



## **Analysis of Occupational Safety and Health Risks in Wharf Structure Rehabilitation Using JSA and HIRARC Methods**

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**Abstract**

**Background:** Jetty rehabilitation combines overwater work, heavy equipment, suspended loads, demolition, temporary access, and changing marine conditions. These interacting factors create substantial occupational risks and require systematic hazard identification and risk assessment to establish appropriate controls.

**Objective:** This study identifies task-level hazards using *Job Safety Analysis (JSA)*, classifies the identified risks using *Hazard Identification, Risk Assessment and Risk Control (HIRARC)*, establishes control priorities, and formulates mitigation recommendations for the rehabilitation of Kijing Port Regional II.

**Methods:** A descriptive case study used a semi-quantitative risk assessment supported by field observations, interviews, and project documents. *JSA* decomposed the rehabilitation activities and identified hazards; *HIRARC* then assessed likelihood and severity to determine risk levels and control priorities. Ratings were validated through triangulation, expert judgment, and consistency checks against occupational safety and health requirements and project procedures.

**Results:** The study identified 32 hazards across eleven work-activity groups. Low, medium, high, and extreme risks accounted for 3.1%, 31.3%, 53.1%, and 12.5%, respectively. High and extreme risks were concentrated in overwater access, lifting and heavy-equipment operations, concrete demolition, and steel pipe pile work.

**Conclusion:** Sequential *JSA-HIRARC* analysis linked task-level hazards to risk priorities and activity-specific controls. High and extreme risks require strengthened engineering and administrative controls, supported by appropriate personal protective equipment and continuous supervision.

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### **INTRODUCTION**

Jetty rehabilitation is a high-risk form of maritime construction because work is performed at the interface between land and water, while heavy equipment, suspended loads, demolition activities, temporary access systems, and piling operations may occur within the same work environment. In addition to conventional construction hazards, workers are exposed to changing tides, waves, wind, humid conditions, restricted movement space, and the possibility of falling into the water. These characteristics can increase the consequences of struck-by, caught-between, electrical, noise, vibration, and overwater-access hazards. Therefore, Occupational Safety and Health (OHS) management must be based on systematic task-level hazard identification and risk prioritization rather than on general construction controls alone (Bourahla et al., 2024; Dewi et al., 2022; Kaup et al., 2022; Yunanto et al., 2024).

PT Pelabuhan Indonesia (Persero) Regional II, located in Mempawah Regency, West Kalimantan Province, is one of the State-Owned Enterprises (SOEs) that plays an important role in providing port services, particularly logistics services, container loading and unloading, and the handling of liquid bulk cargoes such as Crude Palm Oil (CPO). The existence of Kijing Port as one of the national strategic projects makes the region highly important for supporting distribution and trade activities at both the regional and national levels. Along with the increasing intensity of operational activities and the growing demand for service capacity, reliable and safe port infrastructure is essential, one component of which is the rehabilitation of wharf structures. Based on the Work Plan and Conditions (RKS), the rehabilitation work includes complex and high-risk activities, such as steel pipe pile installation, pile head treatment, deck and pier beam construction, and work conducted in the water area. These activities involve the use of heavy equipment and work over water and are strongly influenced by marine environmental conditions, including weather, waves, and tides (I, 2025). This condition indicates that the wharf structure rehabilitation project at Kijing Port not only has strategic value for port operations but also presents significant potential hazards to occupational safety and health. Therefore, the implementation of a planned and measurable OHS management system is essential to ensure worker safety, prevent occupational accidents, and maintain the continuity and smooth execution of the project. This study uses the rehabilitation of the Jetty 03 Dry Bulk Pier at the Kijing Terminal of PT Pelabuhan Indonesia (Persero) Regional II as a case study. The research location was selected based on the characteristics of the work, which involve the dismantling of existing structures, concrete drilling, concrete demolition, material removal using heavy equipment, and the erection and installation of steel pipe piles in areas directly adjacent to the water. These characteristics indicate a high level of OHS risk, making the project suitable as a research object for the application of Job Safety Analysis (JSA) and Hazard Identification, Risk Assessment and Risk Control (HIRARC) methods.

In practice, OHS implementation in port and construction environments may still be constrained by incomplete hazard identification at specific work stages, inconsistent personal protective equipment (PPE) compliance, and control measures that are not always adjusted to changing field conditions. These weaknesses are particularly consequential in rehabilitation work involving lifting operations, demolition, heavy equipment, temporary pontoon access, and work near open water because the hazard profile can change as equipment positions, weather conditions, tides, and work sequences change. Evidence from port workers also shows that PPE compliance cannot be assumed to be adequate without supporting knowledge and organizational controls, while learning from incidents can strengthen safety performance when corrective actions are consistently integrated into work practices (Alifandy & Astuti, 2024; Chan et al., 2023; Devianti et al., 2022; Latifah et al., 2023).

Job Safety Analysis (JSA) is used in this study as the first, task-level stage of the risk analysis. The rehabilitation process is decomposed into eleven major work activity groups: work-area preparation; pontoon mooring and unmooring; equipment mobilization and setup; field survey and measurement; concrete cutting; concrete drilling; concrete demolition; reinforcement cutting; material lifting and removal; steel pipe pile mobilization and positioning; and steel pipe pile installation or driving. For each activity group, JSA is used to identify the work step, potential hazard, possible consequence, and existing controls before a risk score is assigned. This task decomposition is consistent with the strength of JSA in identifying hazards at the operational level, although previous literature also notes that JSA alone does not always provide a standardized basis for ranking risk priorities (Adilla et al., 2025; Andriana et al., 2025; Ghasemi et al., 2023).

Hazard Identification, Risk Assessment and Risk Control (HIRARC) is then applied sequentially to the hazards identified through the JSA, rather than being used as a parallel and independent method. Each JSA-identified hazard becomes an input to the HIRARC assessment, in which likelihood and severity are evaluated and combined to determine the risk category and the urgency of control measures. Previous HIRARC studies have demonstrated the usefulness of this approach for prioritizing hazards in girder erection, dam construction, and port-equipment operations; however, those applications generally begin with an existing hazard list and do not explicitly trace each risk rating back to a detailed JSA breakdown of rehabilitation tasks (Aninditya et al., 2023; Rumondor et al., 2024; Wong et al., 2022).

Previous research provides important but still fragmented evidence for the present problem. A jetty-project review identified technical and environmental risk sources such as water level, weather, installation methods, and design conditions, but it did not provide a task-by-task JSA-to-HIRARC assessment for an ongoing rehabilitation project (Aung et al., 2023; Dewi et al., 2022; Lafhaj et al., 2024;

[Yussif et al., 2025](#)). A port-berth case study applied hazard identification and risk assessment to construction activities, while a systematic review of JSA highlighted the method's value for detailed hazard recognition, together with limitations in standardized risk ranking ([Ghasemi et al., 2023](#); [Mahapatra & Kushwaha, 2020](#)). This creates a research gap in demonstrating a traceable sequence from detailed task-level hazard identification to risk prioritization under changing marine conditions during jetty rehabilitation. Accordingly, this study integrates JSA as the hazard-identification stage and HIRARC as the subsequent semi-quantitative risk-assessment stage to identify and classify OHS risks, establish priorities for high and extreme risks, and formulate mitigation recommendations that can be directly linked to the relevant rehabilitation activities. The contribution of the study is therefore both methodological, through the explicit JSA-HIRARC workflow, and practical, through activity-specific control priorities for the Kijing Terminal Jetty 03 Dry Bulk rehabilitation project.

## METHOD

This study employed a descriptive case-study design with a semi-quantitative risk assessment supported by qualitative field evidence. It was not purely qualitative because each identified hazard was assigned ordinal likelihood and severity values that were combined to produce a numerical risk score, while observations, interviews, and project documents were used to identify hazards and interpret the work context. The case was the rehabilitation of Jetty 03 Dry Bulk at Kijing Terminal, PT Pelabuhan Indonesia (Persero) Regional II, Mempawah Regency, West Kalimantan. The site was selected because the project combines existing-structure demolition, temporary access over water, heavy-equipment movement, material lifting, steel pipe pile positioning and driving, and direct exposure to marine environmental conditions; these characteristics make it an information-rich case for assessing occupational safety and health (OHS) risks in jetty rehabilitation. The analysis covered eleven major work activity groups: work-area preparation; pontoon mooring and unmooring; equipment mobilization and setup; field surveying and measurement; concrete cutting; concrete drilling; concrete demolition; reinforcement cutting; material lifting and removal; steel pipe pile mobilization and positioning; and steel pipe pile installation or driving. Research participants included the Project Manager, HSE Officer, Site Engineer/Site Supervisor, foremen, and field workers. Data were collected from mid-April to early May 2026 through observations, interviews, Job Safety Analysis (JSA) and Hazard Identification, Risk Assessment, and Risk Control (HIRARC) forms, and project and OHS documents, using observation sheets, interview guides, JSA forms, HIRARC forms, and project technical documents as research instruments. Participants were selected purposively based on their direct involvement in the rehabilitation work or their responsibility for OHS implementation, technical supervision, and field execution.

The analysis followed a sequential workflow without testing relationships between variables. First, each rehabilitation activity was broken down using JSA to identify potential hazards, their causes or exposure conditions, possible consequences, and existing controls. Second, every identified hazard was transferred to the HIRARC assessment and rated using likelihood and severity parameters; the product of the two values determined the risk score and risk category. Third, the resulting risk categories were used to establish control priorities and formulate recommendations with reference to the hierarchy of controls, including elimination or substitution where feasible, engineering controls, administrative controls, and personal protective equipment (PPE). Data credibility was strengthened through expert judgment; triangulation of observations, interviews, and project documents; comparison with applicable OHS requirements and project standard operating procedures (SOPs); and internal consistency checks between the JSA hazard descriptions, HIRARC ratings, and recommended controls. This sequence provides a transparent link from field evidence to hazard identification, risk ranking, and mitigation recommendations. For each likelihood and severity rating, observational evidence was cross-checked against interview explanations and project records; inconsistencies were reviewed with the relevant project personnel and checked against applicable OHS requirements and project SOPs before the final rating was retained.

## RESULTS AND DISCUSSION

### Results

#### Overview of Research Locations

This research was conducted on the structural rehabilitation work of Jetty 03 Dry Bulk Pier in

the Kijing Port area of PT Pelabuhan Indonesia (Persero) Region II, Mempawah Regency, West Kalimantan. The pier serves as a supporting facility for dry bulk loading and unloading activities. The work environment is located in an open area directly adjacent to the water and is therefore affected by tides, waves, wind, humidity, and weather changes, resulting in a high level of safety risk. The rehabilitation work includes preparation of the work area, concrete drilling, concrete demolition, material removal, welding and cutting of reinforcement, and preparation for pile installation with the support of various types of heavy and mechanical equipment. Based on field observations, the work area has limited space for movement, a partially uneven surface due to exposure to seawater and residual materials, and direct exposure to environmental conditions, thereby increasing the potential for hazards to workers and making the implementation of Occupational Safety and Health (K3) a critical aspect of project execution.

Visual documentation at each stage of the work—including work-area preparation, equipment mobilization, pontoon mooring and unmooring, concrete cutting, concrete drilling, concrete demolition, reinforcement cutting, material removal, mobilization and positioning of steel pipe piles, and pile driving—was collected during field observations. Given the limitations in the resolution and size of the images that can be displayed individually, the documentation is summarized as a narrative description in the following sections, while the complete photographic documentation is available in the research documentation file.

In addition to structural observations, inspections were conducted on work access and worker-mobilization systems to the work area on the working pontoon. Access to the pontoon is provided by a temporary working ladder connecting the pier to the pontoon in the marine work area. This condition requires special attention because pontoon movement caused by waves and tides can increase the risk of workers falling into the water if safe work procedures are not properly implemented. Considering that the rehabilitation activities are carried out not only on the pier surface but also over water and require temporary access, the condition of work access is an important factor affecting both work execution and occupational safety and health during the construction process.

Access to the working pontoon is provided by a temporary ladder connecting the pier structure to the pontoon used as the work platform. Based on field observations, workers use this access route while carrying work equipment, while pontoon movement caused by waves and tides creates changes in elevation between the pier and the pontoon that may result in slipping, loss of balance, or falling into the water. Therefore, before work begins, the condition of the ladder must be inspected, access routes must be properly arranged, and safe work procedures must be implemented as part of risk control. In addition, observations focused on the condition of the existing concrete structure to identify damaged components as a basis for determining the type of rehabilitation work required at the subsequent stage.

The observations showed that some portions of the concrete structure had deteriorated, as indicated by damage to the concrete surface, cracking, and degradation of concrete components. This condition indicates that the structural elements require rehabilitation to maintain their serviceability in accordance with the operational function of the pier. The findings at this observation stage provide the basis for preparing work methods, beginning with concrete cutting, concrete drilling, and concrete demolition, followed by subsequent structural repair work. In addition to serving as a technical reference for rehabilitation activities, these existing conditions are also used as a basis for identifying potential hazards using the Job Safety Analysis (JSA) method because each type of damage and its corresponding repair method has different safety-risk characteristics.

### **Implementation of Pier Structure Repair Work**

The rehabilitation of the pier structure is carried out in stages according to the construction method and the condition of the existing structure, including preparation of the work area, equipment mobilization, concrete drilling, concrete demolition, welding and cutting of reinforcement, material removal, and preparation for pile installation using a diesel hammer. The work is conducted within an operational port environment and therefore requires coordination with loading and unloading activities. Some work is also performed at the edge of the pier and over water, where the level of safety risk is high. Concrete demolition and debris removal are conducted during both daytime and nighttime, with additional lighting provided; however, nighttime conditions may still reduce visibility and increase occupational risks. The use of heavy equipment and mechanical equipment, combined with working conditions in marine areas, makes the implementation of Occupational Safety and Health (K3) procedures at every stage of the work essential for minimizing the potential for occupational accidents.

### **Work Area Preparation and Equipment Mobilization**

The initial stages of the work began with preparation of the work area and mobilization of construction equipment to the work site. At this stage, the work area was organized, materials were placed in designated locations, work access was inspected, and equipment positions were adjusted to suit field conditions in the pier area. The equipment used in the structural rehabilitation work includes cranes, core drilling machines, jackhammers, welding equipment, steel slings, and various other auxiliary equipment used to support construction activities in the pier area.

In addition to equipment mobilization, preparations were made for a lifting system using cranes to support the lifting of materials and work equipment in the pier area.

Before the lifting process is carried out, workers arrange the slings and crane hook to ensure that the lifting system is in a safe condition and ready for use during the work activity.

### **Implementation of Concrete Drilling Work**

Concrete drilling was carried out as part of the rehabilitation of the existing concrete structures in the pier area to create drilling points according to the technical requirements of the rehabilitation and structural demolition work. The work was performed using a core drilling machine with a gradual drilling method to maintain the accuracy of the drilling points and minimize damage to the surrounding structure. Before work began, the drilling-point locations were verified, the work-area conditions were inspected, the readiness of the equipment was checked, and work-safety procedures were implemented under the supervision of the field supervisor, considering that the work takes place in the pier area directly adjacent to the water. This stage aims to ensure that the drilling process is performed in accordance with the work method while minimizing potential risks during execution.

After the drilling points were determined, concrete drilling was carried out using a core drilling machine to create holes in the existing concrete according to the planned dimensions. This method was selected because it can produce holes with a high degree of precision while minimizing damage to concrete outside the designated work area. During drilling, water is used as a cooling medium for the drill bit and also helps reduce dust generated during the work.

Field observations documented the existing concrete-drilling process using a core drilling machine in the jetty slab area. The work was performed in stages while considering the drilling position, concrete surface condition, and equipment stability. Because the work site was exposed to marine weather and high humidity, particular attention was given to electrical installations, equipment condition, and workers' compliance with personal protective equipment requirements.

### **Implementation of Existing Concrete Demolition**

After concrete drilling was completed, the existing concrete was demolished to remove damaged concrete and expose the reinforcement as part of the rehabilitation of the pier structure. The work was carried out in stages using a jackhammer within predetermined areas so that demolition could be controlled, damage to structurally sound portions could be minimized, and the condition of the existing concrete and reinforcement could be more easily inspected. Because the work was performed in a pier area directly adjacent to the water, potential hazards included vibration, dust, noise, and the risk of working near the pier edge. Therefore, adequate Occupational Safety and Health (K3) controls were required.

### **Implementation of Steel Pipe Pile Piling Work**

Steel pipe pile driving is a major stage of the pier-structure rehabilitation work intended to increase the capacity and reliability of the existing structure. After preparation of the work area and removal of obstructing structural elements, setting out is performed using surveying equipment to ensure that the pile positions correspond to the planned locations. The steel pipe piles are lifted by crane and gradually driven from the working pontoon until they reach the required depth or bearing capacity, while their position and verticality are continuously monitored. The work is influenced by waves, currents, tides, and weather conditions and involves crane operations, welding of pile joints, and material lifting. From the perspective of Occupational Safety and Health (K3), this work presents a high level of risk because it involves heavy equipment, suspended loads, work over water, and the potential for workers to fall, be struck by materials, become caught or pinched, or be exposed to high noise levels. Therefore, adequate supervision, implementation of safe work procedures, use of personal protective

equipment, and proper work-area organization are necessary to minimize the risk of accidents.

Before pile driving begins, the position, alignment, and verticality of the steel pipe piles are checked using surveying equipment to ensure that their coordinates, orientation, and verticality conform to the design drawings and remain within the permissible tolerance limits. This stage is important to ensure integration of the rehabilitation structure with the existing pier and to prevent load eccentricity caused by pile inclination. During the positioning process, measurements are repeated until a position that meets the technical requirements is achieved. This activity involves interaction among workers, surveying instruments, and heavy equipment in the pier-side work area and therefore has the potential to cause hazards such as tripping over materials, exposure to moving heavy equipment, or falling into the water. Adequate supervision and work-area control are therefore required to ensure safe execution.

After the position and verticality of the steel pipe pile are confirmed to be acceptable, pile driving is performed from the working pontoon until the planned depth and required bearing capacity are achieved. During implementation, the position and verticality of the piles are continuously monitored to ensure the quality of the work, considering field conditions, soil characteristics, and equipment stability. Work over water is also affected by weather, waves, and tides and therefore requires effective coordination among personnel. From the perspective of Occupational Safety and Health (K3), pile driving is a high-risk activity because it involves heavy equipment, suspended loads, and workers operating around the pile-driving area. These potential hazards are therefore the focus of further analysis using the Job Safety Analysis (JSA) and Hazard Identification, Risk Assessment and Risk Control (HIRARC) methods.

Welding work and adjustment of steel components are performed to support steel pipe pile installation, including pile splicing, installation of supporting elements, and adjustment of component positions according to field requirements. The work is conducted after inspection of the materials and verification of work-area readiness and is performed by competent workers in accordance with established procedures to ensure the quality of the connections and structural performance. From the perspective of Occupational Safety and Health (K3), this activity presents potential hazards in the form of sparks, arc radiation, high temperatures, fire, and electrical hazards associated with welding equipment and electrical cables. Therefore, the work area must be properly organized, equipment must be inspected, and appropriate work procedures must be implemented to minimize the risk of accidents.

The steel pipe pile driving work is supported by a generator set as a source of electrical power, a welding machine for welding steel components, and a total station for surveying and controlling pile positions according to the design coordinates. Although this equipment supports efficient work execution, its use presents potential hazards such as electrical hazards, noise, cable-related trip hazards, and contact with moving equipment. Therefore, proper work-area organization, equipment inspection, and implementation of Occupational Safety and Health (K3) procedures are necessary. Overall, the rehabilitation of the pier structure includes work-area preparation, concrete drilling, concrete demolition, and steel pipe pile installation, involving heavy equipment, work over water, and material removal with various potential hazards. Therefore, hazard identification is performed using the Job Safety Analysis (JSA) method, and the results are analyzed using the HIRARC method to determine risk levels and control priorities for each work activity.

### **Hazard Identification Using the Job Safety Analysis (JSA) Method**

Hazard identification is the initial stage of risk management and aims to identify all potential hazards associated with rehabilitation work on the pier structure. In this study, hazard identification was performed using the Job Safety Analysis (JSA) method by breaking down each work activity to identify potential hazards, their impacts, and the necessary control measures. The analysis is based on field observations, documentation, discussions with project personnel, and Occupational Safety and Health (K3) documents. The activities analyzed include work-area preparation, pontoon mooring and unmooring, equipment mobilization, concrete cutting, concrete drilling, concrete demolition, reinforcement cutting, material removal, and steel pipe pile mobilization. The characteristics of work over water create various potential hazards, including mechanical hazards, falls into the water, noise, vibration, dust, electrical hazards, ergonomic hazards, and environmental pollution. The identification results show that concrete demolition, material removal, and steel pipe pile handling activities have greater complexity and risk and therefore require more detailed hazard identification as the basis for risk assessment and determination of control measures.

### Hazard Identification Results Based on Work Activities

Hazard identification in this study was performed using the Job Safety Analysis (JSA) method by dividing the rehabilitation of Jetty 03 Dry Bulk Pier at Kijing Terminal into eleven major work-activity groups: work-area preparation; pontoon mooring and unmooring; equipment mobilization and setup; field survey and measurement; concrete cutting; concrete drilling; concrete demolition; reinforcement cutting; material lifting and removal; steel pipe pile mobilization and positioning; and steel pipe pile installation or driving. Each activity has different hazard characteristics according to the work method, equipment, and environmental conditions, including mechanical, physical, electrical, ergonomic, and overwater-work hazards. Concrete demolition, material lifting, and steel pipe pile handling present greater hazard complexity because they combine heavy equipment, suspended loads, dust, noise, vibration, restricted access, and proximity to open water. All hazards identified through JSA were subsequently assessed using HIRARC by evaluating likelihood and severity to determine the risk level and appropriate control priority for each activity.

### Risk Assessment Using Hazard Identification, Risk Assessment and Risk Control (HIRARC) Method

After all potential hazards associated with each work activity are identified using the Job Safety Analysis (JSA) method, the next stage is risk assessment using the Hazard Identification, Risk Assessment and Risk Control (HIRARC) method. The hazard-identification results from JSA serve as the basis for risk assessment by evaluating each potential hazard according to its likelihood of occurrence and the severity of its consequences rather than immediately treating the identified hazard as a control recommendation. Through HIRARC, the risk level of each potential hazard is calculated to determine control priorities according to the level of risk, rather than merely the existence of a potential hazard. Thus, JSA functions to identify hazards at each stage of pier rehabilitation work, while HIRARC evaluates the level of risk. The assessment results therefore not only indicate the magnitude of risk associated with each work activity but also provide a basis for developing Occupational Safety and Health (K3) control recommendations for the rehabilitation of the Kijing Terminal Jetty 03 Dry Bulk Pier structure.

### Determination of Likelihood Value

The likelihood value in this study was assessed for each potential hazard identified through the JSA method. The determination of the likelihood value considers not only the frequency of possible occurrence but also actual field conditions, the intensity of workers' exposure to the hazard source, and the characteristics of each work activity. Therefore, activities involving work over water, the use of heavy equipment, and material-removal processes tend to receive higher likelihood values than activities involving lower levels of exposure.

**Table 1**  
**Likelihood Assessment Criteria**

| Value | Criteria              | Description                                                                             |
|-------|-----------------------|-----------------------------------------------------------------------------------------|
| 1     | <i>Rare</i>           | Very rare and almost never found during the course of the work                          |
| 2     | <i>Unlikely</i>       | The possibility of happening is small but it is still possible under certain conditions |
| 3     | <i>Possible</i>       | Can happen at any time during the work                                                  |
| 4     | <i>Likely</i>         | It happens frequently and has a high chance of appearing during the job                 |
| 5     | <i>Almost Certain</i> | It is almost certain that it will happen if no control is carried out                   |

Based on the criteria in Table 1, the likelihood value is assigned by considering the characteristics of each work activity. Activities involving frequent exposure and direct interaction with hazard sources receive higher likelihood values than supporting activities with relatively limited exposure. The assessment is then combined with the severity parameter to determine the risk level of each potential hazard.

### Determination of Severity Values

In this study, the severity value is determined not only based on potential injury to workers but

also by considering the impact on work continuity, equipment damage, and consequences for the work environment in the pier area. Thus, activities with the potential to cause serious injury or significant disruption to project operations receive higher severity values than activities with relatively minor impacts.

**Table 2**

*Severity Assessment Criteria*

| Value | Criteria      | Description                                                             |
|-------|---------------|-------------------------------------------------------------------------|
| 1     | Insignificant | Does not cause injury and does not interfere with work                  |
| 2     | Minor         | Minor injuries that can be treated with first aid                       |
| 3     | Moderate      | Injuries that require medical attention and cause work disruption       |
| 4     | Major         | Severe injury, temporary disability, or significant material loss       |
| 5     | Catastrophic  | Fatality, permanent disability, or major material or environmental loss |

The criteria in Table 2 are used as a reference for determining the severity of each identified potential hazard. The assessment is performed consistently across all work activities so that the evaluation results can be compared objectively when determining the risk level.

### Risk Assessment Matrix

The risk level is determined by combining the likelihood and severity values through a risk matrix. The combination of these two parameters produces a risk value that represents the level of control priority for each potential hazard identified using the JSA method.

$$\text{Risk Level} = \text{Likelihood} \times \text{Severity}$$

The resulting values are then mapped onto a risk matrix to determine the risk category of each hazard. The risk matrix is used to group risks according to the level of control priority required.

**Table 3**

*Risk Matrix*

| Severity / Likelihood | 1 | 2  | 3  | 4  | 5  |
|-----------------------|---|----|----|----|----|
| 5                     | 5 | 10 | 15 | 20 | 25 |
| 4                     | 4 | 8  | 12 | 16 | 20 |
| 3                     | 3 | 6  | 9  | 12 | 15 |
| 2                     | 2 | 4  | 6  | 8  | 10 |
| 1                     | 1 | 2  | 3  | 4  | 5  |

The higher the product of the likelihood and severity values, the higher the control priority that must be applied. Conversely, a lower risk value indicates that the potential hazard may be controlled through work procedures, routine supervision, and other measures in accordance with applicable occupational safety regulations.

**Table 4**

*Distribution of Risk Values Identified*

| Risk Categories | Risk Value Range | Number of Potential Hazards | Percentage (%) |
|-----------------|------------------|-----------------------------|----------------|
| Low Risk        | 1 – 4            | 1                           | 3.1%           |
| Medium Risk     | 5 – 9            | 10                          | 31.3%          |
| High Risk       | 10 – 16          | 17                          | 53.1%          |
| Extreme Risk    | 17 – 25          | 4                           | 12.5%          |
| Total           | –                | 32                          | 100%           |

Source: Research data processing results, 2026

Based on Table 4, 53.1% of the 32 identified hazards are classified as high risk, 31.3% as medium risk, 12.5% as extreme risk, and 3.1% as low risk. Thus, 65.6% of the identified hazards fall within the high- and extreme-risk categories and require prioritized control. The four extreme-risk hazards are

associated with workers falling into the sea, falling from the pier edge during measurement, concrete collapse during demolition, and lifting or pile-driving activities involving steel pipe piles. Because these hazards can result in fatal or severe consequences, work should not proceed until the required controls have been verified and consistently implemented.

### Risk Level Classification

Based on this classification, all potential hazards in this study are grouped into low-, medium-, high-, and extreme-risk categories. This grouping provides the basis for preparing risk-control recommendations so that control actions correspond to the priority of each hazard. High and extreme risks require more immediate intervention than low and medium risks. The risk-level classification criteria used in this study are presented in Table 5.

**Table 5**

*Risk Level Category*

| Risk Assessment | Categories   | Actions                                                 |
|-----------------|--------------|---------------------------------------------------------|
| 1 – 4           | Low Risk     | Acceptable risk with regular control                    |
| 5 – 9           | Medium Risk  | Requires additional supervision and handling            |
| 10 – 16         | High Risk    | Requires immediate handling action                      |
| 17 – 25         | Extreme Risk | Unacceptable, work must be controlled before proceeding |

Based on the overall assessment process, each potential hazard identified through the Job Safety Analysis (JSA) method is evaluated using likelihood and severity parameters to determine the risk level associated with each work activity. The evaluation results provide the basis for determining control priorities so that risk-mitigation efforts can focus on activities with higher risk levels. With this approach, the hazard-identification and risk-assessment processes in this study form a series of interrelated analyses in which JSA serves as the basis for identifying potential hazards, while HIRARC is used to determine the risk level and control requirements for each pier-structure rehabilitation activity.

### Recapitulation of Risk Assessment Results

**Table 6**

*HIRARC Recapitulation of Dry Bulk Jetty 03 Pier Structure Repair Work*

| No | Activities                   | Potential Hazards                                | Impact                       | Existing Control              | L | S | R  | Control Recommendations                      | PJ                             |
|----|------------------------------|--------------------------------------------------|------------------------------|-------------------------------|---|---|----|----------------------------------------------|--------------------------------|
| 1  | Preparation of the work area | Slippery work surface due to seawater stagnation | Slipping and falling         | Housekeeping work area        | 3 | 3 | 9  | Regular cleaning of the area                 | Field Supervisor / HSE Officer |
| 2  | Preparation of the work area | Materials are scattered on the access road       | Tripping and minor injuries  | Material storage area setting | 3 | 2 | 6  | Pedestrian path marking                      | Field Supervisor / HSE Officer |
| 3  | Preparation of the work area | Prolonged exposure to hot weather                | Dehydration and work fatigue | Periodic breaks               | 3 | 2 | 6  | Provision of drinking water and shaded areas | Field Supervisor / HSE Officer |
| 4  | Pontoon fastening            | The mooring rope                                 | Serious injury from a rope   | Visual inspection of the rope | 3 | 4 | 12 | Replacement of damaged ropes                 | Field Supervisor               |

| N<br>o | Activities                | Potential<br>Hazards                                      | Impact                                                | Existing<br>Control                  | L | S | R  | Control<br>Recommendation<br>s                      | PJ                                     |
|--------|---------------------------|-----------------------------------------------------------|-------------------------------------------------------|--------------------------------------|---|---|----|-----------------------------------------------------|----------------------------------------|
|        |                           | breaks<br>when<br>receiving<br>the load                   | strike                                                |                                      |   |   |    |                                                     |                                        |
| 5      | Pontoon<br>fastening      | Workers<br>fall into<br>the sea                           | Drowning<br>or seriously<br>injured                   | Life Jacket                          | 4 | 5 | 20 | Lifeline and ring<br>buoy                           | Field<br>Supervisor                    |
| 6      | Pontoon<br>unmooring      | Finger<br>pinched<br>with the<br>mooring<br>rope          | Finger<br>injuries                                    | Work gloves                          | 3 | 3 | 9  | Socialization of<br>safe rope release<br>techniques | Field<br>Supervisor                    |
| 7      | Tool<br>mobilization      | Tool<br>dropped<br>when lifted                            | Worker<br>injuries and<br>appliance<br>breakdown<br>s | Use of slings                        | 3 | 4 | 12 | Lifting<br>equipment<br>inspection                  | Field<br>Supervisor /<br>Site Engineer |
| 8      | Tool<br>placement         | Pinched<br>hand when<br>positioning<br>the tool           | Finger and<br>hand<br>injuries                        | Foreman<br>supervision               | 3 | 3 | 9  | Use of handling<br>aids                             | Field<br>Supervisor                    |
| 9      | Tool<br>installation      | Broken<br>power<br>cord                                   | Electric<br>shock                                     | Cable<br>inspection                  | 3 | 4 | 12 | Uses of ELCB                                        | Site Engineer<br>/ Foreman             |
| 10     | Field<br>measurement<br>s | Falling off<br>the edge of<br>the pier                    | Serious<br>injury or<br>drowning                      | PPE and<br>supervision               | 3 | 5 | 15 | Lifeline<br>installation                            | Surveyor                               |
| 11     | Field<br>measurement<br>s | Tripping<br>over a<br>measuring<br>instrument             | Minor<br>injuries                                     | Housekeepin<br>g                     | 2 | 2 | 4  | Arrangement of<br>measurement<br>areas              | Surveyor /<br>Site Engineer            |
| 12     | Field Survey              | Exposure<br>to the<br>sun's heat                          | Heat stress                                           | Periodic<br>breaks                   | 3 | 2 | 6  | Adjustment of<br>working hours                      | Surveyor                               |
| 13     | Concrete<br>cutting       | Broken<br>blade                                           | Serious<br>injuries                                   | Protective<br>guard                  | 3 | 4 | 12 | Routine<br>inspection of<br>blades                  | Structure<br>Foreman                   |
| 14     | Concrete<br>cutting       | Inhaled<br>concrete<br>dust                               | Respiratory<br>disorders                              | Mask                                 | 4 | 3 | 12 | Suitable<br>respirator                              | Structure<br>Foreman                   |
| 15     | Concrete<br>cutting       | High noise                                                | Hearing<br>loss                                       | Ear plug                             | 4 | 3 | 12 | Noise Monitoring                                    | Structure<br>Foreman                   |
| 16     | Concrete<br>drilling      | Electric<br>shock from<br>equipment                       | Serious<br>injuries                                   | Grounding<br>and cable<br>inspection | 3 | 4 | 12 | ELCB and daily<br>inspection                        | Structure<br>Foreman                   |
| 17     | Concrete<br>drilling      | The<br>rotating<br>part of the<br>tool hits<br>the worker | Hand<br>wounds                                        | Work SOP                             | 3 | 4 | 12 | Additional Guard                                    | Structure<br>Foreman                   |
| 18     | Concrete                  | Slurry                                                    | Slipped                                               | Area                                 | 3 | 2 | 6  | Temporary                                           | Structure                              |

| No | Activities                   | Potential Hazards                                   | Impact                         | Existing Control                | L | S | R  | Control Recommendation           | PJ                        |
|----|------------------------------|-----------------------------------------------------|--------------------------------|---------------------------------|---|---|----|----------------------------------|---------------------------|
|    | drilling                     | causes slippery areas                               |                                | cleaning                        |   |   |    | drainage system                  | Foreman                   |
| 19 | Concrete demolition          | Concrete collapses                                  | Injuries sustained by material | Field surveillance              | 4 | 4 | 16 | Exclusion zone                   | Structure Foreman         |
| 20 | Concrete demolition          | Concrete dust                                       | Respiratory disorders          | Mask                            | 4 | 3 | 12 | Watering the work area           | Structure Foreman         |
| 21 | Concrete demolition          | Vibration of the appliance                          | Ergonomic disorders            | Employee rotation               | 3 | 2 | 6  | Working time restrictions        | Structure Foreman         |
| 22 | Cutting reinforcement        | Sparks                                              | Burns                          | Face shield                     | 3 | 3 | 9  | Fire watch                       | Structure Foreman         |
| 23 | Cutting reinforcement        | Eyes exposed to metal debris                        | Eye injury                     | Safety Glasses                  | 3 | 4 | 12 | Full face shield                 | Structure Foreman         |
| 24 | Cutting reinforcement        | Fire due to sparks                                  | Material loss                  | Fire extinguishers available    | 2 | 4 | 8  | Flammable Material-Free Area     | Structure Foreman         |
| 25 | Lifting material             | Falling material                                    | Fatal injury                   | Sling inspection                | 4 | 5 | 20 | Lifting plan                     | Structure Foreman         |
| 26 | Lifting material             | Worker hit by load swing                            | Serious injuries               | Signalman                       | 4 | 4 | 16 | Sterilization of lifting areas   | Rigger/Lifting Supervisor |
| 27 | Lifting material             | Lifting device failure                              | Damage and injury              | Appliance inspection            | 3 | 5 | 15 | Periodic appliance certification | Rigger/Lifting Supervisor |
| 28 | Steel pipe pile mobilization | Lifted load falls                                   | Fatal injury                   | Inspection of slings and cranes | 4 | 5 | 20 | Verified Lifting Plan            | Field Supervisor          |
| 29 | Steel pipe pile positioning  | Workers are sandwiched between poles and structures | Serious injuries               | Signalman surveillance          | 4 | 4 | 16 | Establish a safe zone            | Surveyor                  |
| 30 | Steel pipe pile driving      | Workers are within the machine's radius             | Hit by heavy equipment         | Safety briefing                 | 4 | 5 | 20 | Full HSE oversight               | Designated Supervisor     |
| 31 | Steel pipe pile driving      | Failure of lifting joints                           | Falling load                   | Rigging inspection              | 3 | 5 | 15 | Pre-lifting inspection           | Designated Supervisor     |
| 32 | Steel pipe pile driving      | Noise and vibration of the pile                     | Hearing loss                   | Ear plug                        | 4 | 3 | 12 | Noise Monitoring                 | Designated Supervisor     |

Source: Results of JSA-HIRARC identification and assessment, 2026. Color captions in column R: red =

*extreme risk, yellow = high/medium risk, green = low risk.*

Table 6 shows that the principal control priorities are concentrated in overwater access, material lifting and heavy-equipment operations, concrete demolition, and steel pipe pile mobilization, positioning, and driving.

High and extreme risks account for 65.6% of all identified hazards. This pattern indicates that control resources should first address activities that combine frequent exposure with severe consequences, while lower risks remain subject to routine procedures, housekeeping, supervision, and appropriate PPE.

### **Risk Control Based on HIRARC Results**

Based on the results of hazard identification using Job Safety Analysis (JSA) and risk assessment using Hazard Identification, Risk Assessment and Risk Control (HIRARC), each activity in the rehabilitation of Jetty 03 Dry Bulk Pier at Kijing Terminal has a different level of risk according to the characteristics of the work, environmental conditions, and equipment used. Therefore, risk controls are structured according to the hierarchy of controls, prioritizing engineering controls, administrative controls, and the use of personal protective equipment (PPE), as appropriate to the field conditions. The assessment results show that work over water, material removal using heavy equipment, demolition of existing concrete, and steel pipe pile driving are the highest-risk activities and therefore require strict work procedures, continuous supervision, and worker compliance with K3 requirements. Meanwhile, activities with moderate risk levels require greater emphasis on strengthening work procedures, field supervision, and control of work-area conditions. These findings show that the effectiveness of controls depends on the suitability of the selected control measures for the level of risk and the consistency with which they are implemented during work execution.

### **Discussion**

#### **Discussion of the Results of K3 Risk Analysis on Pier Structure Repair Work**

The risk pattern identified in the Jetty 03 Dry Bulk rehabilitation project is closely related to the interaction between the work methods and the maritime environment. High and extreme risks arise where workers are simultaneously exposed to suspended loads, heavy-equipment movement, open-water edges, unstable or changing access conditions, and activities with potentially severe consequences, such as demolition and pile driving. This explains why material lifting, work near the jetty edge, concrete demolition, and steel pipe pile activities received higher priorities than routine preparation or survey activities. The finding is consistent with previous jetty and seaport research showing that marine construction risk is shaped not only by the construction task itself but also by water levels, weather, equipment movement, installation methods, and the operational environment ([Dewi et al., 2022](#); [Kaup et al., 2022](#); [Mahapatra & Kushwaha, 2020](#)). It also aligns with the broader port-sector literature, which emphasizes the need to manage occupational risk factors comprehensively rather than as isolated hazards ([Gonçalves et al., 2025](#)).

#### **The Relationship between Job Safety Analysis (JSA) and Hazard Identification, Risk Assessment and Risk Control (HIRARC)**

The relationship between JSA and HIRARC in this study is methodological and sequential. JSA improves the completeness of hazard identification because it requires the analyst to examine each work stage before assigning a risk value, while HIRARC converts the identified hazards into a comparable priority structure through likelihood and severity ratings. This sequence addresses an important limitation noted in JSA literature: detailed task analysis may identify many hazards but, when used alone, may not provide a consistent basis for determining which hazards require the earliest intervention ([Ghasemi et al., 2023](#)). Conversely, HIRARC can effectively prioritize hazards, but the quality of the ranking depends on the completeness of the hazard list entering the assessment, as illustrated by its application in construction and infrastructure projects ([Aninditya et al., 2023](#); [Wong et al., 2022](#)). The sequential JSA-HIRARC workflow therefore reduces the risk of treating hazard identification and risk ranking as disconnected activities and makes each control recommendation traceable to a specific work task and risk score.

### Comparison of JSA, HIRARC, and JSA–HIRARC Integration Analysis Results

The comparison of the three analytical approaches also clarifies the expected effectiveness of the proposed controls. Existing controls in the project include PPE, inspections, supervision, housekeeping, and work procedures; however, for high- and extreme-risk hazards, these measures should not be considered sufficient when the hazard source can be further isolated or controlled through engineering measures. The recommended controls therefore strengthen measures such as exclusion zones, lifelines and ring buoys, ELCB protection, temporary drainage, verified lifting plans, safe positioning zones, pre-lifting inspections, and equipment certification before relying on PPE as the final layer of protection. This prioritization is important because maritime rehabilitation conditions can change during a work shift, particularly because of tides, weather, pontoon movement, and equipment repositioning. Continuous supervision and learning from incidents are consequently necessary to ensure that controls remain effective in practice rather than merely being documented in the JSA or HIRARC forms (Chan et al., 2023; Gonçalves et al., 2025).

**Table 7**

*Comparison of OHS Analysis Using JSA, HIRARC, and JSA–HIRARC Integration*

| Analysis Aspect             | JSA                                                                           | HIRARC                                                                                  | JSA–HIRARC Integration                                                                                                                                          |
|-----------------------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Focus of Analysis           | Outline work activities and recognize potential hazards at each stage of work | Assess the magnitude of the risk based on likelihood and severity                       | Linking hazard identification with risk assessment and prioritization                                                                                           |
| Unit of Analysis            | Stages and activities of work                                                 | Potential hazards that have been identified                                             | Activities, hazards, risk levels, and control needs                                                                                                             |
| Key Results                 | List of potential hazards and their impacts                                   | Risk level assessment and classification                                                | Risk priorities and the direction of control                                                                                                                    |
| Pros                        | Provide detailed hazard identification at the level of job activity           | Provide a measure of the level of risk so that risk can be prioritized                  | Provide an analysis flow from the source of the hazard to the determination of control priorities                                                               |
| Limitations when used alone | Has not provided a risk rating based on likelihood and severity               | The accuracy of the assessment depends on the completeness of the hazard identification | Requires a longer analysis stage because JSA results must be traced to the HIRARC assessment                                                                    |
| Contributions to research   | Produce a basis for hazard identification of dock repair work                 | Generate classification and prioritization of risk levels                               | Generate an integrated analysis flow of eleven activities and 32 potential hazards towards prioritization and risk control recommendations for dock repair work |

The principal contribution of the integrated analysis is a traceable decision path from the work activity to the identified hazard, the likelihood-severity score, and finally the required control priority. This is particularly useful for HSE management because high- and extreme-risk hazards can be linked directly to the responsible activity and person in charge rather than being managed as a general project-level list. Nevertheless, the findings should be interpreted within the limitations of a single rehabilitation case and a semi-quantitative matrix whose scores depend on field judgment and current exposure conditions. Risk ratings should therefore be revalidated when work methods, equipment, weather, tides, access arrangements, or project stages change. Within these limitations, the JSA–HIRARC sequence offers a practical framework for updating OHS controls throughout jetty rehabilitation and supporting more consistent communication among supervisors, HSE personnel, and work crews.

## CONCLUSION

The study demonstrates that OHS management in jetty rehabilitation should move beyond hazard listing toward a traceable prioritization process that reflects the specific characteristics of overwater construction. JSA identified 32 potential hazards across eleven major work-activity groups, while HIRARC showed that high- and extreme-risk hazards require the greatest management attention, particularly in overwater access, material lifting, heavy-equipment movement, concrete demolition, steel pipe pile positioning, and pile-driving activities. The sequential JSA-HIRARC approach strengthens OHS accountability because each risk rating and control recommendation can be traced to a specific work activity and responsible role.

For practice, contractors and project implementers should prioritize engineering and administrative controls for high- and extreme-risk hazards and update the JSA and HIRARC whenever work methods, equipment arrangements, access conditions, weather, tides, or project stages change. Future studies may test this integrated workflow across other maritime rehabilitation projects or compare it with additional risk-analysis methods to assess its consistency and transferability.

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## AUTHOR CONTRIBUTION STATEMENT

Elisabeth Alfaomasi Daeli contributed to field data collection, hazard identification using JSA, risk assessment using HIRARC, data analysis, and manuscript preparation. Parwadi Moengin supervised the research, guided the methodology, validated the conceptual framework, and critically revised the manuscript. Both authors approved the final manuscript.

## REFERENCES

- Adilla, A., Andre, P., Nofta, E., & Indah, A. (2025). Analysis of Occupational Safety Risks in Construction Projects: A Case Research of the Implementation of JSA and Hierarchy of Control. *Devotion: Journal of Research and Community Service*, 6(8), 852–865. <https://doi.org/10.59188/devotion.v6i8.25514>
- Alifandy, N., & Astuti, D. (2024). Hubungan antara Kepatuhan Penggunaan Alat Pelindung Diri dengan Risiko Kecelakaan pada Pekerja Fasad. *Jurnal Kesmas Asclepius*, 6(1). <https://doi.org/10.31539/jka.v6i1.9625>
- Andriana, A., Sety, L. O. M., & Rahman. (2025). Analisis risiko kecelakaan kerja pada proses bongkar muat dengan metode Job Safety Analysis (JSA) di PT. Pelabuhan Nusantara Kendari. *Jurnal Kesehatan Dan Keselamatan Kerja Universitas Halu Oleo*, 6(3), 232–238. <https://doi.org/10.37887/jk3uho.v6i3.156>
- Aninditya, B., Dinariana, D., & Suryani, F. (2023). Implementation of the Hazard Identification, Risk Assessment and Risk Control (HIRARC) Method on Erection Girder Work of South Japek II Toll Road Construction Project Package 3. *Interdisciplinary Journal and Humanity (INJURITY)*, 2(9), 824–835. <https://doi.org/10.58631/injury.v2i9.127>
- Aung, T., Liana, S. R., Htet, A., Bhaumik, A., & Scholar, R. (2023). Risk Management in Construction Projects: A Review of Literature. *International Journal of Creative Research Thoughts (IJCRT)*, 11.
- Bourahla, A., Fernandes, G., & Ferreira, L. M. D. F. (2024). Managing occupational health and safety risks in construction projects to achieve social sustainability: A review of literature. *Procedia Computer Science*, 239, 1053–1061. <https://doi.org/10.1016/j.procs.2024.06.269>
- Chan, A. P. C., Guan, J., Choi, T. N. Y., Yang, Y., Wu, G., & Lam, E. (2023). Improving Safety Performance of Construction Workers through Learning from Incidents. *International Journal of Environmental Research and Public Health*, 20(5). <https://doi.org/10.3390/ijerph20054570>
- Devianti, I. C., Rupiwardani, I., & Susanto, B. H. (2022). Faktor-Faktor yang Mempengaruhi Kepatuhan Penggunaan Alat Pelindung Diri (APD) pada Pekerja Konstruksi di PT "X". *Banua: Jurnal Kesehatan Lingkungan*, 2(2). <https://doi.org/10.33860/bjkl.v2i2.1579>

- Dewi, K. P., Kurniawan, J., Irawan, H., & Purba, H. H. (2022). Risks Identification in Construction of Jetty Projects: Literature Review. *Rekayasa Sipil*, 11(2), 59–69. <https://doi.org/10.22441/jrs.2022.v11.i2.02>
- Ghasemi, F., Doosti-Irani, A., & Aghaei, H. (2023). Applications, Shortcomings, and New Advances of Job Safety Analysis (JSA): Findings from a Systematic Review. *Safety and Health at Work*, 14(2), 153–162. <https://doi.org/10.1016/j.shaw.2023.03.006>
- Gonçalves, A., Dutra, A., & Mussi, C. C. (2025). Occupational risks and health and safety management strategies in the port sector: A systematic literature review. *Safety Science*, 184. <https://doi.org/10.1016/j.ssci.2024.106767>
- I, P. T. P. I. (Persero) R. I. (2025). *Rencana Kerja dan Syarat-syarat (RKS): Rehabilitasi struktur Dermaga Jetty 03 Curah Kering Terminal Kijing*. PT Pelabuhan Indonesia (Persero) Regional II.
- Kaup, M., Łozowicka, D., Baszak, K., Ślaczka, W., & Kalbarczyk-Jedynak, A. (2022). Risk Analysis of Seaport Construction Project Execution. *Applied Sciences*, 12(16). <https://doi.org/10.3390/app12168381>
- Lafhaj, Z., Rebai, S., Albalkhy, W., Hamdi, O., Mossman, A., & Alves Da Costa, A. (2024). Complexity in Construction Projects: A Literature Review. *Buildings*, 14(3). <https://doi.org/10.3390/buildings14030680>
- Latifah, H., Awaluddin, A., & Darwis, A. M. (2023). Kepatuhan penggunaan alat pelindung diri pada pekerja di PT Pelabuhan Indonesia (Persero) Regional 4 Makassar. *Hasanuddin Journal of Public Health*, 4(3), 272–281. <https://doi.org/10.30597/hjph.v4i3.26906>
- Mahapatra, R., & Kushwaha, N. (2020). Hazards Identifications and Risk Assessment in Port Berth Construction: A Case Study. *International Journal of Engineering Research & Technology*, 9(1), 193–200. <https://doi.org/10.17577/IJERTV9IS010097>
- Rumondor, I., Arungpadang, T. A. R., & Mende, J. (2024). Penerapan metode HIRARC untuk analisis risiko keselamatan kerja pada container crane di Pelabuhan Peti Kemas Bitung. *Jurnal Poros Teknik Mesin UNSRAT*, 13(1), 60–70. <https://doi.org/10.35793/jptmu.v13i1.57193>
- Wong, C. F., Teo, F. Y., Selvarajoo, A., Tan, O. K., & Lau, S. H. (2022). Hazard Identification Risk Assessment and Risk Control (HIRARC) for Mengkuang Dam Construction. *Civil Engineering and Architecture*, 10(3), 762–770. <https://doi.org/10.13189/cea.2022.100302>
- Yunanto, R. A., Purnama, A. W., & Lestiani, M. E. (2024). Analisis pengaruh kinerja program keselamatan dan kesehatan kerja (K3) dalam meningkatkan produktivitas kinerja di Pelabuhan Patimban. *Jurnal Keselamatan Kesehatan Kerja Dan Lingkungan*, 5(2), 111–121. <https://doi.org/10.25077/jk3l.5.2.111-121.2024>
- Yussif, A. M., Taiwo, R., Shakor, P., Han, T., Mohandes, S. R., Antwi-Afari, M. F., Qazi, K., Singh, A. K., Christo, M. S., & Shah, M. A. (2025). A comprehensive literature review on risk identification and assessment in green building construction projects. In *Cleaner Engineering and Technology* (Vol. 29). <https://doi.org/10.1016/j.clet.2025.101089>