Analysis of Occupational Safety Risks in Iron and Steel Unloading Activities

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ABSTRACT

Iron and steel unloading activities in port operations involve various work processes that present significant occupational health and safety (OHS) risks due to the use of heavy equipment, the handling of heavy materials, and interactions between workers, equipment, and the work environment. This study aimed to identify potential hazards, assess occupational safety risks, and determine appropriate risk control measures in iron and steel unloading activities at PT Pelindo Multi Terminal, Gresik Branch. A descriptive research design with a semi-quantitative approach was applied using the Hazard *Identification, Risk Assessment, and Risk Control (HIRARC) method. Data were collected through field observations, semi-structured interviews, and documentation studies. The results identified nine stages of unloading activities and 24 potential hazards originating from human factors, equipment, materials, work methods, and environmental conditions. Risk assessment revealed 1 low-risk hazard, 8 medium-risk hazards, and 15 high-risk hazards. The highest risk levels were associated with lifting, material transportation, and stacking activities. Recommended control measures include equipment inspection and maintenance, implementation of standard operating procedures, safety briefings, worker training, increased supervision, and the use of personal protective equipment. These measures are expected to reduce workplace accidents and improve occupational safety performance.*

Keywords : Occupational Safety, HIRARC, Risk Assessment, Iron and Steel, Port Operations

Introduction

Ports play a vital role in supporting the distribution of goods and logistics activities. One of the primary operations in ports is cargo handling, which involves interactions among workers, mechanical equipment, and cargo materials. These activities are associated with a high level of occupational safety risk due to the dynamic working environment and the extensive use of heavy equipment. Therefore, the implementation of Occupational Health and Safety (OHS) is essential to prevent workplace accidents and ensure operational continuity (ISO 45001, 2018).

One type of cargo with a high hazard potential is iron and steel. These materials are characterized by their heavy weight, rigid structure, and large dimensions, requiring special handling methods during unloading operations. Activities such as rigging, lifting, landing, transportation, and material stacking may expose workers to hazards including falling loads, equipment entrapment, collisions with operational machinery, and lifting equipment failure. If

not properly controlled, these hazards may result in worker injuries, equipment damage, and operational disruptions (Tarwaka, 2015).

PT. Pelindo Multi Terminal Branch Gresik is one of the port terminals handling general cargo, including iron and steel materials. Iron and steel unloading operations at Pier 78 involve the use of cranes, forklifts, slings, and other supporting equipment that may pose safety hazards to workers. Preliminary observations indicated that these operations consist of several work stages requiring effective risk management to minimize the likelihood of occupational accidents.

Previous studies have examined steel cargo handling activities in port environments. Riyadi and Pratama (2025) investigated factors affecting the loading process of steel plates and steel coils, while Rafli and Sahara (2023) analyzed the performance of unloading equipment used for steel coil operations. In addition, Nurprihatin et al. (2025) applied the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method to general port operations. However, studies specifically addressing occupational safety risks in iron and steel unloading activities at PT. Pelindo Multi Terminal Branch Gresik remain limited, particularly those employing the HIRARC method in port cargo operations. This condition indicates the existence of a research gap that warrants further investigation.

Hazard Identification, Risk Assessment, and Risk Control (HIRARC) is a widely adopted method in occupational risk management. The method enables the systematic identification of hazards, assessment of risk levels based on likelihood and consequence, and determination of appropriate control measures (Ramli, 2010). Through this approach, organizations can establish risk control priorities and improve workplace safety performance.

Based on the aforementioned background, this study aims to identify potential hazards, assess occupational safety risks, and determine appropriate risk control measures in iron and steel unloading activities at PT. Pelindo Multi Terminal Branch Gresik using the HIRARC method. The findings are expected to provide valuable input for improving occupational safety practices and reducing workplace accident risks during unloading operations.

Research Method

This study employed a descriptive method with a semi-quantitative approach to analyze occupational safety risks in iron and steel unloading activities at PT. Pelindo Multi Terminal Branch Gresik. The descriptive approach was used to describe actual field conditions related to potential hazards arising at each stage of the unloading process, while the semi-quantitative approach was applied to assess risk levels based on the likelihood and consequence of identified hazards.

Data were collected through direct observation of iron and steel unloading activities at Pier 78, semi-structured interviews with operational personnel, and documentation studies of standard operating procedures (SOPs), occupational health and safety (OHS) documents, and other supporting records. The research object covered all stages of the unloading process, including safety briefing, personal protective equipment (PPE) inspection, equipment inspection, rigging, lifting, landing, sling release, material transportation, and material stacking.

Data analysis was conducted using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method. The first stage, hazard identification, was performed to identify

potential hazards associated with each work activity. The second stage, risk assessment, involved evaluating the likelihood and consequence of each identified hazard. The risk level was calculated using the following equation:

$R = L \times C$

Where:

R = Risk Level

L = Likelihood of Occurrence

C = Consequence Severity

The calculated risk values were then classified into low, medium, and high-risk categories using the HIRARC risk matrix. Finally, the risk control stage was conducted by determining appropriate control measures based on the hierarchy of controls to minimize the likelihood of workplace accidents during iron and steel unloading operations.

Results and Discussion

Hazard Identification

Hazard identification was conducted across all stages of iron and steel unloading activities at PT. Pelindo Multi Terminal Branch Gresik using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method. The identification process was carried out through field observations, interviews with operational personnel, and reviews of existing work procedures. The objective of this stage was to identify potential hazards that could lead to workplace accidents during unloading operations.

The results revealed that the iron and steel unloading process consists of nine work activities, namely safety briefing and work preparation, personal protective equipment (PPE) inspection, work equipment inspection, rigging, lifting, landing, sling release, material transportation, and material stacking. A total of 24 potential hazards were identified, originating from human factors, equipment, materials, the work environment, and work methods.

Table 1. Hazard Identification in Iron and Steel Unloading Activities

Work Activity	Example of Potential Hazards	Number of Hazards
Safety Briefing and Work Preparation	Workers do not understand work instructions; poor communication among workers	2
PPE Inspection	Incomplete use of PPE; damaged PPE equipment	2
Work Equipment Inspection	Failure to detect damaged equipment; defective lifting gear; worn sling condition	3
Rigging	Improper sling installation; incorrect load attachment; workers exposed to pinch points; sling detachment	4
Lifting	Falling material; sling failure; workers within suspended load area; crane malfunction	4
Landing	Material shifting during placement; workers struck by moving loads	2
Sling Release	Hands caught between sling and load; sudden sling movement during release	2
Material Transportation	Forklift collision with workers; falling material during transport; unsafe travel routes	3
Material Stacking	Unstable material arrangement; collapse of stacked materials	2
Total		**24**

Source: Author (2026)

As shown in Table 1, the rigging and lifting stages recorded the highest number of potential hazards, with four hazards identified in each activity. These stages involve direct interaction between workers, heavy lifting equipment, and large steel materials, thereby increasing the likelihood of occupational accidents. Material transportation and equipment inspection activities also exhibited significant hazards that require appropriate control measures.

The identified hazards included incomplete use of PPE, lifting equipment failure, improper sling installation, workers entering suspended load zones, falling materials during lifting operations, forklift collisions, and unstable material stacking. These findings indicate that activities involving the handling and movement of heavy materials present a higher level of risk compared to other operational activities.

The results are consistent with the findings of Ancione and Milazzo (2024), who reported that handling and lifting operations are associated with high hazard potential due to human error, equipment failure, and falling loads. Therefore, a comprehensive risk assessment is required to determine the severity of each identified hazard and establish appropriate control measures.

Risk Assessment

A risk assessment was conducted on the 24 identified hazards using the HIRARC method. Each hazard was evaluated based on its likelihood of occurrence and consequence severity to determine its overall risk level. The resulting risk scores were then classified into low, medium, and high-risk categories using the risk mapping matrix.

Table 2. Risk Mapping Matrix

Likelihood	***Consequence Severity***				
	1	**2**	**3**	**4**	**5**
5 (Almost Certain)	5	10	15	20	25
4 (Likely)	4	8	12	16	20
3 (Possible)	3	6	9	12	15
2 (Unlikely)	2	4	6	8	10
1 (Rare)	1	2	3	4	5

Source : Adapted from Ramli (2010)

Green cells indicate low risk, yellow cells indicate medium risk, and red cells indicate high risk.

Table 3. Risk Category Classification

Risk Score	Category
1–4	Low
5–12	Medium
15–25	High

Source : Author's analysis based on Ramli (2010)

Based on the risk mapping matrix presented in Table 2, risk scores ranging from 1–4 were classified as low risk, scores of 5–12 as medium risk, and scores of 15–25 as high risk. The risk level for each hazard was determined by multiplying the likelihood score by the consequence score.

Table 4. Risk Assessment Results

Risk Category	Number of Risks	Percentage (%)
Low	1	4.2
Medium	8	33.3
High	15	62.5
Total	**24**	**100**

Source: Author (2026)

Table 4 shows that most identified hazards fall into the high-risk category, accounting for 15 risks (62.5%). Medium-risk hazards represent 8 risks (33.3%), while only 1 hazard (4.2%) is classified as low risk. These findings indicate that iron and steel unloading operations are dominated by high-risk hazards, emphasizing the need for immediate and effective control measures to reduce the likelihood of workplace accidents.

Due to space limitations, Table 5 presents representative high-risk hazards identified during the assessment process.

Table 5. Dominant High-Risk Hazards

Work Activity	Potential Hazard	Potential Risk	Risk Category
Rigging	Improper sling installation	Load detachment during lifting	High
Lifting	Sling or lifting equipment failure	Workers struck by falling materials	High
	Workers entering suspended load areas	Serious injury or fatality	High
Material Transportation	Forklift collision with workers	Severe injury	High
Material Stacking	Unstable material arrangement	Material collapse and worker injury	High

Source: Author (2026)

The assessment results indicate that high-risk hazards are predominantly associated with rigging, lifting, material transportation, and material stacking activities. Among these activities, lifting represents the most critical stage because it involves handling heavy steel materials using cranes. Equipment failure, improper sling installation, and worker exposure to suspended loads can result in severe injuries, fatalities, and significant operational disruptions.

These findings are consistent with the study conducted by Ancione and Milazzo (2024), which identified human error, equipment failure, and falling loads as major contributors to accidents in lifting and load-handling operations. The dominance of high-risk hazards also suggests that existing safety controls require further improvement, particularly in activities involving direct interaction between workers, heavy equipment, and large steel materials.

Based on the risk assessment results, appropriate control measures are necessary to reduce the identified risks to an acceptable level and improve overall workplace safety performance during iron and steel unloading operations.

Risk Control

Risk control measures were developed based on the results of the risk assessment. The proposed controls follow the hierarchy of controls, including engineering controls, administrative controls, and the use of personal protective equipment (PPE). Priority was given to activities

classified as high risk, particularly rigging, lifting, material transportation, and material stacking.

Table 6. Recommended Risk Control Measures

Work Activity	Potential Risk	Recommended Control Measures
Rigging	Load detachment due to improper sling installation	Inspect slings before use, provide rigging training, and ensure supervision by qualified personnel
Lifting	Falling loads during lifting operations	Conduct periodic crane and lifting equipment inspections, assign signalmen, and establish restricted lifting zones
	Workers exposed to suspended loads	Install safety signs and barriers around lifting areas and prohibit entry into hazardous zones
Material Transportation	Forklift collision with workers	Designate transportation routes, assign spotters, and enforce speed limits
Material Stacking	Material collapse during storage	Arrange materials according to SOPs and regularly inspect stack stability
All Activities	Injuries caused by unsafe worker behavior	Conduct routine safety briefings, strengthen supervision, and enforce PPE compliance

Source: Author (2026)

The recommended controls emphasize both engineering and administrative measures to reduce the likelihood of workplace accidents. Engineering controls focus on maintaining equipment reliability through regular inspections and preventive maintenance, while administrative controls emphasize worker training, supervision, safety communication, and compliance with established procedures.

Among the proposed measures, the implementation of periodic inspections for cranes, forklifts, slings, and other lifting equipment is considered essential, as equipment failure was identified as one of the primary sources of high-risk hazards. In addition, routine safety briefings and worker training programs can improve hazard awareness and reduce unsafe acts during unloading operations.

The application of these control measures is expected to reduce the risk level of critical activities and improve overall occupational safety performance in iron and steel unloading operations at PT. Pelindo Multi Terminal Branch Gresik. Engineering controls were prioritized for lifting-related activities because equipment failure and falling loads represented the most severe hazards. Administrative controls were emphasized to improve worker compliance with safety procedures and reduce unsafe acts during unloading operations.

Discussion

The findings indicate that iron and steel unloading activities at PT. Pelindo Multi Terminal Branch Gresik involve significant occupational safety risks. Out of the 24 identified hazards, 15 were classified as high risk, 8 as medium risk, and only 1 as low risk. This distribution demonstrates that unloading operations involving heavy steel materials present substantial hazards that require systematic risk management.

The lifting stage was identified as the most critical activity due to its potential to cause severe injuries and fatalities. Hazards such as sling failure, falling loads, and worker exposure to suspended materials contributed significantly to the high-risk classification. These findings are consistent with the study conducted by Ancione and Milazzo (2024), which highlighted

equipment failure, human error, and load drops as the primary causes of accidents in lifting and material-handling operations.

Human factors were also found to play a significant role in the occurrence of workplace hazards. Several identified hazards were associated with improper PPE use, inadequate attention to hazardous areas, and non-compliance with established work procedures. This finding supports Heinrich's theory that unsafe acts are among the leading causes of workplace accidents. Therefore, improving worker safety awareness and strengthening compliance with safety procedures are essential for reducing accident risks.

The results also align with the findings of Nurprihatin et al. (2025), who reported that most operational hazards in port activities fall within medium to high-risk categories and require a combination of engineering and administrative controls. In the present study, engineering controls such as equipment inspections and maintenance were particularly important for lifting-related activities, while administrative controls were necessary to address behavioral and procedural issues among workers.

The dominance of high-risk hazards indicates that unloading operations involving heavy steel materials require stricter safety supervision and more comprehensive equipment inspections. Without adequate control measures, the likelihood of workplace accidents may increase, potentially affecting both worker safety and operational efficiency.

Overall, the application of the HIRARC method proved effective in identifying hazards, assessing risk levels, and developing appropriate control measures for iron and steel unloading operations. The study provides practical insights that can support the improvement of occupational safety management systems and contribute to accident prevention in port operations.

Conclusion

This study identified 24 potential hazards associated with iron and steel unloading activities at PT. Pelindo Multi Terminal Branch Gresik. The identified hazards originated from human factors, equipment, materials, work environments, and work methods. Based on the HIRARC risk assessment, 1 hazard (4.2%) was classified as low risk, 8 hazards (33.3%) as medium risk, and 15 hazards (62.5%) as high risk. The highest risk levels were found in rigging, lifting, material transportation, and material stacking activities due to the involvement of heavy equipment and large steel materials.

The findings demonstrate that the HIRARC method is effective in identifying workplace hazards, assessing risk levels, and establishing appropriate risk control measures for iron and steel unloading operations. Recommended control measures include periodic equipment inspections and maintenance, strict implementation of standard operating procedures, enhanced supervision, routine safety briefings, worker training programs, and consistent use of personal protective equipment. These measures are expected to reduce workplace accident risks and improve operational safety performance.

The contribution of this study lies in providing a specific occupational safety risk profile for iron and steel unloading activities at PT. Pelindo Multi Terminal Branch Gresik. The results can serve as a reference for developing more effective risk control strategies and strengthening

occupational safety management practices in port operations. This study contributes to the limited body of research on occupational safety risk assessment in steel cargo handling activities within Indonesian port operations.

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