

Occupational Risk Analysis at PT. Blambangan Bahari Shipyard Using FMEA and 5S-Based Risk Control.

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Abstract — Occupational accidents remain a major concern in fiberglass shipbuilding due to the presence of physical, chemical, ergonomic, and electrical hazards throughout the production process. Previous studies have generally applied Failure Mode and Effect Analysis (FMEA), ISO 45001:2018, or the 5S concept separately, resulting in limited guidance for integrating systematic risk prioritization with practical workplace organization. Therefore, this study aims to identify occupational hazards, assess occupational risks using the FMEA method, and develop integrated risk control recommendations based on the ISO 45001:2018 hierarchy of controls supported by the 5S concept at PT. Blambangan Bahari Shipyard. A quantitative approach was employed through direct observation, interviews, and questionnaires involving 20 respondents from the fabrication and sub-assembly workshops. Occupational risks were evaluated using Severity, Occurrence, and Detection scores to calculate the Risk Priority Number (RPN). The results identified 40 potential hazards, consisting of 30 low-risk, 2 medium-risk, and 8 high-risk hazards. The highest RPN (64) was assigned to hazards related to fiberglass dust and resin particles, grinding noise, and sanding and cutting dust, while the lowest RPN (1–3) was assigned to prolonged static posture, wax/PVA spills, unstable hull movement, and poorly arranged frames and materials. Based on these findings, integrated risk control recommendations were developed using the ISO 45001:2018 hierarchy of controls supported by the 5S concept, emphasizing engineering improvements, administrative controls, personal protective equipment, and workplace organization. This study contributes by integrating FMEA, ISO 45001:2018, and the 5S concept into a comprehensive occupational risk management framework that supports systematic risk prioritization and sustainable workplace safety improvement in fiberglass shipbuilding.

Keywords — Occupational Accident Risk, FMEA, ISO 45001:2018, 5S, Shipyard.

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I. INTRODUCTION

Occupational Safety and Health Management Systems (OSHMS) are an essential aspect of shipbuilding industries due to the complexity of production activities and the presence of various workplace hazards. In fiberglass shipyards, workers are exposed to physical, chemical, ergonomic, and electrical hazards arising from fiberglass lamination, resin and catalyst handling, welding operations, grinding processes, manual material handling, and work in confined spaces. Without systematic hazard management, these activities may result in occupational accidents, occupational diseases, decreased productivity, and financial losses for the company [4, 5, 6, 17, 20].

Risk management plays an important role in preventing occupational accidents through systematic hazard identification, risk assessment, and implementation of appropriate control measures. Rather than relying on corrective actions after accidents occur, modern occupational safety management emphasizes proactive identification of hazards and prioritization of

preventive actions [2, 9, 16, 18, 23, 24]. One of the most widely used methods for occupational risk assessment is Failure Mode and Effect Analysis (FMEA). FMEA systematically evaluates potential failure modes using Severity (S), Occurrence (O), and Detection (D), which are combined to calculate the Risk Priority Number (RPN). This method enables organizations to prioritize hazards objectively and allocate resources toward the most critical occupational risks [2, 9, 16, 18, 23].

Risk control should follow the hierarchy of controls established in ISO 45001:2018, including elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). ISO 45001 also promotes continual improvement through risk-based thinking and systematic occupational safety management. However, the effectiveness of these control measures largely depends on workplace organization and employee discipline. Therefore, the implementation of the 5S concept (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke) complements ISO 45001 by improving workplace organization, standardization, housekeeping, and worker discipline. Previous studies have demonstrated that 5S implementation improves workplace efficiency, strengthens safety culture, and supports Occupational Safety and Health Management Systems (OSHMS) [8, 11, 12, 17, 20].

Previous studies have investigated occupational risk assessment using FMEA [3, 5, 7, 16, 18], implementation of the 5S concept for improving workplace organization [8, 11, 12, 14, 17], and ISO 45001-based occupational safety management systems [4, 6, 14, 25]. However, these studies generally examined each approach separately. Studies integrating

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FMEA, ISO 45001:2018, and the 5S concept within a single occupational risk management framework for fiberglass shipbuilding remain limited. However, no previous study has comprehensively integrated FMEA for risk prioritization, ISO 45001:2018 for hierarchy-based risk control, and the 5S concept for workplace organization within the context of fiberglass shipbuilding. Consequently, comprehensive guidance linking these three approaches has not yet been established for fiberglass shipyards [8, 11, 17, 18, 19, 25].

The novelty of this study lies in the development of an integrated occupational risk management framework that combines FMEA for systematic risk prioritization, ISO 45001:2018 for determining appropriate control

measures based on the hierarchy of controls, and the 5S concept for supporting practical implementation through workplace organization and continuous worker discipline. Unlike previous studies that applied these approaches independently, this study demonstrates how the three methods complement one another to provide more comprehensive occupational risk management in fiberglass shipbuilding environments [3, 4, 5, 14].

Accordingly, this study aims to identify occupational hazards, assess occupational risks using the FMEA method, and develop integrated occupational risk control recommendations based on the ISO 45001:2018 hierarchy of controls supported by the 5S concept for fiberglass shipbuilding activities.



Figure 1. PT. Blambangan Bahari Shipyard. (Source: Author Documentation, 2026).

II. METHOD

This research employed a quantitative approach to analyze occupational accident risks at PT. Blambangan Bahari Shipyard. The research was conducted in the fabrication and sub-assembly workshops of the new shipbuilding division because these areas have high work intensity and significant occupational hazards. Primary data were obtained through direct observation,

interviews, and questionnaires, while secondary data were collected from company documents and relevant standards, including ISO 45001:2018 and ISO 31000:2018. The collected data were analyzed using the Failure Mode and Effect Analysis (FMEA) method to identify occupational hazards, assess risk priorities, and formulate risk control recommendations based on ISO 45001:2018 supported by the 5S concept [2, 24, 25].

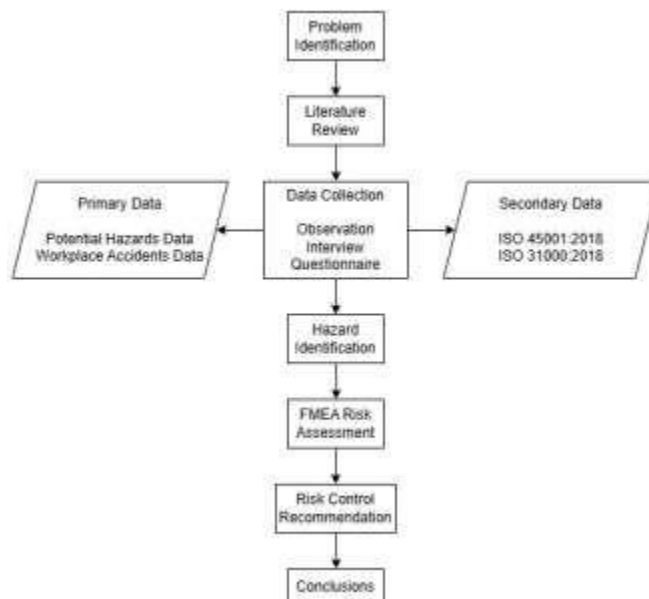


Figure 2. Research Flowchart

1. Data Collection Technique

Primary data such as the data on potential hazards and workplace accident data were collected through direct observations, interviews with workers and supervisors, and questionnaires for the workers. The data collection technique used in this research are as follows:

a. Observation

Direct observations were conducted in the fabrication and sub-assembly workshops to identify work activities, workplace conditions, and potential occupational hazards.

b. Interviews

Interviews were conducted with workers and supervisors to obtain information regarding work processes, hazard causes, and existing control measures that could not be fully identified through observations and questionnaires.

c. Questionnaire

Questionnaires were distributed to 20 respondents, consisting of 10 fabrication workers and 10 sub-assembly workers, to evaluate the Severity, Occurrence, and Detection values of each identified hazard. 20 respondents were selected because they directly represented workers involved in the fabrication and sub-assembly processes.

Secondary data are relevant occupational safety standards, such as ISO 45001:2018 and ISO 31000:2018.

2. Data Analysis Technique

The data analysis technique used in this research are as follows:

a. Hazard Identification

Hazard identification was carried out by observing each work activity and identifying potential hazards, failure modes, causes, and possible effects associated with the fabrication and sub-assembly processes. The identified hazards were then assessed using the FMEA method [2].

b. Risk Assessment

Each hazard was evaluated based on three parameters: Severity, Occurrence, and Detection. The values were then multiplied to obtain the Risk Priority Number (RPN):

$$RPN = S \times O \times D$$

Where (S) represents Severity, (O) represents Occurrence, and (D) represents Detection. Each parameter was assessed using a five-point scale. The RPN values were then classified into three priority categories, as shown in Table 1. below:

TABLE 1.
RPN VALUES & PRIORITY CATEGORY. (SOURCE: ADAPTED FROM [21].)

RPN	Priority Category
1 – 20	Low
21 – 45	Medium
46 – 125	High

The RPN classification used in this research was adapted from previous research [21]. The calculated RPN values were then classified into low-, medium-, and high-risk categories to determine the priority of corrective actions.

c. Risk Control Recommendation

The risk priorities obtained from the FMEA analysis served as the basis for developing risk control recommendations according to the hierarchy of controls in ISO 45001:2018, including elimination, substitution, engineering controls, administrative

controls, and personal protective equipment (PPE). These recommendations were further supported by the implementation of the 5S concept (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke) to improve workplace organization, housekeeping, and worker discipline [1, 25].

The proposed control measures were then assigned according to the priority level of each identified risk, ensuring that higher-priority risks received more comprehensive control strategies than lower-priority risks.

III. RESULTS AND DISCUSSION

This section presents the results of hazard identification, risk assessment using the *Failure Mode and Effect Analysis (FMEA)* method, and the formulation of risk control recommendations based on ISO 45001:2018 and the 5S concept. The analysis was conducted on work activities in the fabrication and sub-assembly workshops of PT. Blambangan Bahari Shipyard to determine potential occupational hazards, evaluate their risk priorities, and propose appropriate control measures to improve workplace safety and organization.

1. Hazard Identification

Hazard identification was conducted through direct observation and interviews to identify potential occupational hazards associated with each work activity in the fabrication and sub-assembly workshops. This stage serves as the foundation of the risk management process because it provides information on potential hazards, their associated risks, possible causes, and potential consequences before further assessment using the FMEA method [10, 12, 24]. Effective hazard identification is essential because incomplete identification may lead to inaccurate risk prioritization and less effective control strategies.

TABLE 2.
HAZARD IDENTIFICATION IN THE FABRICATION WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	Cause of Failure	Effect of Failure
1	Hull Frame Assembly	Manual handling of heavy materials	Muscle and back injuries	Manual lifting without ergonomic procedures	Causes injuries, reducing productivity and increasing accident risk.
		Frame and metal components	Struck by frame/material	Unstable material placement without proper securing	Causes injuries that disrupt work activities.
		Poorly arranged materials and frames	Tripping over frame/material	Materials and tools are improperly arranged	May cause trips, injuries, and workplace accidents.
		Continuous use of electrical tools	Muscle injury and hearing problems	Prolonged repetitive use without adequate rest	Causes fatigue, minor injuries, and mechanical failure.
		Exposed electrical installation and cables	Electric shock	Lack of regular inspection of cables and electrical systems	May result in electric shock and worker injury.
2	Mold Preparation	Slippery and dusty floor	Slipping	Poor housekeeping and floor maintenance	May cause slips, injuries, and accidents.
		Mold positioned in work pathway	Collision injury	Improper mold placement and protection	Causes injuries that interfere with work.
		Non-ergonomic working posture	Ergonomic injury	Improper posture and work method	Leads to muscle fatigue and reduced performance.
3	Wax & PVA Coating	Wax and PVA chemical splashes	Skin and eye irritation (conjunctivitis)	Direct contact without adequate PPE	Causes irritation affecting worker comfort and performance.
		Chemical vapor exposure	Respiratory disorder	Poor chemical storage and inadequate ventilation	Causes respiratory discomfort and health problems.
		Wax/PVA spills	Slipping	Spills are not cleaned immediately	May cause slips, injuries, and accidents.
4	Gelcoat Coating	Gelcoat vapor	Respiratory disorder	Repeated exposure without adequate PPE	Causes respiratory discomfort and health problems.
		Direct contact with gelcoat/resin	Skin and eye irritation (conjunctivitis)	Incomplete or improper PPE use	Causes irritation that interferes with work.
		Gelcoat spills	Slipping	Improper handling and storage of gelcoat	May cause slips, injuries, and accidents.
5	Fiberglass Lamination	Repeated resin and catalyst exposure	Health disorders (respiratory, skin, and eye irritation)	Repeated exposure without adequate control and PPE	May cause short-term health disorders.
		Fiberglass dust and resin particles	Respiratory disorder	Long exposure and inconsistent respiratory PPE use	Causes respiratory problems and discomfort.
		Prolonged static posture	Ergonomic injury (back and muscles)	Non-ergonomic posture during lamination	Causes muscle fatigue and reduced productivity.
5	Fiberglass Lamination	Grinding tool noise	Hearing impairment	High noise exposure without adequate control	May cause hearing loss and reduced comfort.
6	Hull Removal from Mold	Unstable hull movement	Loss of balance/struck by hull	Hull lifted without adequate lifting aids	May cause serious injuries and workplace accidents.
		Manual lifting of heavy loads	Back injury	Heavy manual lifting with poor posture	Causes back pain and reduced work ability.
		Hull lifting without aids/coordination	Struck or trapped by hull	Poor communication and task coordination	May result in work errors and accidents.

In the fabrication workshop, six major work activities were identified: hull frame assembly, mold preparation, wax and PVA coating, gelcoat application, fiberglass lamination, and hull removal from the mold. The identified hazards were primarily related to manual material handling, chemical exposure, electrical equipment, poor housekeeping, and ergonomic working postures. Manual lifting activities may cause musculoskeletal injuries, while exposure to resin, catalyst, gelcoat, and fiberglass dust may result in

respiratory disorders and skin irritation. In addition, repetitive use of electrical tools and inadequate electrical installations may increase the risk of fatigue and electrical accidents. Based on the hazard identification results, fabrication activities involve diverse hazard sources originating from both operational processes and workplace conditions, emphasizing the need for comprehensive hazard control measures.

TABLE 3.
HAZARD IDENTIFICATION IN THE SUB-ASSEMBLY WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	Cause of Failure	Effect of Failure
1	Structural Frame Assembly	Manual lifting and frame adjustment	Muscle and back injuries	Manual handling with heavy loads and poor posture	Causes muscle injuries and back pain, reducing work ability.
		Frame and metal components	Caught between frames	Frame assembly without stable material securing	May cause hand or body injuries.
		Poorly arranged frame materials	Tripping	Materials are improperly arranged in the work area	May cause trips and worker injuries.
		Exposed electrical installation and cables	Electric shock	Lack of regular inspection of cables and electrical systems	May result in electric shock and worker injury.
2	Structural Reinforcement	Continuous use of electrical tools	Muscle injury and hearing problems	Prolonged repetitive use without adequate rest	Causes fatigue, minor injuries, and mechanical failure.
		Resin and coating chemicals	Skin, eye, and respiratory irritation	Direct chemical contact with inconsistent PPE use	Causes skin, eye, and respiratory irritation.
		Chemical spills	Slipping	Spilled chemicals are not cleaned immediately	May cause slips and worker injuries.
3	Structural Reinforcement Installation	Dust from sanding and cutting	Respiratory and visual disorders	Sanding and cutting without exhaust ventilation	Causes respiratory irritation, eye discomfort, and reduced work comfort.
		Sharp reinforcement edges	Cuts and lacerations (tetanus risk)	Handling sharp materials without adequate protection	May cause cuts, lacerations, and tetanus risk.
3	Structural Reinforcement Installation	Manual and power tools (drill, grinder, etc.)	Muscle injury, cuts, and hearing problems	Prolonged tool use, poor posture, vibration, noise, and inadequate PPE	Causes fatigue, minor injuries, and mechanical failure.
		Protruding ship structures	Collision	Improper work pathways increase collision risk	May cause bruises and minor injuries.
4	Upper Structure Assembly	Working at height without protection	Falling	Work performed without adequate fall protection	May cause fractures and serious injuries.
		Poorly arranged materials and tools	Collision or tripping	Lack of organized work pathways and housekeeping	May cause minor injuries that disrupt work.
		Welding light and hot metal spatter	Eye injury and burns	Inadequate eye and skin protection during welding	May cause visual impairment and burn injuries.
5	Surface Sanding	Fiberglass dust	Respiratory and visual disorders	Sanding without exhaust ventilation	Causes respiratory problems, eye irritation, and discomfort.
		Prolonged bending or squatting posture	Muscle injury	Long-duration sanding with poor posture	Causes muscle fatigue, back and shoulder pain, and reduced productivity.
		Noise from electrical tools	Hearing impairment	Exposure to high noise levels from power tools	May cause hearing loss and reduced work comfort.

Meanwhile, in the sub-assembly workshop, five main work activities were analyzed: structural frame assembly, structural reinforcement, structural support installation, upper structure assembly, and surface sanding. The identified hazards included manual handling of heavy materials, welding exposure, fiberglass dust, workplace noise, sharp materials, and unsafe workplace organization. These hazards may lead to musculoskeletal disorders, eye injuries, respiratory problems, hearing impairment, and other occupational accidents if appropriate control measures are not implemented. Compared with fabrication activities, sub-assembly work involves additional hazards related to welding operations and work at height, increasing the complexity of occupational risk management.

Based on the hazard identification results, 21 potential hazards were identified in the fabrication workshop and 19 potential hazards in the sub-assembly workshop, resulting in a total of 40 identified hazards. The hazards originated from human factors, materials, work methods, equipment, and workplace conditions, indicating that occupational safety management should address both technical and organizational aspects to minimize accident risks. The hazard identification results reveal that occupational accident risks arise from the interaction between workers, tools, materials, and the working environment [4, 9, 24]. Similar findings have been reported in previous studies on fiberglass shipbuilding industries, where manual material handling, chemical exposure, and inadequate workplace organization were identified as major contributors to

occupational hazards [4, 5]. However, unlike previous studies that primarily focused on hazard identification [4, 5, 19], this study comprehensively identified hazards across both fabrication and sub-assembly workshops, providing a broader basis for subsequent FMEA-based risk prioritization and the development of integrated control recommendations based on ISO 45001:2018 and the 5S concept.

The analysis also reveals that occupational hazards in fiberglass shipbuilding are influenced not only by technical production activities but also by workplace organization, material arrangement, and worker behavior. This study demonstrates that technical hazards and organizational factors coexist throughout the fabrication and sub-assembly processes, highlighting the importance of integrating workplace organization with systematic risk management. This finding extends previous studies, which mainly emphasized hazard identification or accident sources individually [4, 5, 19], by providing a more comprehensive perspective for occupational risk management through the integration of hazard identification, risk prioritization, and workplace organization.

2. FMEA Risk Assessment

Risk assessment was conducted after the hazard identification stage to determine the priority level of each identified occupational hazard. The assessment employed the FMEA method by evaluating three parameters: Severity, Occurrence, and Detection. These parameter values were obtained from questionnaire responses provided by the respondents and subsequently multiplied to calculate the Risk Priority Number [2, 9]. The resulting RPN values were then classified into low-, medium-, and high-priority categories to determine risk levels and establish priorities for implementing appropriate control measures [21].

TABLE 4.
RISK ASSESSMENT RESULTS IN THE FABRICATION WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	S	O	D	RPN	Risk Level
1	Hull Frame Assembly	Manual handling of heavy materials	Muscle and back injuries	1	2	2	4	Low
		Frame and metal components	Struck by frame/material	2	1	2	4	Low
		Poorly arranged frames and materials	Tripping over frame/material	1	3	1	3	Low
		Continuous use of electrical tools	Muscle injury and hearing impairment	3	4	4	48	High
		Exposed electrical installation and cables	Electric shock	5	2	5	50	High
2	Mold Preparation	Slippery and dusty floor	Slipping	1	2	2	4	Low
		Mold positioned in work pathway	Collision injury	1	1	4	4	Low
		Non-ergonomic working posture	Ergonomic injury	2	3	3	18	Low
3	Wax & PVA Coating	Wax and PVA chemical splashes	Skin and eye irritation	2	3	2	12	Low
		Chemical vapor exposure	Respiratory disorder	3	3	2	18	Low
		Wax/PVA spills	Slipping	2	1	1	2	Low
4	Gelcoat Application	Gelcoat vapor	Respiratory disorder	2	2	2	8	Low
		Direct contact with gelcoat/resin	Skin and eye irritation	2	3	2	12	Low
		Gelcoat spills	Slipping	4	1	2	8	Low
5	Fiberglass Lamination	Repeated resin and catalyst exposure	Health disorders (respiratory, skin, and eye irritation)	2	3	2	12	Low
		Fiberglass dust and resin particles	Respiratory disorder	4	4	4	64	High
		Prolonged static posture	Ergonomic injury	1	1	1	1	Low
		Noise from grinding tools	Hearing impairment	4	4	4	64	High
6	Hull Removal from Mold	Unstable hull movement	Loss of balance and struck by hull	1	1	2	2	Low
		Manual lifting of heavy loads	Back injury	3	1	2	6	Low
		Hull lifting without lifting aids or coordination	Caught/crushed by hull	2	1	4	8	Low

The FMEA assessment revealed that several work activities in the fabrication workshop require higher priority for risk control than others. The highest RPN values were identified for fiberglass dust and resin particle exposure (RPN = 64) and grinding noise (RPN = 64), followed by exposed electrical installations and cables (RPN = 50) and continuous use of electrical tools (RPN = 48). The high RPN associated with fiberglass dust exposure is mainly attributable to its high severity because prolonged inhalation may lead to respiratory disorders that can affect workers' long-term health. Likewise, excessive workplace noise presents a

high-priority risk due to its potential to cause permanent hearing impairment after continuous exposure. Electrical hazards also received high RPN values because electric shock may result in severe injury or fatality, while damaged cables or hidden electrical faults are often difficult to detect before an accident occurs. In addition, the repetitive use of electrical tools contributes to muscle injury and hearing impairment as workers are exposed to prolonged physical strain, vibration, and equipment noise during hull frame assembly activities.

Overall, the fabrication workshop contained 21 identified occupational hazards, consisting of 17 low-priority risks and 4 high-priority risks, with no medium-priority risks observed. The predominance of low-priority risks suggests that most work activities remain manageable under the existing working conditions. Nevertheless, the presence of several high-priority risks associated with electrical hazards, repetitive use of power tools, fiberglass dust exposure, and grinding noise highlights the need for immediate

preventive measures to minimize both occupational accidents and work-related health disorders. Accordingly, the fabrication workshop represents the production stage where electrical equipment utilization and fiberglass processing generate the most critical occupational risks, emphasizing the importance of prioritizing engineering controls, administrative measures, and appropriate personal protective equipment for these activities.

TABLE 5.
RISK ASSESSMENT RESULTS IN THE SUB-ASSEMBLY WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	S	O	D	RPN	Risk Level
1	Structural Frame Assembly	Manual lifting and frame adjustment	Muscle and back injuries	2	1	3	6	Low
		Frame and metal components	Caught between frames	2	2	3	12	Low
		Poorly arranged frame materials	Tripping	1	1	2	2	Low
		Exposed electrical installation and cables	Electric shock	5	2	5	50	High
		Continuous use of electrical tools	Muscle injury and hearing impairment	3	4	4	48	High
2	Structural Reinforcement Layering	Resin and coating chemicals	Skin, eye, and respiratory irritation	2	2	5	20	Low
		Chemical spills	Slipping	2	1	2	4	Low
		Dust from sanding and cutting	Respiratory and visual disorders	4	4	4	64	High
3	Structural Reinforcement Installation	Sharp reinforcement bars or metal edges	Cuts and lacerations (potential tetanus)	2	2	3	12	Low
		Manual and power tools (drill, grinder, etc.)	Muscle injury, cuts, and hearing impairment	2	1	4	8	Low
		Protruding structural components	Collision injury	1	2	2	4	Low
4	Upper Structure Assembly	Working at height without protection	Fall from height	1	1	4	4	Low
		Poorly arranged materials/tools	Collision or tripping	2	4	3	24	Moderate
		Exposure to welding arc and hot sparks	Eye injury and spatter burns	4	3	4	48	High
5	Surface Sanding	Fiberglass dust during sanding	Visual and respiratory disorders	1	5	2	10	Low
		Prolonged bending/squatting posture	Muscle injury	2	2	2	8	Low
		Noise from power tools	Hearing impairment	2	5	3	30	Moderate

The FMEA assessment also identified several work activities in the sub-assembly workshop that require higher priority for risk control. The highest RPN value was associated with dust generated from sanding and cutting activities (RPN = 64), followed by exposed electrical installations and cables (RPN = 50), continuous use of electrical tools (RPN = 48), and exposure to welding arc and hot sparks (RPN = 48). The high RPN for sanding and cutting dust is primarily attributed to its potential to cause respiratory and visual disorders following prolonged exposure. Electrical hazards also received a high priority because electric

shock may result in severe injury or fatality, while damaged electrical installations and cables are often difficult to detect before incidents occur. Likewise, continuous use of electrical tools contributes to muscle injury and hearing impairment due to prolonged physical exertion, repetitive movements, and continuous equipment noise. Welding activities also represent high-priority hazards because intense arc radiation and hot sparks may cause eye injuries and burn injuries without adequate protective measures. In addition to these high-priority risks, moderate-priority hazards were identified for poorly arranged materials

and tools (RPN = 24), which increase the likelihood of collisions and tripping incidents, as well as excessive noise from power tools (RPN = 30), which may gradually impair workers' hearing during prolonged exposure.

Overall, the risk assessment in the sub-assembly workshop identified 19 potential hazards, comprising 13 low-priority risks, 2 medium-priority risks, and 4 high-priority risks. Although low-priority risks accounted for most identified hazards, the presence of medium- and high-priority risks related to electrical hazards, sanding dust, welding activities, workplace organization, and excessive noise indicates the need for more comprehensive preventive measures. Unlike the fabrication workshop, where high-priority risks were mainly associated with fiberglass processing and electrical equipment, the sub-assembly workshop exhibited a broader range of hazards resulting from structural assembly, welding, material handling, and finishing operations. This finding suggests that the diversity of work activities in the sub-assembly workshop requires more varied risk control strategies to effectively address both accident prevention and occupational health protection.

Overall, the FMEA assessment identified 30 low-priority risks, 2 medium-priority risks, and 8 high-priority risks, indicating that most identified hazards remain within a relatively controllable level. However, several activities involving repetitive use of electrical equipment, fiberglass dust exposure, workplace noise, welding operations, and electrical hazards produced higher RPN values due to the combination of greater severity, frequent occurrence, and limited detectability. These results suggest that the distribution of occupational risks is not determined solely by the frequency of work activities, but also by the severity of potential consequences and the ability to detect hazards before accidents occur. Consequently, medium- and high-priority risks should receive greater attention despite representing a smaller proportion of the identified hazards. Similar findings have been reported in previous shipyard studies, where material handling, equipment utilization, hazardous work environments, and production processes were identified as major contributors to occupational accident risks [5, 6, 10, 13, 19]. The consistency between the present findings and

previous studies suggests that electrical hazards, fiberglass dust exposure, and workplace organization remain persistent occupational safety issues in fiberglass shipbuilding industries [4, 6, 19]. Furthermore, the results demonstrate that the FMEA method provides a systematic approach for evaluating hazard priorities through the RPN, thereby supporting the development of more targeted and effective risk control strategies [2, 9, 18]. Unlike previous studies that primarily reported occupational risk levels within a single production area, this study provides a more comprehensive prioritization by evaluating both fabrication and sub-assembly workshops using a unified FMEA framework. This approach enables the development of integrated risk control recommendations based on ISO 45001:2018 and supported by the 5S concept.

The assessment results also indicate that high-risk activities are consistently associated with hazards characterized by high Severity and Detection scores rather than Occurrence alone. This finding suggests that occupational risks in fiberglass shipbuilding are influenced more by the potential consequences of hazardous exposures and the difficulty of detecting unsafe conditions before accidents occur than by the frequency of work activities. Therefore, risk control should prioritize hazards with severe consequences even when their occurrence is relatively infrequent. This finding reinforces the importance of incorporating Severity and Detection simultaneously during occupational risk evaluation, particularly in fiberglass shipbuilding, where hazardous exposures may not occur frequently but can result in serious occupational injuries or long-term health effects if preventive measures are inadequate.

3. Risk Control Recommendation

Based on the risk assessment results, risk control measures were formulated to reduce occupational accident risks according to the characteristics of each identified hazard. The proposed controls were developed by referring to the hierarchy of controls in ISO 45001:2018 and supported by the implementation of the 5S concept to improve workplace organization, cleanliness, and safety culture [1, 25]. This integrated approach ensures that control measures address not only technical hazards but also behavioral and organizational factors influencing occupational safety performance.

TABLE 6.
RISK CONTROL IN THE FABRICATION WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	Recommended Control	
				ISO 45001 Standard	5S Concept
1	Hull Frame Assembly	Manual handling of heavy materials	Muscle and back injuries	Use lifting aids, apply team lifting procedures, and wear back support belts.	Arrange material storage close to the workstation to minimize manual handling.
		Frame and metal components	Struck by frame/material	Secure materials with supports, organize placement, and use helmets and safety shoes.	Store and secure frame materials in an orderly and stable arrangement.

CONTINUED - TABLE 6.
 RISK CONTROL IN THE FABRICATION WORKSHOP.
 (SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	Recommended Control	
				ISO 45001 Standard	5S Concept
1	Hull Frame Assembly	Poorly arranged frames and materials	Tripping	Maintain clear walkways through proper housekeeping and wear anti-slip safety shoes.	Remove unnecessary items, mark walkways, and maintain a clean and organized workplace.
		Continuous use of electrical tools	Muscle injury and hearing impairment	Use ergonomic tools, schedule rest periods, and wear protective gloves.	Maintain tools regularly and encourage proper work-rest discipline.
		Exposed electrical installation and cables	Electric shock	Protect and inspect electrical installations regularly and use insulated gloves.	Separate damaged cables, organize wiring, and perform routine inspections.
2	Mold Preparation	Slippery and dusty floor	Slipping	Provide anti-slip flooring, conduct routine cleaning, and wear anti-slip safety shoes.	Maintain workplace cleanliness through routine cleaning and standardized housekeeping.
		Mold positioned in work pathway	Collision injury	Arrange molds safely, improve workplace layout, and wear helmets and gloves.	Keep molds away from walkways and provide designated storage locations.
		Non-ergonomic working posture	Ergonomic injury	Provide adjustable work supports and encourage proper working posture.	Promote proper working posture through visual reminders and regular breaks.
3	Wax & PVA Coating	Wax and PVA chemical splashes	Skin and eye irritation	Provide safety training and use long-sleeved clothing, gloves, and respirators.	Provide dedicated chemical handling areas and reinforce PPE compliance.
		Chemical vapor exposure	Respiratory disorder	Improve ventilation, limit exposure time, and wear respirators.	Establish designated application areas and encourage consistent respirator use.
		Wax/PVA spills	Slipping	Clean spills immediately and use anti-slip safety shoes.	Store chemicals properly and clean spills immediately.
4	Gelcoat Application	Gelcoat vapor	Respiratory disorder	Install local ventilation, reduce exposure duration, and wear respirators.	Provide designated coating areas and promote consistent respiratory protection.
		Direct contact with gelcoat/resin	Skin and eye irritation	Conduct safety briefings and use face shields, gloves, and protective clothing.	Organize chemical storage, standardize PPE use, and clean work areas after use.
		Gelcoat spills	Slipping	Remove spills immediately and wear anti-slip safety shoes.	Ensure safe chemical storage and immediate housekeeping after spills.
5	Fiberglass Lamination	Repeated resin and catalyst exposure	Health disorders	Improve ventilation, limit exposure time, and use gloves and respirators.	Standardize PPE use and maintain routine cleaning of resin residues.
		Fiberglass dust and resin particles	Respiratory disorder	Use local exhaust ventilation, clean dust regularly, and wear respirators.	Clean dust regularly and ensure simultaneous use of respirators and exhaust ventilation.
		Prolonged static posture	Ergonomic injury	Provide ergonomic workstations and schedule periodic breaks.	Adjust working positions and encourage periodic rest breaks.

CONTINUED - TABLE 6.
RISK CONTROL IN THE FABRICATION WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	Recommended Control	
				ISO 45001 Standard	5S Concept
5	Fiberglass Lamination	Noise from grinding tools	Hearing impairment	Limit noise exposure and use earplugs or earmuffs.	Standardize hearing protection and reinforce consistent PPE use.
6	Hull Removal from Mold	Unstable hull movement	Loss of balance and struck by hull	Use lifting/support equipment, establish safe procedures, and wear helmets and safety shoes.	Keep the removal area clear, establish safe zones, and ensure workers follow designated procedures.
		Manual lifting of heavy loads	Back injury	Use lifting devices, perform team lifting, and wear back support belts.	Organize lifting routes and encourage teamwork during manual handling.
		Hull lifting without lifting aids or coordination	Caught/crushed by hull	Use cranes or hoists, establish clear communication procedures, and wear helmets and safety shoes.	Clear obstructions, organize lifting areas, and standardize communication before lifting operations.

Based on the risk control analysis, most recommended control measures in the fabrication workshop are focused on administrative controls, engineering improvements, proper use of personal protective equipment (PPE), and workplace organization through the 5S concept. Since several work activities are essential parts of the production process, elimination and substitution controls are generally not feasible. Therefore, engineering and administrative measures become the most practical alternatives. For example, manual lifting activities during hull frame assembly can be controlled through lifting aids, workload management, and better material arrangement based on the Seiton principle to minimize unnecessary handling. Chemical exposure during wax, PVA, gelcoat, and fiberglass lamination processes can be reduced by consistent use of respirators and gloves, supported by standardized procedures (Seiketsu) and

routine workplace cleaning (Seiso). Meanwhile, electrical hazards and repetitive use of power tools require periodic equipment inspection, cable management, work-rest scheduling, and proper storage systems. Overall, the recommended controls emphasize improving work discipline and workplace organization while implementing the hierarchy of controls in accordance with ISO 45001. According to these results, effective risk reduction in fabrication activities depends not only on engineering improvements but also on consistent worker discipline and systematic workplace organization through the implementation of the 5S concept. Since most fabrication hazards are associated with repetitive work, electrical equipment, and fiberglass processing, integrating the hierarchy of controls with the 5S principles provides a more practical approach by addressing both technical and organizational factors simultaneously.

TABLE 7.
RISK CONTROL IN THE SUB-ASSEMBLY WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	Recommended Control	
				ISO 45001 Standard	5S Concept
1	Structural Frame Assembly	Manual lifting and frame adjustment	Muscle and back injuries	Use lifting aids, provide manual handling training, and wear back support belts.	Material placement near work areas, manual lifting limits, and improved housekeeping practices.
		Frame and metal components	Caught between frame components	Use frame clamps, establish safe hand positioning, and wear gloves and safety helmets.	Organized and stable material storage, safe joining procedures, and worker awareness.
		Poorly arranged frame materials	Tripping	Provide designated storage areas and maintain proper material organization.	Removal of unnecessary items, marked walkways, routine housekeeping, and standardized material storage.
		Exposed electrical installations and cables	Electric shock	Replace damaged cables, secure electrical installations, conduct inspections, and use insulated gloves.	Segregation of defective equipment, proper cable arrangement, periodic inspection, and routine equipment checks.

CONTINUED - TABLE 7.
RISK CONTROL IN THE SUB-ASSEMBLY WORKSHOP.
(SOURCE: PROCESSED DATA, 2026)

No	Activity / Process	Potential Hazard	Failure Mode / Risk	Recommended Control	
				ISO 45001 Standard	5S Concept
1	Structural Frame Assembly	Continuous use of electrical tools	Muscle injury and hearing impairment	Use anti-vibration tools, implement job rotation, and provide adequate rest periods.	Scheduled equipment maintenance and adequate work-rest arrangements.
		Resin and coating chemicals	Skin, eye, and respiratory irritation	Use low-toxicity materials where possible, provide ventilation, and ensure proper PPE use.	Designated chemical storage areas, chemical segregation, housekeeping practices, and mandatory PPE compliance.
2	Structural Reinforcement Layering	Chemical spills on the floor	Slipping	Install anti-slip surfaces and enforce immediate spill cleanup procedures.	Immediate spill cleanup procedures, housekeeping practices, and worker discipline.
		Dust from sanding and cutting	Respiratory and eye disorders	Use local exhaust ventilation, apply wet sanding methods, and wear respirators and goggles.	Routine dust cleaning, mandatory PPE use, and dust hazard awareness.
		Sharp reinforcement edges	Cuts and lacerations	Install edge protection and require cut-resistant gloves.	Segregation of sharp materials, warning signs, edge protection, and safe work practices.
3	Structural Reinforcement Installation	Manual and powered tools	Muscle injury, cuts, and hearing impairment	Provide tool-use training and require gloves and hearing protection.	PPE standardization and pre-use equipment inspection.
		Protruding ship structure components	Collision injury	Improve workplace layout and require safety helmet use.	Designated walkways, obstacle-free access routes, warning signs, and worker vigilance.
		Working at height without protection	Falls from height	Use scaffolding and guardrails, implement work-at-height procedures, and wear safety harnesses and helmets.	Removal of obstacles, organized elevated work areas, work-at-height procedures, and mandatory fall protection.
4	Upper Structure Assembly	Poorly arranged materials and tools	Collision or tripping	Provide dedicated storage areas, maintain clear walkways, and enforce workplace organization.	Organized storage, routine cleaning, standardized workplace layout, and worker discipline.
		Welding sparks and arc light exposure	Eye injury and burns	Install welding screens, implement welding procedures, and use appropriate welding PPE.	Designated welding areas, warning signage, PPE enforcement, and pre-work safety briefings.
		Fiberglass dust exposure	Respiratory and eye disorders	Apply wet sanding methods, provide local exhaust ventilation, and require respirators and goggles.	Routine dust removal, mandatory respiratory protection, and dust hazard signage.
5	Surface Sanding	Prolonged bending or squatting posture	Musculoskeletal injury	Provide ergonomic workstations and regulate work-rest schedules.	Improved work positioning, ergonomic work standards, and scheduled rest periods.
		Noise from power tools	Hearing impairment	Limit noise exposure duration and require earplugs or earmuffs.	Hearing protection requirements, noise warning signs, and PPE compliance.

In the sub-assembly workshop, the proposed risk controls are similarly directed toward administrative measures, engineering controls, PPE utilization, and implementation of the 5S principles to improve workplace safety and efficiency. Because most identified hazards originate from manual operations and production-related activities, elimination or substitution cannot be effectively applied. Consequently, risk reduction is achieved through better work procedures and environmental management. For instance, risks associated with structural assembly can be minimized by improving lifting techniques, enhancing worker coordination, and arranging materials according to the Seiri and Seiton principles to reduce obstruction in work areas. Chemical exposure and fiberglass dust generated during reinforcement and sanding activities are controlled through mandatory

PPE usage, routine cleaning practices (Seiso), and standardized work procedures (Seiketsu). In addition, hazards related to welding operations, electrical equipment, and working at height require regular equipment inspections, appropriate protective devices, and continuous worker awareness (Shitsuke) to ensure consistent safety practices. These recommendations demonstrate that combining the ISO 45001 hierarchy of controls with the 5S concept can provide a more comprehensive approach to occupational risk mitigation. Compared with the fabrication workshop, risk control in the sub-assembly workshop requires greater emphasis on coordination among workers and adherence to standardized work procedures due to the more complex nature of assembly, welding, and work-at-height activities.



Figure 3. Recommended visual controls for 5S and workplace safety.
(Source: Developed by the Authors, 2026)

The proposed control measures indicate that most recommendations are focused on administrative controls, consistent use of personal protective equipment, and workplace organization through the implementation of the 5S concept based on the risk priorities identified by the FMEA analysis. Previous studies have also reported that the implementation of Occupational Safety and Health Management Systems (OSHMS) in many industries is often not yet optimal, highlighting the importance of integrating management systems with workplace organization and worker discipline [12, 14, 17, 20, 25]. Therefore, the proposed controls are expected to support the implementation of ISO 45001:2018 while strengthening the 5S concept to create a safer and more organized working environment, thereby reducing the likelihood of occupational accidents and work-related health problems. The predominance of administrative and organizational controls also reflects the practical conditions of fiberglass shipbuilding, where many production activities cannot be eliminated or substituted because they constitute essential stages of the manufacturing process. Previous studies have also demonstrated that 5S implementation contributes to workplace efficiency, cleanliness, and overall work performance improvement [8, 11, 15, 17, 22].

The present findings further demonstrate that integrating FMEA-based risk prioritization with the ISO 45001:2018 hierarchy of controls and the 5S concept provides a more systematic framework for selecting control measures according to the characteristics and

priority level of each occupational hazard. Unlike previous studies, which generally focused on individual safety management approaches, this study combines risk assessment, control prioritization, and workplace organization into an integrated occupational safety management strategy for fiberglass shipbuilding [2, 8, 25].

Building upon these results, this study demonstrates that integrating FMEA, ISO 45001, and the 5S concept provides a more comprehensive framework for occupational risk management. FMEA enables systematic prioritization of occupational hazards, ISO 45001 provides a structured basis for selecting appropriate control measures, while the 5S concept supports practical implementation through workplace organization and continuous improvement [2, 8, 25]. This integrated approach represents the main contribution of the present study to occupational safety management in fiberglass shipbuilding.

The integration of ISO 45001:2018 and the 5S concept demonstrates that effective occupational risk control is not limited to engineering improvements or PPE usage alone. Workplace organization and worker discipline contribute substantially to reducing exposure to occupational hazards by supporting the consistent implementation of control measures. Therefore, the proposed framework provides a practical approach for translating risk assessment results into sustainable workplace safety practices [1, 14, 17, 25].

IV. CONCLUSION

This study successfully identified occupational hazards, assessed occupational risks using the Failure Mode and Effect Analysis (FMEA) method, and developed integrated risk control recommendations based on ISO 45001:2018 supported by the 5S concept for the fabrication and sub-assembly workshops of PT. Blambangan Bahari Shipyard. The hazard identification stage revealed 21 potential hazards in the fabrication workshop and 19 potential hazards in the sub-assembly workshop, resulting in 40 identified occupational hazards. The identified hazards originated from physical, chemical, ergonomic, electrical, and workplace organization factors, indicating that occupational accident risks in fiberglass shipbuilding are influenced not only by technical production activities but also by workplace organization and worker behavior.

The FMEA-based risk assessment successfully prioritized occupational hazards according to their Risk Priority Number (RPN). In the fabrication workshop, the assessment identified 17 low-priority risks and 4 high-priority risks, while no medium-priority risks were found. In the sub-assembly workshop, 13 low-priority risks, 2 medium-priority risks, and 4 high-priority risks were identified. Overall, the assessment produced 30 low-priority risks, 2 medium-priority risks, and 8 high-priority risks. The highest-priority risks were associated with repetitive use of electrical equipment, fiberglass dust exposure, workplace noise, welding activities, and electrical hazards because these hazards were characterized by relatively high Severity and Detection scores. According to these results, demonstrate that the FMEA method provides a systematic and objective approach for prioritizing occupational risks and determining the urgency of corrective actions.

Based on the identified risk priorities, integrated occupational risk control recommendations were formulated by applying the ISO 45001:2018 hierarchy of controls and supported by the implementation of the 5S concept. The proposed controls emphasize engineering improvements where feasible, administrative controls, consistent use of personal protective equipment (PPE), workplace organization, housekeeping, standardization, and continuous worker discipline. The integration of FMEA, ISO 45001:2018, and the 5S concept represents the main contribution of this study by providing a comprehensive occupational risk management framework that combines systematic risk prioritization with practical workplace organization strategies. Therefore, the proposed recommendations are expected to support safer, cleaner, and more organized working environments while improving occupational safety management practices in fiberglass shipbuilding industries.

This study was limited to the fabrication and sub-assembly workshops of a single fiberglass shipyard and involved a limited number of respondents. Future studies are recommended to include additional shipbuilding processes, involve multiple shipyards, and evaluate the effectiveness of the proposed control measures after implementation to further validate the applicability of the integrated framework under different industrial conditions.

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