JURNAL VENUS
Vol. 14, No. 1, March 2026, pp. 54–64
p-ISSN 2338-4611 | e-ISSN 2798-0995

Optimizing Lifting Equipment Safety in Container Handling Operations: A Comprehensive Strategy to Minimize Workplace Accidents at PT Pelindo Terminal Petikemas New Makassar

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ARTICLE INFO

Article History
Received: 2 January 2026
Revised: 15 February 2026
Accepted: 31 March 2026
Published: 31 March 2026

Keywords
Workplace Safety; Container Terminal; Preventive Maintenance; Workplace Accidents; Digital Technology

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ABSTRACT

Workplace accidents at ports, particularly during the operation of container handling equipment, remain a critical issue that threatens both worker safety and operational efficiency. At the New Makassar Container Terminal, despite the implementation of safety procedures, gaps in their execution persist, increasing the risk of accidents. This study aims to identify the factors affecting workplace safety in the operation of lifting equipment at the New Makassar Container Terminal and to formulate strategies for optimizing workplace safety. Using a mixed-methods approach, the research combines qualitative methods (case study, in-depth interviews, field observations, and document analysis) with quantitative methods (descriptive statistical analysis of questionnaire responses). The findings indicate that technical factors, such as equipment condition and maintenance, human factors related to training and safety communication, and environmental factors such as extreme weather significantly contribute to workplace accidents. This research recommends enhancing preventive equipment maintenance, improving the socialization of Standard Operating Procedures (SOPs), and implementing digital technology for real-time monitoring of equipment and weather conditions to improve workplace safety at the port. These findings may also be relevant to other container terminals with similar operating conditions.

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How to cite: Sulistiono, A., Idris, M., Karubaba, O. C., Adiputra, I. K. H. P., & Saparuddin, H. (2026). Optimizing lifting equipment safety in container handling operations: A comprehensive strategy to minimize workplace accidents at PT Pelindo Terminal Petikemas New Makassar. *Jurnal Venus*, *14*(1), 54–64. https://doi.org/10.48192/vns.v14i1.849

1. INTRODUCTION

Ports play a critical role in the global transportation system that supports the distribution of goods across countries (Li et al., 2023; Verschuur et al., 2020). Along with the increasing volume of international trade, particularly in the container sector, the intensity of loading and unloading activities at ports has also increased. The New Makassar Container Terminal, as one of the main terminals in Indonesia, faces a significant challenge in maintaining a balance between operational efficiency and workplace safety. In Indonesia, major ports such as the New Makassar Container Terminal serve as key links for the flow of goods, with a very high volume of loading and unloading activities. However, loading and unloading operations using heavy lifting equipment such as container cranes (CC) and rubber-tyred gantry cranes (RTGs) carry

workplace accident risks that cannot be ignored (Arnold et al., 2020; Budiyanto & Fernanda, 2020).

Accident risks in ports are often caused by various factors, including human, technical, and environmental factors. Although loading and unloading equipment technology continues to advance, its operation still requires strict safety procedures to minimize potential hazards. Sarah et al. (2018) explain that work accidents in the port sector are usually caused by a combination of operator incompetence, poorly maintained equipment, and unfavorable environmental conditions. At the New Makassar Container Terminal, despite the presence of SOPs and operator training, some gaps in safety implementation are still found, particularly in terms of SOP communication and the lack of uniform dissemination among workers.

Based on this, this study has high urgency. Therefore, it is important to conduct an in-depth analysis of the factors affecting workplace safety in ports and formulate more effective strategies for managing safety risks. This study aims to introduce innovation in port workplace safety approaches by integrating digital technology, improving safety culture, and implementing more systematic preventive maintenance. The successful implementation of an effective safety system at the New Makassar Container Terminal is expected not only to enhance the operational performance of the port but also to contribute significantly to the development of workplace safety science, both in Indonesia and globally.

Workplace safety in container loading and unloading activities is crucial for maintaining productivity and reducing the risk of work accidents that can impact port operations and workers' health (Dewi et al., 2024; Fabiano et al., 2010; Gonçalves et al., 2025; Walters & Wadsworth, 2020). Although technology continues to develop, accident risks remain if safety management is not properly implemented. Therefore, this study is essential to identify factors that influence operational safety and provide practical recommendations to reduce accident risks at ports.

This study also introduces innovation with a more comprehensive approach to optimizing workplace safety in ports, considering technical, environmental, and social factors related to the operation of lifting equipment in container loading and unloading. One of the innovations in this study is the emphasis on the application of digital technology and data-driven management to monitor equipment conditions in real time and improve coordination among operations. According to Nguyen et al. (2023), sensor-based technology combined with port information management systems can reduce human error, improve efficiency, and provide more accurate data in managing workplace safety.

By highlighting the role of technology in workplace safety, this study has the potential to become an important reference in the development of safety policies at global ports. The findings from this study are expected to have a positive impact in creating a safer working environment, both in Indonesia and in international ports with similar characteristics. Therefore, this study is not only relevant for safety management at the New Makassar Container Terminal, but also contributes to a broader understanding of workplace safety in the port sector at the global level.

Operational safety at ports is an urgent issue, especially considering the high volume of international trade occurring today (Basulo-Ribeiro et al., 2024; Wang et al., 2024). Accidents involving lifting equipment during container loading and unloading activities can lead to significant losses, including operational costs, equipment damage, and worker injuries or even fatalities. Therefore, this study is of high urgency in identifying factors that affect safety in the operation of lifting equipment and formulating strategies that can be implemented to significantly reduce work accident risks. The results of this study are expected to serve as a foundation for the development of better safety policies at major ports worldwide.

This study also contributes new knowledge by offering technology-based solutions, such as sensor-based equipment monitoring and digital information management systems, which can improve the effectiveness and efficiency of workplace safety in ports. With this approach, the study is expected to have a positive influence on port safety management, both in Indonesia and in international ports facing similar challenges in maintaining operational safety.

2. METHODS

2.1. Research Approach

This study uses a mixed-methods approach, focusing on qualitative descriptive and quantitative analysis. The qualitative descriptive approach is used to explore and examine the factors influencing workplace safety in container loading and unloading activities at the New Makassar Container Terminal, considering technical, human, and environmental variables. This method allows the researcher to understand the existing phenomena in depth and contextually. On the other hand, quantitative analysis is applied to describe workers' perceptions of the effectiveness of existing safety procedures in the field.

This mixed-methods approach was chosen because it provides a more comprehensive understanding of workplace safety by combining the strengths of both approaches. Quantitative analysis can provide more objective evidence, while qualitative analysis enables the researcher

to gain deeper insights into the perceptions and experiences of workers that cannot be uncovered solely through a quantitative approach (Creswell & Plano Clark, 2018).

2.2. Research Design

This research design uses a case study that focuses on the New Makassar Container Terminal as the unit of analysis. A case study was chosen because it provides an opportunity to explore in depth the specific workplace safety factors in a real-world context. This study also adopts a cross-sectional approach, which allows data collection at a single point in time to analyze existing phenomena without the need to track changes over time. The cross-sectional design also enables the researcher to explore the relationships between various factors affecting workplace safety at the port (Mugenda & Mugenda, 2003).

2.3. Location

This research was conducted at the New Makassar Container Terminal, one of the main ports in Indonesia handling high-volume container loading and unloading. This terminal was chosen because of its complex operational conditions and high safety risks, as well as being representative of other large ports in Indonesia facing similar challenges. This study is expected to contribute to improving safety at similar ports.

2.4. Participants and Sample

The sample in this study was selected using purposive sampling by choosing participants with direct experience in container loading and unloading operations and safety management at the New Makassar Container Terminal. A total of 30 participants were involved in this study, consisting of 10 lifting equipment operators, 10 field supervisors, and 10 safety managers. The sample selection, based on direct experience and in-depth knowledge of safety procedures in the field, ensures that the data collected are relevant and trustworthy.

2.5. Data Collection Techniques

The data were collected through three complementary main techniques:

a. **Participatory Observation.** The researcher conducted direct observations of the container loading and unloading activities in the field. Observations were made to note the operational conditions affecting workplace safety, such as the use of lifting equipment, interactions between workers and managers, and the working environment conditions. The researcher also observed compliance with safety procedures and equipment maintenance.

b. **In-Depth Interviews.** Interviews were conducted with lifting equipment operators, field supervisors, and safety managers. Semi-structured interviews were used to explore their views on the implementation of safety procedures, the challenges faced, and the solutions

they considered effective. This interview technique allows the researcher to uncover personal experiences and perceptions that cannot be measured through quantitative data.

c. **Documentation.** Data were also obtained from related documents such as SOPs, equipment maintenance records, work accident reports, and safety inspection records. This documentation was used to evaluate whether safety procedures have been properly implemented and to identify potential gaps in SOP implementation.

2.6. Research Instruments

The research instruments used include:

a. **Observation Sheet.** This is used to record the technical and environmental factors affecting workplace safety, such as the condition of lifting equipment, weather, and field conditions.

b. **Interview Guide.** The interview guide consists of open-ended questions designed to gather in-depth information about workers' experiences and perceptions of workplace safety, as well as the implementation of safety procedures.

c. **Questionnaire.** The questionnaire was given to lifting equipment operators and field supervisors to measure their perceptions of workplace safety at the New Makassar Container Terminal. This questionnaire uses a 1–5 Likert scale to measure their attitudes and satisfaction with the safety procedures implemented.

2.7. Data Analysis

The qualitative data were analyzed using thematic analysis. This analysis process involves:

a. Data Reduction: identifying key themes from the interview and observation data related to workplace safety and the factors influencing it.

b. Data Presentation: organizing the data in a format that is easy to understand to present the research findings.

c. Conclusion Drawing: drawing conclusions from the research by linking the data and findings, and formulating recommendations for safety strategies that can be implemented.

For the quantitative data from the questionnaires, descriptive statistics were used to describe workers' perceptions of safety procedures and the effectiveness of SOP implementation.

3. RESULTS AND DISCUSSION

3.1. Factors Affecting Workplace Safety in Container Loading and Unloading Activities at the New Makassar Container Terminal

This study successfully identified the factors influencing workplace safety in the operation of lifting equipment for container handling at the New Makassar Container Terminal. Based on interviews with lifting equipment operators and field supervisors, it was found that technical, human, and environmental factors play a significant role in reducing or increasing the risk of workplace accidents at the port.

Technical factors, such as equipment condition and maintenance, have proven to be a critical element in operational safety. One operator, S1, stated, "The condition of the equipment, which has started to age and is rarely inspected periodically, sometimes causes the equipment to become unstable, especially when operating in bad weather." This indicates that irregular equipment maintenance increases the likelihood of damage, which can lead to accidents. Table 1 shows that the lifting equipment at the New Makassar Container Terminal, although still operational, frequently experiences minor technical issues that are often overlooked and require more attention in terms of preventive maintenance.

Table 1. Evaluation of container handling equipment condition

No	Lifting Equipment	Equipment Condition	Maintenance Frequency	Scheduled Maintenance	Notes
1	Container Crane	Good condition, rarely problematic	Once every 3 months	Regular	Well-maintained, only minor issues occasionally
2	RTG	Fair condition, rarely problematic	Once every 3 months	Regular	Well-maintained, but requires more frequent maintenance
3	Forklift	Good condition	Once every 6 months	Irregular	Sometimes not maintained, requires additional maintenance

Based on an interview with a field supervisor, S2, it was highlighted that "Safety socialization is often done in a one-way manner, with no open discussions about the issues faced by workers." This finding suggests that communication around safety procedures at the New Makassar Container Terminal is limited. While safety procedures have been implemented, the lack of two-way communication and insufficient engagement from workers on safety concerns contributes to an increased risk of accidents. This aligns with the research by Hakim et al. (2024), which stresses the importance of two-way communication between management and workers for the effective implementation of safety procedures.

In terms of equipment maintenance, the container crane is now in good condition and has regular maintenance every 3 months. This regular upkeep has significantly reduced the likelihood of breakdowns and operational disruptions. Unlike previous conditions where small issues were overlooked, the crane is now well-maintained, with only minor issues that can be resolved promptly. The reliable operation of the container crane is crucial for maintaining safety standards, as timely and consistent maintenance minimizes the risk of equipment failure and associated accidents. Ensuring that maintenance remains consistent and thorough will continue to reduce the potential for malfunctions that could disrupt operations and compromise worker safety.

Moreover, while technical factors and human involvement are crucial, environmental factors, such as extreme weather conditions and unsafe ground, still remain key contributors to workplace safety challenges at the New Makassar Container Terminal. Severe weather, including heavy rain and strong winds, coupled with slippery or uneven surfaces, significantly increases the risk of accidents. As stated by one operator, S3, "During heavy rain and strong winds, we are very limited in moving the equipment, which can risk hitting objects or even causing the equipment to overturn." This illustrates how extreme weather can undermine the stability of lifting equipment and increase the likelihood of accidents. This finding is consistent with research by Filomena and Picchio (2024), confirming that adverse weather conditions and unsafe ground conditions can elevate operational safety risks.

3.2. Workers' Perceptions of the Effectiveness of Existing Safety Procedures

For the quantitative data obtained from the questionnaire, descriptive statistics were used to describe workers' perceptions of safety procedures and the effectiveness of SOP implementation. The results are presented in Table 2.

Table 2. Description of workers' perception of safety procedures

Factors	Agree (%)	Disagree (%)
Clear SOP Communication	70	30
Proper Equipment Maintenance	65	35
Effective Safety Training	75	25

Table 2 shows that the majority of workers (70%) agree that the communication of SOPs is clear, although 30% are dissatisfied. This indicates a gap in the understanding of safety procedures among workers, which could be due to a lack of socialization or ineffective communication. This figure highlights the importance of management's role in ensuring that all workers fully understand and follow the procedures correctly (Rahman et al., 2023).

Regarding equipment maintenance, 65% of workers agree that the equipment used is well-maintained. However, about 35% of workers feel that the maintenance is not being carried out optimally. This indicates that although procedures are in place, equipment maintenance is not being done consistently, which could increase the risk of workplace accidents if not addressed immediately (Costella et al., 2020). Additionally, data related to safety training show a relatively high level of satisfaction, with 75% of workers feeling that the training provided is effective, although 25% of workers feel dissatisfied, indicating that the training needs to be improved and updated regularly.

Technical factors, such as equipment condition and maintenance, have proven to be key elements in maintaining operational safety at the port. This finding suggests that irregular equipment maintenance contributes to an increased risk of accidents. This aligns with the research by Chen et al. (2025), which shows that timely maintenance can reduce damage and equipment failure that could lead to accidents. Although equipment is still functional, small technical issues that are often overlooked can lead to potentially fatal accidents.

Human factors, particularly related to operator competence and training, also play a significant role. The data show that while most workers are satisfied with the safety training received, there are still gaps in the deep understanding of SOPs. This reflects the findings by Ramadhani and Hasibuan (2024), which state that without continuous training and a deep understanding, the risk of workplace accidents remains high. Better socialization of safety and emergency procedures needs to be introduced more thoroughly among workers.

Environmental factors, especially extreme weather, play a large role in increasing the risk of workplace accidents. Bad weather can affect port operations and cause instability in equipment (Cao & Lam, 2019; Maulidia et al., 2024). Therefore, effective weather management through real-time weather monitoring systems becomes crucial to ensure worker safety and operational effectiveness at the port.

Digital technology plays a very important role in improving workplace safety at the port. The application of sensor-based technology and integrated port management information systems can help detect potential problems before larger failures occur (Nguyen et al., 2023). The use of technology such as Vessel Traffic Services (VTS) to monitor vessel movements and weather conditions in real time can improve coordination between various parties involved in port operations and reduce accidents caused by delayed responses.

Based on the research findings, several strategies for improving workplace safety at the New Makassar Container Terminal include increasing preventive maintenance of lifting equipment, better two-way communication in SOP socialization, and implementing digital

technology to monitor weather and equipment conditions in real time. Improving communication between management and workers about the risks they face and existing safety procedures is crucial to creating a strong safety culture and reducing accidents at the port (Walters & Wadsworth, 2020).

4. CONCLUSION

This study aimed to analyze the impact of technical, human, and environmental factors on workplace safety at the New Makassar Container Terminal. The qualitative analysis highlighted communication issues regarding safety procedures, revealing that safety socialization is often one-way and does not encourage open discussions among workers. This limits the workers' understanding of emergency procedures, which may increase the potential for accidents. The questionnaire results showed that 35% of workers considered equipment maintenance not yet optimal, while observations and interviews indicated that timely maintenance, as applied to the container cranes, reduces risks related to equipment failure; overlooked minor technical issues can lead to major accidents. Operator competence and training were found to be crucial in mitigating accidents, with workers reporting gaps in the understanding of safety protocols despite receiving training. Extreme weather and unsafe ground conditions further limit the safe operation of lifting equipment.

Based on these findings, it is recommended that the New Makassar Container Terminal enhance its two-way communication regarding safety procedures, involving workers more actively in discussions about risks and emergency protocols. Furthermore, improving preventive maintenance schedules for equipment and integrating real-time weather monitoring systems are essential strategies to reduce operational risks. These actions would help mitigate the potential hazards caused by both technical failures and adverse environmental conditions, ultimately improving overall workplace safety at the port.

5. DECLARATIONS

Author contributions: A.S.: Conceptualization, Methodology, Formal analysis, Writing – original draft; M.I.: Supervision, Validation, Writing – review & editing; O.C.K.: Investigation, Data curation; I.K.H.P.A.: Investigation, Resources; H.S.: Data curation, Visualization, Writing – review & editing. All authors have read and approved the final manuscript.

Conflict of interest: The authors declare no conflict of interest.

AI usage statement: The authors did not use generative AI tools in preparing this manuscript.

Ethical approval: Not applicable. This study did not involve clinical or experimental procedures on human participants; participation in the interviews and questionnaire was voluntary, and participants' identities are kept confidential.

Funding: This research received no external funding.

Data availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments: The authors thank the supervisors for their guidance and expertise throughout this study, and the staff and management of the New Makassar Container Terminal for their cooperation and for providing the necessary data and insights.

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