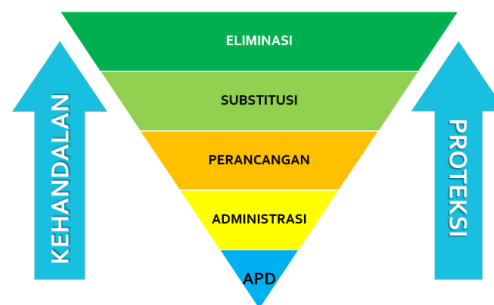


Figure 3. Hierarchy of Control [23]

III. RESULTS AND DISCUSSION

This section details the hazard identification and risk assessment using FMEA method, alongside risk control formulation based on SMK3 using the JSA method. This analysis was conducted on work activities within the hull replating section's construction workshop and the blasting & painting section's outfitting workshop at PT. Kodja Bahari Dock and Shipyard I Jakarta to determine potential hazards, identify the most critical risks, evaluate their risk priorities, and implement appropriate

control measures to enhance workplace safety.

1. FMEA Risk Identification

The factors influencing the problems were identified through a series of methods, namely direct field observations, interviews with relevant parties within the company, and supported by relevant literature studies [24].

TABLE 3.
RISK IDENTIFICATION IN THE BLASTING & PAINTING

No	Work Activity	Specific Activity	Hazard Type	Risk / Failure Mode	Cause of Failure	Failure Effect
1	Preparation of work equipment	Compressor engine preparation	Physical Hazard: Wet hands when connecting the compressor	Electrocution from energized work equipment	Exposed or damaged equipment cables	Burns due to electric shock
		Paint material preparation	Chemical Hazard: Paint material hazards	Respiratory distress caused by paint odor during paint equipment preparation	Failure to use PPE (such as masks)	Dizziness, nausea, and shortness of breath
2.	Scraping or cleaning of the ship's hull	Use of work tools such as hand scrapers	Physical Hazard: Airborne particles from marine growth debris	Foreign objects entering the eyes (<i>kelilipan</i>) during the removal of marine growth or barnacles from the hull	Failure to use PPE (such as safety glasses)	Eye irritation
			Biological Hazard: Scattered marine growth in the work area	Inhaling unpleasant odors from marine growth	Failure to use a mask during barnacle or marine growth cleaning	Discomfort and loss of focus during work

CONTINUED TABLE 4.
RISK IDENTIFICATION IN THE BLASTING & PAINTING

No	Work Activity	Specific Activity	Hazard Type	Risk / Failure Mode	Cause of Failure	Failure Effect
3	Blasting Process	Use of tools and materials such as blasting hose and steel grit	Physical Hazard: Airborne particles from sprayed sand/grit	Getting blasting dust in the eyes	Failure to comply with or follow PPE usage rules	Eye irritation
		Use of scaffolding staging	Physical Hazard: Slippery scaffolding area	Falling from heights	Failure to use a body harness	Injuries such as fractures or head trauma
		Use of blasting hose and blasting pot	Physical Hazard: Noise from the blasting nozzle	Excessive noise from the blasting process	Failure to maintain awareness and caution in the work area	Disruption of comfort during work
		Use of tools and materials such as blasting hose and steel grit	Physical Hazard: Airborne particles from sand and friction between blasting grit sparks and hull plating	Exposure of skin to blasting dust sparks	Failure to wear recommended work clothes	Skin irritation due to exposure to blasting dust sparks
		Use of blasting pot equipment	Mechanical Hazard: High pressure from the nozzle	Blasting hose rupture/explosion	Failure to wear safety gloves	Bruises and contusions from blasting hose backlash
4	Hull washing using freshwater	Use of water jet and high-pressure hose	Biological Hazard: Direct contact with dirt residues	Exposure to remaining dirt residues on the ship's hull	Failure to use PPE according to existing rules	Eye and skin irritation
5	Paint Mixing	Use of materials such as paint and thinner	Physical Hazard: Hot ambient temperature	Fire due to flammable substances (paint and solvents/thinner)	Absence of "No Smoking" or "No Open Flames" warning signs	Burn injuries
6	Paint Spraying	Use of scaffolding staging	Physical Hazard: Slippery scaffolding area	Falling from heights	Failure to wear a body harness	Injuries such as fractures, head lacerations, concussion, and eye irritation

The risk identification results for the blasting & painting section indicate that every work process within this section carries inherent risks, particularly the blasting process, which accounts for the highest number of potential risks with 5 identified hazards. The blasting process poses numerous potential risks because it involves spraying high-pressure abrasive media, which

can lead to foreign objects entering the eyes, inhalation of blasting dust, physical injuries, high noise levels, and exposure to hazardous dust that potentially causes hearing impairment, eye injuries, and respiratory irritation [25]. The blasting process dominates the hazard list as a single spraying operation simultaneously triggers multiple risks.

TABLE 5.
RISK IDENTIFICATION IN THE HULL REPLATING

No	Work Activity	Specific Activity	Hazard Type	Risk/ Failure Mode	Cause of Failure	Failure Effect
1	Plate layer inspection / gauging	Inspection using Ultrasonic Testing (UT) equipment	Physical Hazard: Slippery graving dock area	Slipping during plate inspection	Lack of alertness during work	Bruises
2	Plate Marking	Use of spray paint (Pilox) or chalk	Chemical Hazard: Hazard from paint or chalk materials	Eye and respiratory irritation during spray paint use	Working too close to the eye area	Red and sore eyes
3	Plate Cutting	Use of equipment such as cutting torches (blander) and argon cylinders	Physical Hazard: Exposure to sparks	Burn injuries from cutting sparks	Failure to use PPE according to rules	Burn injuries
4	Proses fit up dan proses bending	Use of forklift equipment	Mechanical Hazard: Failure of fit-up auxiliary tools (forklift or chain block)	Crushed by the plate during fit-up	Failure to use PPE according to rules	Bone fractures, head lacerations, and concussion

CONTINUED TABLE 6.
RISK IDENTIFICATION IN THE HULL REPLATING

No	Work Activity	Specific Activity	Hazard Type	Risk/ Mode	Failure	Cause of Failure	Failure Effect
5	Plate Installation	Use of chain block equipment	Mechanical Failure of auxiliary tools	Hazard: fit-up	Chain block line snaps during plate fit-up	Lack of alertness during work	Concussion, bone fractures
			Physical Scattered remnants	Hazard: plate	Tripping over plate remnants/blocks in the fit-up area	Lack of alertness during work	Bruises
		Use of chain hoist equipment	Mechanical Wear and tear of the chain block	Hazard: of the	Hoist chain snaps during plate installation	Absence of hoist tool inspection	Concussion
			Mechanical Tack weld failure	Hazard:	Struck by the plate during installation with the hoist	s Lack of alertness	Bruises
			Use of wedge tools (<i>baji</i>)	Mechanical Hazard: pressure from shifting plates	Caught/pinched between plates	Failure to use PPE according to rules	Hand injuries (abrasions and scratches)
6	Welding	Use of torch gun, welding tongs, and welding machine	Physical Damage to cables	Hazard: welding	Electrocution during welding	Sweating or wet conditions	Muscle spasms, cardiac arrest

The risk identification results for the hull plate replacement section show that the laying & bending operation and plate installation dominate with the same 3 potential risks, surpassing other phases like plate measurement, marking, cutting, and welding. Since both of these processes require lifting heavy plates using forklifts, chain blocks, and hoists, they pose a serious risk of chain failure [26]. Such failures can result in an instantaneous load drop, which is inherently fatal to workers.

Based on the hazard identification results explained earlier, there are 12 potential risks coming from various activities in the Blasting & Painting section, while the Hull Replating section has 10 potential risks throughout its activities. The first step in the risk management process is to identify potential risks that might appear in the work environment or areas prone to damage. Various techniques and methods can be used to identify hazard and risk factors at the workplace or during certain work processes. In identifying hazards for workers in the Blasting & Painting and Hull Replating sections, the

main approach used was interviews with the division heads of each section who are directly involved in these activities. The results of this hazard identification will serve as the main basis for developing a work plan aimed at controlling and preventing unwanted incidents related to hazards in the Blasting & Painting and Hull Replating work areas at PT. Kodja Bahari Dock and Shipyard I Jakarta.

2. FMEA Risk Assessment

After completing the risk identification, a risk assessment was performed to classify the risk levels of all identified hazards. The evaluation utilized the FMEA method based on three parameters: Severity, Occurrence, and Detection. These parameter values were derived from the respondents' questionnaire ratings and multiplied to determine the Risk Priority Number (RPN). The calculated RPN values were then categorized into low, medium, and high priorities to define the risk level.

TABLE 7.
RISK ASSEMENT IN THE BLASTING & PAINTING

Preparation of work equipment		Severity	Occurance	Detection	RPN	Risk
Electrocution from energized work equipment		4	2	5	40	Low
Respiratory distress caused by paint odor during paint equipment preparation		3	2	5	30	Low
Scraping or cleaning of the ship's hull						
Foreign objects entering the eyes during the removal of marine growth or barnacles from the hull		6	7	4	168	Moderate
Inhaling unpleasant odors from marine growth		3	7	4	84	Low
Blasting Process						
Getting blasting dust in the eyes		7	8	3	168	Moderate
Falling from heights		7	2	7	98	Moderate
Excessive noise from the blasting process		4	3	5	60	Low
Exposure of skin to blasting dust sparks		4	7	5	140	Moderate

CONTINUED TABLE 8.
RISK ASSEMENT IN THE BLASTING & PAINTING
Preparation of work equipment

Blasting hose rupture/explosion	6	2	7	84	Low
Hull washing using freshwater					
Exposure to remaining dirt residues on the ship's hull	3	4	5	60	Low
Paint Mixing					
Fire due to flammable substances (paint and solvents/thinner)	9	3	6	162	Moderate
Paint Spraying					
Falling from heights	7	2	7	98	Moderate

According to the results, the medium risk category is dominated by the blasting process—specifically Getting blasting dust in the eyes (RPN = 168), Exposure of skin to blasting dust sparks (RPN = 140), and Exposure of skin to blasting dust sparks (RPN = 140). These hazards are attributed to abrasive dust exposure from sand sprayed via the blasting hose. Furthermore, painting operations pose a fire risk from flammable materials (paints and solvents) with an RPN of 162, which is associated with temperature-sensitive paint chemicals that can ignite in hot ambient environments. Even though both processes are classified as medium risk and blasting involves a wider exposure area, the fire hazard from flammable substances is deemed highly critical due to its potential to cause severe burns or permanent disability

The overall assessment results identified 12 potential risks, consisting of 6 low-category risks, 6 medium-category risks, and no high-category risk. These findings indicate that the resulting impacts are generally low. Furthermore, the average rating for occurrence, or the frequency of failure, is rare due to several influencing conditions. This low frequency of occurrence can be attributed to workers consistently complying with regulations by wearing personal protective equipment (PPE). Additionally, the detection assessment demonstrates that it is reasonably easy for workers to detect the causes of risk failures. Consequently, when calculated with these supporting factors, the overall risks fall into the low-level category.

TABLE 9
RISK ASSEMENT IN THE HULL REPLATING
(SOURCE: PROCESSED DATA, 2026)

Plate layer inspection / gauging					
Risk/Failure Mode	Severity	Occurance	Detection	RPN	Risk
Slipping during plate layer inspection	3	4	4	48	Low
Plate Marking					
Eye and respiratory irritation during spray paint use	3	4	4	48	Low
Plate Cutting					
Burn injuries from cutting sparks	4	5	5	100	Moderate
Explosion of hoses or regulator cylinders	6	4	4	96	Moderate
Fit-up and Bending Process					
Crushed by the plate during fit-up	6	2	8	96	Moderate
Chain block line snaps during plate fit-up	5	2	8	80	Low
Plate Installation					
Pulley/hoist chain snaps during plate installation	5	2	8	80	Low
Struck by plate during plate installation using the pulley/hoist	5	4	5	100	Moderate
Welding					
Electrocution during welding	8	6	7	336	High
Exposure to welding arc radiation	5	5	5	125	Moderate

In the hull replating section, a high-category risk level was found during welding activities, specifically the risk of electrocution with an RPN value of 336. This risk is identified as a critical level that can endanger workers because the electrical current generated during welding has a higher voltage than other processes utilizing electricity. Additionally, medium-category risk levels were identified in the plate cutting process, with the risk of burns from sparks (RPN = 100), the risk of being struck by plates during plate fit-up (RPN = 100), and the risk of explosion of hoses or regulator cylinders (RPN = 96). While low-priority hazards predominate overall, the medium- and high-priority risks tied to electrical factors, falling objects, and burns demand stricter oversight given their severe potential impacts on occupational safety and health. Consequently, mitigating

these specific risks must be prioritized in subsequent control strategies.

3. Risk Control Recommendation

The hierarchy of controls is utilized in efforts to mitigate identified risks, comprising elimination (removing the hazard source), substitution (replacing the hazard), engineering controls (isolating workers from the hazard), administrative controls (e.g., safety signs), and lastly, PPE (the use of personal protective equipment). PT. Dok & Perkapalan Kodja Bahari Shipyard I Jakarta implements ISO 45001:2018 standards and SMK3 (Occupational Health and Safety Management System), referencing Government Regulation No. 50 of 2012 concerning the Occupational Health and Safety Management System (SMK3). Consequently, the company is required to formulate OHS policies, establish

OHS objectives and programs, identify hazards and risks, and implement documented control procedures and equipment. This ensures that every production process,

including fabrication, blasting, and painting, is carried out in an environment strictly controlled against the risks of occupational accidents and work-related diseases [27]

TABLE 10.
RISK CONTROL IN THE BLASTING & PAINTING

JOB SAFETY ANALYSIS			
Job Title : Blasting & Painting		Departement : Outfitting	
PPE Required: Safety Gloves, Safety Mask			
No.	Work Activity	Hazard Identification	Recommendation Control
1	Preparation of work equipment	Electrocution from energized work equipment	Substitution: Replace damaged or exposed cables. PPE: Wear PPE that complies with specifications and standard blaster painter requirements.
2	Scraping or cleaning of the ship's hull	Respiratory distress caused by paint odor during paint equipment preparation	PPE: Providing personal protective equipment, such as masks or respirators, for workers to protect them from inhaling chemical fumes from paint.
		Foreign objects entering the eyes during the removal of marine growth or barnacles from the hull	Administrative Control: Provide training to workers regarding work procedures. PPE: Use PPE such as safety glasses to protect the eyes.
		Inhaling unpleasant odors from marine growth	PPE: Providing personal protective equipment, such as masks or respirators, to protect workers from inhaling unpleasant odors during the scraping process.
3	Blasting Process	Getting blasting dust in the eyes	PPE: Use PPE such as safety glasses to protect the eyes. Administrative Control: Providing training to workers regarding work procedures. Conducting routine inspections of shipyard facilities. Checking the condition of ladders used during the work process.
		Falling from heights	PPE: Wearing PPE in accordance with regulations or standards, such as a body harness when working at heights.
		Excessive noise from the blasting process	Administrative Control: Coordinating with other sections located around the sandblasting area. Providing training for workers regarding work procedures. Arranging work schedules for workers. PPE: Wearing PPE in accordance with regulations or standards, such as ear plugs.
		Exposure of skin to blasting dust sparks	Engineering Control: Adding a pre-filter or strainer at the end of the hose.
		Blasting hose rupture/explosion	Administrative Control: Installing warning signs or boundaries during the sandblasting process. PPE: Workers are recommended to wear overalls/wearpacks in accordance with company SOPs, such as a blasting suit, blasting helmet, respirator mask, blasting gloves, and safety shoes. Engineering Control: Installing a pressure gauge/controller on the blasting hose system to limit the maximum pressure.
4	Hull washing using freshwater	Exposure to remaining dirt residues on the ship's hull	Administrative Control: Installing signs or boundaries when performing sandblasting. Providing training for workers regarding work procedures. Conducting routine inspections of shipyard facilities. PPE: Wearing PPE in accordance with regulations or standards, such as a filter-type respirator along with eye, face, hearing, head, and hand protection.
5	Paint Mixing	Fire due to flammable substances (paint and solvents/thinner)	Administrative Control: Provide training to workers regarding work procedures. PPE: Wear Safety Gloves, Safety Boots, and Safety Glasses.
			Engineering Control: Provide fire extinguishers / APAR.
6	Paint Spraying	Falling from heights	Administrative Control: Provide training for workers on the hazards of flammable materials and their handling methods, organize the work area with warning signs and restrictions against smoking or lighting fires, and do not perform hot work. PPE: Use PPE in accordance with standards.
			Administrative Control: Conduct training for workers regarding work procedures, perform routine inspections of shipyard facilities, check the condition of ladders PPE: Wear PPE according to regulations or standards, such as a body harness when working at heights (Tiara Alda, 2025).

The implementation of the risk hierarchy of controls in this study was sampled from risks classified into the medium and low-level categories. Based on the analysis, the hierarchy of controls for blasting & painting activities is significantly dominated by the use of Personal Protective Equipment (PPE) as the final line of defense. This dominance occurs because the operational characteristics of the blasting & painting process in the shipyard still involve various inherent hazards such as exposure to high-pressure silica dust, abrasive material splashes, and toxic chemical vapors from thinners which are technically very difficult to eliminate completely at the source. Meanwhile, higher levels of control such as

elimination and substitution are nearly impossible to apply at this stage.

Blasting & painting operations cannot be simply omitted without removing the core function of the ship hull maintenance process and the coating system, both of which are crucial for corrosion prevention. Therefore, when engineering and administrative controls have reached their maximum limits, the provision of specific and standardized PPE such as respirators and specialized coveralls becomes the most rational control instrument to isolate residual risks on the workers' bodies, while simultaneously reducing the severity of occupational accident impacts in the field..

TABLE 11.
RISK CONTROL IN THE HULL REPLATING
JOB SAFETY ANALYSIS

Job Title: Hull Repair			Departement : Construction
PPE Required: Coveralls/Wearpack, Safety Gloves, Safety Mask			
No.	Work Activity	Hazard Identification	Recommendation Control
1	Plate layer inspection / gauging	Slipping during plate layer inspection	Administrative Control: Place warning signs in the work area to alert of potential hazards, conduct inspections related to the work environment. PPE: Wear correct PPE in accordance with applicable electrical safety regulations, such as wearing a coverall/wearpack.
2	Plate Marking	Eye and respiratory irritation during spray paint use	Substitution: Replace the plate marking tools with non-dust electrical markers. Administrative Control: Provide training to workers on work procedures for hot work/chemical activities, organize the work area with warning signs and electrical safety boundaries to maintain a safe distance from heat sources.
3	Plate Cutting	Burn injuries from cutting spark Scratched by the plate	PPE: Wear correct or appropriate PPE in accordance with applicable safety regulations, such as heat-resistant gloves and coveralls while working. PPE: Use personal protective equipment such as gloves.
4	Fit-up and Bending Process	Crushed by the plate during fit-up	Administrative Control: Inspect the condition of equipment before starting work, ensure that the weight of the material to be lifted does not exceed the designated capacity. PPE: Wear correct or appropriate PPE in accordance with applicable safety regulations, such as a safety helmet while working.
		Tripping over plate remnants/blocks in the fit-up area	Elimination: Clean up material waste/remnants in the Graving Dock area.
4	Plate Installation	Struck by the plate during installation with the hoist	Administrative Control: Provide training to workers regarding relevant work procedures. PPE: Wear correct or appropriate PPE in accordance with applicable safety regulations. Substitution: Replace damaged or exposed cables by covering or replacing them (Tiara Alda, 2025).
5	Welding	Electrocution during welding	Administrative Control: Check equipment periodically, provide training regarding procedures in the work (Tiara Alda, 2025). PPE: Wear correct or appropriate PPE according to applicable company safety regulations, such as safety gloves (Tiara Alda, 2025).

The implementation of the risk hierarchy of controls within the hull replating section was found to be predominantly dominated by administrative controls [28]. This occurs because the operational characteristics of ship hull repair involve extreme, heavy mechanical activities—such as gas cutting, plate fit-up, and welding—where the primary hazard sources cannot be eliminated or substituted without halting the entire repair process itself. Therefore, the most effective and technically-economically rational mitigation strategy is

to isolate the risks through work management interventions.

The administrative controls applied include formulating strict standard operating procedures (SOPs), scheduling work to avoid overlapping hazardous activities, conducting regular OHS competency training, and providing intensive safety briefings or toolbox talks to workers before they enter the dock area. Furthermore, field data indicates a high potential for unsafe acts driven by worker negligence regarding applicable safety procedures. This phenomenon of non-compliance

underscores that strengthening administrative controls—such as rigorous supervision, hot work permit systems, and visual education through safety signage—serves as a highly crucial pillar to control worker behavior, reduce occurrence values, and prevent fatal occupational accidents in the shipyard environment.

IV.CONCLUSION

Research at PT. Kodja Bahari Dock and Shipyard I Jakarta successfully identified 22 potential work accident risks: 12 risks in the Blasting & Painting section and 10 risks in the Hull Replating section, with critical hazards including exposure to high pressure and electric shocks. The FMEA analysis results showed that medium-level risks (RPN = 168) were mostly from dust particles from blasting and marine organism debris, while high-level risks (RPN = 336) were found in the hull replating section in the form of potential electric shock hazards. The integration of FMEA and JSA methods proved effective in mapping risk levels (high, medium, and low) based on RPN calculations, while also producing appropriate control strategies using the hazard control hierarchy through engineering measures, administrative protocols, and mandatory PPE usage. The combination of these two methods significantly strengthens and improves the occupational safety management system.

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REFERENCES

- [1] V. Dekanawati, J. Subekti, E. Budi Santoso, and J. Adinata Lie, 'Risk Analysis in Ship Repair Work with Hazard Identification Risk Assessment and Determining Control (HIRADC) at Banjarmasin Shipyard', *Natl. Semin. Marit. Interdiscip. Stud.*, vol. Volume 3, no. 1, pp. 34–39, 2021.
- [2] Yanda, 'Identification and Analysis of Work Accident Risks Using FMEA (Failure Mode and Effect Analysis) on the Palas Baru Rumbai Farmers Group', *Al-Tamimi Kesmas Journal of Public Health Science.*, vol. 9, no. 1, pp. 10–16, 2021, doi: 10.35328/kesmas.v9i1.930.
- [3] Park, 'Development of an ultrasound technology-based indoor-location monitoring service system for worker safety in shipbuilding and offshore industry', *Processes*, vol. 9, no. 2, pp. 1–16, 2021, doi: 10.3390/pr9020304.
- [4] Setyawan, 'Application of the HIRARC Method Based on Multivariate Statistical Analysis in Occupational Health and Safety Risk Study in the Production Process.', vol. 13, no. 3, pp. 1–14, 2025.
- [5] J. D. Fairussihan and D. Setiono, 'Safety and Health Risk Analysis (K3) in the Ship Repair Process at PT. Dock and Shipbuilding Surabaya Using the HIRARC Method (Hazard Identification, Risk Assessment, and Risk Control)', *Zo. Laut J. Innovation. Science and Technology. Maritime.*, pp. 23–29, 2023, doi: 10.62012/zl.v4i1.18977.
- [6] T. Nurhayati *et al.*, 'Hazard Identification Using Job Safety Analysis Method AT PT XYZ'.
- [7] Ilham Dwi Septya Widodo, Ida Rosanti, Purbawati Purbawati, Mad Yusup, and Diyaa Aaisyah Salmaa Putri Atmaja, 'Work Accident Risk Analysis Using Job Safety Analysis Method at PT. Sarana Sampit Mentaya Utama Balikpapan, Venus J. Publ. Branch of Science.', vol. 3, no. 4, pp. 150–161, Aug. 2025, doi: 10.61132/venus.v3i4.1056.
- [8] R. Z. Rayoga, 'Occupational Health and Safety Risk Analysis Using Job Safety Analysis and the FMEA Method at PT ABC Warehouse', *Ind. Eng. Online J.*, vol. 13, no. 3, 2024.
- [9] Alfiah, 'Work Accident Risk Analysis Using Failure Mode and Effect Analysis on Construction Project Workers: Literature Review, J. of Psychology and Health Sciences.', vol. 1, no. 4, pp. 283–290, 2023, doi: 10.47353/sikontan.v1i4.715.
- [10] Sukanta, 'System failure analysis in evaporator machine maintenance using FMEA and FTA methods, Proceedings of the National Seminar on Research and Community Service. 2018, pp. 289–295, 2018.
- [11] R. Alfatiyah, J. Surya Kencana No, and T. Selatan, 'Occupational Safety and Health Risk Management Analysis Using the HIRARC Method on Casting Section Workers, J. Mesin Teknol. (Sintek J., vol. 11, no. 2, 2017.
- [12] M. Afandi, S. Kirana Anggraeni, and A. S. Mariawati, 'OHS Risk Management Using the HIRARC Approach (Hazard Identification, Risk Assessment, and Risk Control) to Identify Potential Hazards'.
- [13] Rustono, 'Failure Mode And Effect Analysis On Risk Management At An Oil And Gas Survey Company In Indonesia', *Int. J. Sci. Technol. Manag.*, vol. 4, no. 6, pp. 1725–1732, 2023, doi: 10.46729/ijstm.v4i6.988.
- [14] Yousefi, 'HSE risk prioritization using robust DEA-FMEA approach with undesirable outputs: A study of automotive parts industry in Iran', *Saf. Sci.*, vol. 102, no. June 2017, pp. 144–158, 2018, doi: 10.1016/j.ssci.2017.10.015.
- [15] I. Dzikria, M. N. Khasanah, and N. Faisa, 'The Comparisom of The Design and Implementation of The Risk', *Pros. Semin. Nas. Teknol. dan Sist. Inf.* 2024, no. ISSN (Online) 2828-786X, pp. 517–526, 2024.
- [16] F. Ramadhan, 'Health and Safety at Work (K3) Analysis using the Hazard Identification Risk Assessment and Risk Control (HIRARC) method, National Seminar on Therapeutic Research, no. November, pp. 164–169, 2017.
- [17] I Wayan Erick Triswandana & Ni Komang Armaeni, 'Ukarst: Kadir University Civil Engineering Research Assessment of Construction OHS Risks Using the HIRARC Method, Ukarst, vol. 4, no. 1, p. 13, 2020, [Online]. Available: <http://dx.doi.org/10.30737/ukarst.v3i2>
- [18] Sunaryo, 'Safety risks assessment on container terminal using hazard identification and risk assessment and fault tree analysis methods', *Procedia Eng.*, vol. 194, pp. 307–314, 2017, doi: 10.1016/j.proeng.2017.08.150.
- [19] Tri Wibowo, Novi Purnama Sari, and HB Rudi Kusumantoro, 'Failure Risk Analysis Using the FMEA Method on UV Digital Printing Machines at PT XYZ, Journal of Research in Science Fields Tek., vol. 4, no. 2, pp. 173–184, 2025, doi: 10.55606/jurritek.v4i2.5524.

- [20] T. Joe and H. Chang, 'A study on user-oriented and intelligent service design in sustainable computing: A case of shipbuilding industry safety', *Sustain.*, vol. 9, no. 4, Apr. 2017, doi: 10.3390/su9040544.
- [21] S. Kumar Akula, H. Salehfar, and S. Behzadiraifi, 'Comparision of Traditional and Fuzzy Failure Mode and Effects Analysis for Smart Grid Electrical Distribution Systems'.
- [22] B. R. Saputra and I. D. Widodo, 'Analysis of Occupational Health and Safety (OHS) Risk Control Using the Failure Mode and Effect Analysis (FMEA) Method at PT. ABC, JMPM (Journal of Materials and Manufacturing Processes), vol. 7, no. 2, pp. 128–139, Dec. 2023, doi: 10.18196/jmpm.v7i2.19405.
- [23] Kristin Mei Nora Aruan and Moses Laksono Singgih, 'HSSE Accident Risk Control in the Steel Pipe Manufacturing Process', *J. Tek. Its*, vol. 2, no. 2, pp. 52–57, 2021.
- [24] J. R. Agusti, U. N. Harahap, and Y. M. Hasibuan, 'Implementation of Failure Mode and Effect Analysis to Minimize Defective Products, Method. J. Tech. Ind., vol. 11, no. 1, p. 2025.
- [25] M. A. Sofwan, R. A. Ratriwardhani, and M. Sunaryo, 'Identification of Lung Function Conditions in Sandblasting Area Workers at PT. X BACKGROUND The metal manufacturing and fabrication industry is one of the sectors that has a large contribution to economic growth in Indonesia. However, behind the producti ...', pp. 241–248, 2025.
- [26] L. Widiastuty, R. Ekasari, D. R. Wijaya, and Muh Adam Izzulhaq, 'Analysis of Hazard Potential in Ship Maintenance Workers at PT. X Makassar City, Hig. J. Environ. Health., vol. 6, no. 2, pp. 90–99, 2020.
- [27] V. Rutu and E. Susanti, 'Pada PT Indotirta suaka Health and Safety (K3) is one of the problems that occur in the company . occupational accidents usually occur because of factors of the workers themselves or the work environment . Occupational safety is a primary means of preve', 2021.
- [28] S. Atsya, A. Dien, and R. Purwaningsih, 'HIRARC Approach (Case Study: PT Krakatau Bandar Samudera)', pp. 1–11, 2024.