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Work Safety Mitigation On Bunker Ships Case Study: Nw Maritime Ptd Ltd

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Abstract

Bunkering operations are high-risk maritime activities involving flammable fuels, pressurized transfer systems, environmental conditions, and potential human error. At NW Maritime Pte Ltd, safety mitigation is essential to prevent fires, explosions, oil spills, hazardous exposure, equipment failure, and accidents. This study aims to analyze the implementation of safety systems, evaluate safety conditions, identify bunkering hazards, and assess the effectiveness of existing mitigation measures. This qualitative study employed a case study approach using in-depth interviews, observations, and document analysis. Data were analyzed through coding and the Miles, Huberman, and Saldaña interactive model, supported by triangulation. Findings indicate that NW Maritime Pte Ltd has implemented a Safety Management System through SOPs, Risk Assessment, JSA, Toolbox Meetings, Permit to Work, PPE, safety training, inspections, drills, emergency procedures, and incident reporting. Overall, mitigation measures are effective, and safety conditions are good and controlled. However, human factors remain the dominant challenge, particularly fatigue, communication deficiencies, inconsistent discipline, overconfidence, and operational pressure. Technical and environmental conditions require continuous control. The study concludes that effective mitigation depends on safety leadership, risk governance, human reliability, technical reliability, and continuous improvement. The company should strengthen scenario-based training, digital safety monitoring, workload management, near-miss reporting, preventive maintenance, and unannounced safety audits

Keywords: Bunkering Operations, Safety Mitigation, Safety Management System, Human Factors, Safety Culture, Risk Management.

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INTRODUCTION

The shipping and bunker service industry plays a strategic role in supporting energy distribution, particularly the provision of fuel as a primary requirement for maritime transportation operations. Bunkering activities are complex and high-risk processes because they involve flammable materials, high operational pressure, and dynamic marine working environments. These risks require occupational safety to be prioritized throughout every stage of bunkering activities. Effective safety control is essential to ensure operational continuity while protecting crew members, vessels, and the marine environment.

In practice, bunkering activities still face various potential accidents, including fires, explosions, oil spills, and accidents caused by human error. These conditions indicate that the implementation of occupational safety systems does not always operate optimally. The causes of accidents are not limited to technical aspects but also involve human factors, work procedures, communication, and risk management. Therefore, safety on bunker vessels needs to be viewed as an integrated system involving technical, human, procedural, and managerial aspects.

Occupational safety is one of the main pillars in ensuring the smooth operation of shipping and marine fuel distribution. As the number of vessels and the complexity of maritime operations increase, the demand for bunker fuel also continues to grow. Bunkering involves the transfer of fuel from a bunker vessel to a receiving vessel, either at sea or in port (Mahardhika, 2025). This process requires a high level of precision and control because of the flammable characteristics of the fuel and its significant potential risks.

The risks associated with bunkering activities can have serious consequences if they are not properly controlled. An oil spill can endanger crew members, pollute the marine environment, damage ecosystems, and result in legal consequences for the company. In addition, fires and explosions may occur due to exposure to fuel vapors, while failures involving hoses, valves, and pumping systems may trigger accidents. Human error, fatigue, lack of competence, and indiscipline are also important factors contributing to the emergence of these risks.

Safety phenomena in bunkering operations indicate that incidents continue to occur with relatively similar patterns. These risks include fires or explosions caused by fuel vapors, oil spills resulting from hose/valve connection failures, and accidents while handling equipment in confined and slippery work areas. Their impacts include not only crew injuries and asset damage but also operational disruptions, claim costs, legal

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consequences, and damage to the company's reputation. Although international guidelines such as ISGOTT, SOLAS, and MARPOL are available, compliance with documentation does not always guarantee effective safety implementation in the field.

Another problem is the gap between written safety procedures and actual work practices during bunkering operations. This gap may be influenced by time-target pressures, changing weather conditions, equipment conditions, differences in crew competence, human error, fatigue, ineffective communication, and inconsistent supervision. Such conditions may cause mitigation efforts to become reactive, meaning that they are strengthened only after an incident occurs rather than proactively through hazard identification and comprehensive risk control. Therefore, a systematic evaluation of the effectiveness of occupational safety mitigation on bunker vessels is necessary, particularly within the operations of NW Maritime PTD LTD.

As a company operating bunker vessels, NW Maritime PTD LTD has a responsibility to ensure that its operational activities comply with applicable safety standards. ISGOTT (International Safety Guide for Oil Tankers and Terminals) provides guidance on safety and the control of fuel transfer operations, while MARPOL (Marine Pollution) regulates the prevention of marine pollution caused by oil spills, and SOLAS (Safety of Life at Sea) serves as a fundamental framework for the safety of life at sea. In addition to these international regulations, the company's internal procedures are important instruments for maintaining consistency in safety implementation. However, dynamic field conditions, crew competence, operational pressures, extreme weather, and limited supervision demonstrate the need for a comprehensive evaluation of the implementation of these procedures.

Based on these conditions, research on occupational safety mitigation at NW Maritime PTD LTD is necessary to identify risk factors, evaluate the effectiveness of the existing safety system, and formulate more optimal mitigation strategies. This study focuses on hazard identification, assessment of preventive measures, and the development of comprehensive mitigation actions to reduce potential accidents and improve crew safety. The findings are expected to strengthen the safety culture, support compliance with international standards, and maintain the company's operational sustainability. With appropriate mitigation strategies, the company can minimize human, material, and environmental losses while improving its reputation, business partner confidence, and long-term operational stability.

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Research Novelty

The novelty of this study lies in its specific examination of occupational safety mitigation in bunkering activities aboard bunker vessels operated by NW Maritime PTD LTD. Unlike previous studies, which generally discuss occupational safety on merchant vessels or shipping operations in general, this study focuses on the specific risk characteristics of bunkering activities. The approach adopted is holistic, integrating technical aspects, human factors, and safety culture within a single analytical framework. This study also employs an in-depth case study to obtain a comprehensive understanding of actual occupational safety practices in the field. In addition to identifying potential hazards, the study evaluates the effectiveness of the safety system implemented by the company. Thus, this study provides a more comprehensive perspective on occupational safety mitigation strategies for high-risk bunkering activities.

LITERATURE REVIEW

Occupational Safety on Ships

Occupational safety is a fundamental aspect of the shipping industry, particularly on bunker vessels, which face risks such as fire, oil spills, explosions, and exposure to hazardous substances. According to the International Maritime Organization, safety mitigation involves hazard identification, risk assessment, and the implementation of controls to minimize potential accidents (IMO, 2022). Reason (2000) explains that maritime safety is influenced by the interaction of human factors, technology, equipment, procedures, and environmental conditions. Therefore, occupational safety on bunker vessels represents a systematic effort to identify, analyze, and control hazards to ensure safe and controlled operations.

Occupational safety mitigation is part of safety risk management, which aims to reduce the likelihood of accidents and minimize their consequences through hazard identification, risk analysis, risk control, and continuous evaluation. This approach is particularly important in bunkering activities because they involve flammable fuels, high-pressure systems, and interactions between vessels or port facilities (Yorulmaz & Erküvün, 2026). Hazard identification focuses on potential risks such as fuel leakage, flammable gases, toxic chemicals, high-pressure equipment, and slippery work surfaces. According to Duong et al. (2024), the effectiveness of risk control depends largely on an organization's ability to identify all potential hazards during bunkering activities.

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Risk assessment is conducted to determine the likelihood of hazards occurring and the magnitude of their potential consequences. In bunkering operations, the assessment may include fuel leakage, explosion, and crew-related accident risks, using methods such as Formal Safety Assessment (FSA) and Failure Mode and Effect Analysis (FMEA). Ünal and Arıcan (2025) demonstrate that structured risk analysis helps shipping companies determine control priorities and allocate safety resources effectively. Once risks have been assessed, controls can be implemented through PPE, permit to work, safety alarm systems, SOPs, and effective communication between the bunker vessel and the receiving vessel.

Monitoring and review are necessary to ensure that safety procedures are consistently implemented and that equipment remains fully operational. Periodic evaluation is also essential to adapt risk-control systems to developments in technology, regulations, and operational conditions (Mišković & Wang, 2025). This concept is consistent with the International Safety Management (ISM) Code, which emphasizes hazard identification, risk control, and continuous safety improvement. Consistent implementation of the ISM Code can strengthen the safety culture and reduce accident risks in vessel operations, including bunkering activities (Karahalios, 2026).

The effectiveness of safety mitigation is influenced by crew competence and training, particularly their understanding of safety procedures, fuel handling, and emergency response. Continuous training, emergency simulations, and professional certification can improve preparedness and reduce the risk of occupational accidents (Chowdhury et al., 2024; Yorulmaz & Erküvün, 2026). In addition to human factors, the readiness of equipment such as fire extinguishers, gas detectors, emergency shutdown systems (ESD), and firefighting systems must be maintained through regular inspection and maintenance (Ünal & Arıcan, 2025). The implementation of clear and standardized SOPs is also important for reducing human error, particularly during complex ship-to-ship fuel transfer operations (Duong et al., 2024).

Environmental conditions, leadership, and safety culture also influence the effectiveness of occupational safety mitigation. Poor weather, high waves, and inadequate lighting can increase operational risks; therefore, environmental conditions must be considered in operational decision-making. Strong leadership and a positive safety culture can improve crew compliance, awareness, and commitment to established safety procedures. Karahalios (2026) indicates that organizations with a strong safety culture tend to have lower occupational accident rates.

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Safety Management

Safety management is a systematic approach used to identify, analyze, control, and monitor risks that may affect operational safety in the workplace. In the maritime industry, this approach is essential because shipping activities involve risks such as occupational accidents, fires, explosions, and pollution caused by fuel spills. Effective safety management includes safety planning, the implementation of operational procedures, continuous risk monitoring, and periodic evaluation (Melnyk et al., 2025). Therefore, potential hazards can be identified at an early stage, allowing preventive measures to be taken before they develop into serious incidents.

The implementation of safety management in the shipping industry is realized through the Safety Management System (SMS), which is required by the International Maritime Organization (IMO) through the International Safety Management (ISM) Code. The SMS provides a framework for managing safety that includes safety policies, SOPs, incident reporting, and internal and external audits. According to Mišković and Wang (2025), consistent implementation of the SMS can improve the effectiveness of risk control through continuous monitoring of safety procedures and corrective improvements to system weaknesses. Operationally, a structured safety system also contributes to efficiency by standardizing procedures and clarifying the safety responsibilities of each crew member.

Safety management functions not only as a risk-control instrument but also supports operational efficiency and business sustainability in shipping companies. An effective safety system can reduce losses resulting from accidents, equipment damage, and vessel operational disruptions. Furthermore, effective SMS implementation contributes to the development of a safety culture, reflected in organizational values, attitudes, and behaviors that prioritize safety. Arif et al. (2024) found that shipping organizations with a strong safety culture tend to have lower accident rates due to higher levels of safety awareness and compliance with established procedures.

Overall, safety management is a continuous process that integrates risk identification, safety procedures, operational monitoring, and ongoing system improvement. In high-risk activities such as bunkering, the implementation of a structured safety system is essential to prevent occupational accidents while protecting the marine environment from pollution. Its success depends not only on regulations and systems but also on management commitment and the active participation of all crew members. Supported by a strong safety culture, safety management can create a safer

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working environment and improve the overall reliability of vessel operations (Durlik et al., 2024; Todingan et al., 2025).

Human Error Theory

Human error is one of the common causes of work failures that can affect product quality, operational efficiency, and occupational safety (Wijayanti et al., 2025). In high-risk industries, including the maritime sector and fuel transfer activities, human error is a dominant contributing factor to accidents. Such errors may take the form of incorrect decisions, negligence, inadequate understanding of procedures, or communication failures. Therefore, understanding human error theory is important for designing an effective safety system.

According to James Reason's Human Error Model, human errors can be categorized into skill-based errors, rule-based errors, knowledge-based errors, and violations. Skill-based errors occur when individuals fail to perform routine actions correctly, such as incorrectly opening a valve, forgetting to check pressure, or failing to notice an alarm, which may be triggered by fatigue, loss of concentration, workload, or time pressure. Rule-based errors occur when individuals apply inappropriate rules or procedures, such as using the wrong SOP or selecting an inappropriate emergency procedure. Meanwhile, knowledge-based errors arise from limitations in knowledge, experience, or training when dealing with unfamiliar situations.

Violations differ from errors because they occur when individuals intentionally disregard SOPs, for example, to complete work more quickly, due to overconfidence in their experience, or because of a permissive work culture. Violations may include routine violations, which become habitual, and exceptional violations, which occur under emergency conditions or high operational pressure. On bunker vessels, examples include failing to use complete PPE, skipping checklists, or accelerating fuel transfer without authorization. Such conditions can increase the likelihood of accidents and reduce the effectiveness of the safety system.

The occurrence of human error is influenced by various factors, including individual factors such as fatigue, stress, competence, and experience; organizational factors such as weak safety culture, management, and training; and environmental and work-related factors such as adverse weather, noise, inadequate facilities, workload, time pressure, and operational complexity. In the context of bunker vessels, the interaction of these factors may result in operational errors such as oil spills, valve misalignment, overpressure, and fires. Therefore, controlling human error requires

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improved competence, compliance with procedures, effective workload management, strengthened safety culture, and consistent supervision.

RESEARCH METHODOLOGY

This study employs a qualitative descriptive approach to provide an in-depth description of occupational safety conditions during bunkering activities through observation, interviews, and documentation. A case study approach is used because the research focuses on bunker vessel operations at NW Maritime PTD Ltd., including safety mitigation processes, potential hazards, and factors influencing the effectiveness of implementation. According to Creswell and Creswell (2023), qualitative research is used to understand phenomena in depth through the experiences and perspectives of individuals, while Yin (2024) emphasizes that case studies are appropriate for examining contemporary phenomena within real-life contexts. The research object covers all stages of bunkering, from pre-bunkering, equipment inspection, fuel transfer, risk control, and emergency response to post-bunkering activities and corrective evaluation.

Research informants are selected using purposive sampling, involving individuals with relevant experience, competence, and direct involvement in operations and occupational safety implementation. These include the Master, Chief Officer, Chief Engineer, Bosun/Foreman/Pumpman, Deck Crew, HSE/HSSE Officer, Marine/Operations Superintendent, and Crewing/Training Officer. The inclusion criteria comprise direct involvement in bunker operations, a minimum of 1–2 years of work experience or experience handling several bunkering operations, previous involvement in incidents/near misses, and willingness to provide information for the study.

The analysis focuses on identifying potential hazards, implementing mitigation measures such as PPE, permit to work, and emergency response, crew compliance with safety standards, the condition of safety equipment, accident and incident history, and the effectiveness of the ISM Code, SMS, and SOPs. The research also considers the interaction of organizational, human, and technical aspects in the implementation of bunkering safety. These aspects provide a comprehensive basis for assessing the effectiveness of existing safety controls. Through this methodological approach, the study is expected to provide a comprehensive understanding of occupational safety implementation in bunker vessel operations. The findings are also expected to identify existing safety gaps and factors affecting mitigation effectiveness. Furthermore, the study aims to formulate realistic and applicable recommendations for improving occupational safety in bunkering operations. Thus, the research can contribute to

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strengthening safety practices and supporting safer and more reliable bunker operations at NW Maritime PTD Ltd.

The data collection method in this study consists of primary and secondary data. Primary data are obtained through direct observation, interviews, and questionnaires to examine operational conditions, the implementation of safety procedures, potential hazards, and the perceptions and compliance of crew members, as described by Creswell and Creswell (2023), Yin (2024), Kvale and Brinkmann (2022), and Dillman et al. (2023). Secondary data are obtained from company safety documents, including the SMS, SOPs, Risk Assessments, accident/incident reports, and international standards such as the ISM Code, SOLAS, MARPOL, and OCIMF Guidelines, which are used to evaluate the consistency between written procedures and actual practices in the field. The data are then analyzed using a qualitative descriptive approach based on the interactive model of Miles, Huberman, and Saldaña (2014), consisting of data condensation, data display, and conclusion drawing and verification through source and technique triangulation and member checking. The study is conducted within NW Maritime PTD Ltd. and on the bunker vessels managed by the company, enabling the researcher to obtain empirical data on operational conditions, safety implementation, crew interactions, equipment use, and safety culture directly from the field.

RESULT

Implementation of the Occupational Safety System in Bunkering Activities at NW Maritime Pte Ltd

The implementation of the Safety Management System (SMS) in bunker vessel operations at NW Maritime Pte Ltd refers to the International Safety Management (ISM) Code, International Safety Guide for Oil Tankers and Terminals (ISGOTT), and the company's internal SOPs. Based on the results of in-depth interviews, the pre-bunkering stage emphasizes document readiness, equipment preparedness, PPE compliance, and coordination between the Bunker Barge and Receiving Vessel. Key activities include completing the Bunker Safety Checklist, inspecting PPE and safety equipment including the Emergency Shut-Down (ESD) system, and conducting a Toolbox Meeting to discuss work procedures, potential hazards, weather/current conditions, and task assignments. The principle applied is to ensure that all safety aspects have been verified before operations begin *("No briefing, no operation").*

The during-bunkering stage is the most critical phase because it involves risks of oil spills, fire, explosion, and exposure to hazardous gases such as H_2S. Risk controls

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are implemented through pressure monitoring, beginning fuel transfer at a low pumping rate to ensure that hose and flange connections are secure before gradually increasing the pumping rate. In addition, a Safety Watch Patrol is conducted to monitor the condition of the hose, mooring lines, and work area, while ensuring that no ignition sources or hazardous activities are present. The ESD system and Stop Work Authority are also implemented, allowing crew members to stop operations when leakage, sudden pressure increases, or hazardous weather conditions occur.

The post-bunkering stage includes stopping the transfer operation, hose blowing/draining, disconnecting connections, cleaning, inspecting the work area, and completing safety documentation. The draining process is carried out carefully to prevent residual fuel from spilling into the sea, with the scupper plug remaining installed during hose disconnection. After the flange connection is disconnected, the manifold valve is closed and the blind flange is reinstalled, followed by an inspection to ensure that the area is safe. Finally, completion documents such as the Bunker Delivery Note (BDN) are signed after the entire operation has been completed and confirmed to be safe.

Table 1. Synthesis Matrix of Interview Results for the Implementation of Occupational Safety and Health

Dimensions of Occupational Safety and Health	In-Depth Interview Findings	Standard Conformity Evaluation (ISM Code / ISGOTT)
Procedures & Documents	*Bunker* Safety *Checklist, Permit to Work,* and JSA are filled out prior to operation.	Appropriate (Application of ISGOTT Chapter 21).
Equipment & PPE	The use of MARPOL/ Occupational Safety and Health standard PPE, SOPEP kit readiness, and ESD button testing.	Appropriate (Implementation of ISM Code Element 7 - Operational Plans).
Supervision & Communication	Toolbox meeting before work, tight supervision of the mooring rope, use of intrinsically safe (ATEX) radio.	Appropriate (Ongoing operational risk monitoring).

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Field Constraints	Crew fatigue factors, sudden weather changes, and impatience on the part of the receiving ship.	Additional mitigation is needed (related to human factors & fatigue management).

Source: Processed by Researcher, 2026

Current Implementation of Occupational Safety Risk Mitigation

The research findings indicate that the occupational safety conditions on the bunker vessels of NW Maritime Pte Ltd are generally categorized as good, as reflected in crew compliance with safety procedures, the availability of adequate safety equipment, and the development of a safety culture. Most crew members use PPE such as safety helmets, fire-retardant coveralls, safety shoes, chemical-resistant gloves, safety goggles, face shields, life jackets, and portable gas detectors according to operational requirements. Safety equipment, including fire-fighting equipment, oil spill kits, scupper plugs, Emergency Shut Down (ESD), EEBD, SCBA, eye wash stations, and first aid boxes, is available and regularly inspected through Daily Safety Checks, Weekly Inspections, Monthly Inspections, the Planned Maintenance System (PMS), and Internal Safety Audits. Nevertheless, some crew members tend to remove PPE during prolonged work activities, indicating that continuous supervision is still necessary to prevent unsafe behavior caused by complacency.

The safety culture is reflected in the consistent implementation of toolbox meetings before operations, covering task assignments, potential hazards, risk controls, communication procedures, and emergency response. Crew members also demonstrate an increasing awareness of reporting potential hazards, such as hose leaks, damaged valves, defective PPE, adverse weather conditions, and potential oil spills, indicating a more proactive approach to safety management. Communication during operations is conducted through Handy Talkies (HT), hand signals, direct verbal communication, and communication checklists to minimize coordination errors. Furthermore, the roles of the Master, Chief Officer, and Safety Officer in providing leadership and supervision are important factors in strengthening crew compliance and the overall safety culture.

Although overall safety conditions are good, several challenges remain, particularly those related to human factors. Some crew members occasionally perceive routine tasks as low-risk, PPE use is not always consistent during prolonged activities,

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and new crew members require time to adapt to the company's safety culture. Weather and wave conditions may also affect concentration and increase operational risks, while safety equipment requires continuous inspection to prevent functional deterioration due to service life. Therefore, the main challenges in safety mitigation are more closely related to human behavior than to equipment availability, making continuous supervision, strengthened discipline, and sustained development of the safety culture essential.

Potential Hazards Emerging in Bunkering Activities

Based on direct observations, interviews with the Master, Chief Officer, Chief Engineer, Safety Officer, Bunker Surveyor, and crew members, as well as analysis of JSA, Risk Assessment, Near Miss Reports, and Safety Meeting Records, the study indicates that bunkering is a high-risk operation because it involves the transfer of large quantities of fuel, pressurized equipment, and interactions among people, machinery, and the marine environment. The identified hazards include fire and explosion, which may be triggered by electrical sparks, static electricity, open flames, hot work, electrical short circuits, and overheating, as well as oil spills caused by hose leakage, loose manifold connections, defective valves, overflow, communication errors, and pump failures. To control these risks, the company implements a No Smoking Policy, suspends hot work, and provides scupper plugs, oil spill kits, drip trays, and oil booms when necessary.

Other hazards are associated with exposure to hazardous substances and high pressure, including hydrocarbon vapors, toxic gases, fuel contact with the skin or eyes, as well as risks of hose rupture, disconnection, overpressure, manifold leakage, and pump failure. In addition, slippery deck conditions caused by oil, water, hoses, communication cables, rain, and waves create slip, trip, and fall hazards. Human factors are also significant, including human error, lack of concentration, fatigue, ineffective communication, limited experience among new crew members, and non-compliance with SOPs. These findings demonstrate that human behavior has a substantial influence on the safety of bunkering operations.

Bunkering activities are also affected by environmental and mechanical hazards, including high waves, strong winds, heavy rain, poor visibility, strong currents, and lightning, which may affect vessel stability and communication. From a mechanical perspective, risks include defective valves, hose wear, pump failures, pipe corrosion, flange leakage, and damaged pressure gauges. The company controls these risks

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through regular inspections and maintenance under the Planned Maintenance System (PMS). Overall, these eight hazard categories demonstrate that safety mitigation in bunkering operations must be implemented in an integrated manner, considering technical, human, procedural, and environmental aspects.

Effectiveness of the Occupational Safety Mitigation Implemented by the Company

The research findings indicate that the occupational safety mitigation system implemented by NW Maritime Pte Ltd is generally effective in reducing potential hazards and preventing accidents during bunkering operations. This effectiveness is demonstrated through the implementation of multiple layers of protection, including Risk Assessment, Job Safety Analysis (JSA), Toolbox Meetings, equipment and PPE inspections, Permit to Work, weather and communication checks before operations. During bunkering, continuous monitoring of pump pressure and tank levels, radio communication, manifold supervision, PPE compliance, and the implementation of stop work authority are applied to ensure that unsafe conditions can be addressed immediately.

The effectiveness of the system is further supported by regular Emergency Drills and a structured Emergency Response System. Drills include Fire Drill, Oil Spill Response Drill, Emergency Shutdown Drill, Man Overboard Drill, Abandon Ship Drill, First Aid Drill, and Communication Drill, followed by debriefing and corrective actions. The company also implements an Emergency Response Plan, Muster List, emergency communication procedures, Emergency Shutdown System, Fire Fighting System, and Oil Spill Response Equipment. Company records indicate that no major bunker-related occupational accidents have occurred in recent years, while near miss events are documented, investigated, and used as organizational learning to prevent recurrence.

Several factors support the effectiveness of mitigation, including management commitment, consistent safety leadership, comprehensive SMS implementation, adequate safety equipment, regular inspections and audits, continuous training, emergency drills, a no-blame culture for near miss reporting, and continuous improvement. Nevertheless, several challenges remain, particularly complacency during routine activities, differences in the competence and experience of new crew members, unpredictable extreme weather, the need for continuous competency development, and limited use of digital technology for real-time safety monitoring. Overall, the findings indicate that the mitigation system is effective, but its sustainability depends on

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strengthening human factors, continuous supervision, competency development, and technological support.

DISCUSSION

Implementation of the Occupational Safety System in Bunkering Activities at NW Maritime Pte Ltd

The research findings indicate that the implementation of the occupational safety system in bunkering activities at NW Maritime Pte Ltd has been carried out systematically through the application of international regulations, Standard Operating Procedures (SOPs), and safety protocols integrated into the company's Safety Management System (SMS). The implementation covers planning, risk identification, work execution, supervision, and post-operation evaluation. These findings indicate that the company not only maintains safety documentation as an administrative requirement but also internalizes it into daily operational practices through disciplined PPE use, toolbox meetings, Job Safety Analysis (JSA), Permit to Work, and hierarchical supervision. Therefore, the occupational safety system serves as a fundamental foundation for minimizing occupational accident risks and preventing environmental pollution during bunkering activities.

Current Conditions of Occupational Safety Risk Mitigation Implementation

Based on the results of interviews, observations, and document analysis, the current occupational safety conditions on the bunker vessels of NW Maritime Pte Ltd can be analyzed as good and well controlled. This is demonstrated by the high level of crew compliance with PPE use, the availability of safety equipment that meets operational standards, and the development of a safety culture supported by leadership, effective communication, and regular inspections. Nevertheless, the study also identifies human factors, such as decreased alertness during routine activities and the adaptation process of new crew members, as ongoing challenges that need to be continuously managed through strengthening the safety culture, training, and consistent supervision. These findings confirm that the effectiveness of the safety system is determined not only by the completeness of procedures and equipment but also by the behavior and commitment of all personnel in applying occupational safety principles throughout every bunkering activity.

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Potential Hazards Emerging in Bunkering Activities

The research findings indicate that bunkering activities at NW Maritime Pte Ltd involve various potential hazards that are multidimensional in nature, including technical, mechanical, chemical, environmental, and human factors. Among all identified categories, human factors, fire hazards, and oil spills are the most dominant hazards because they have relatively high likelihoods of occurrence and significant impacts on worker safety, company assets, and the marine environment. These findings indicate that risk management in bunkering activities cannot rely solely on the availability of safety equipment but also requires systematic hazard identification, continuous risk assessment, compliance with SOPs, and the strengthening of a safety culture across all levels of the organization. Therefore, the identification of potential hazards serves as an important foundation for developing effective occupational safety risk mitigation strategies in bunkering operations at NW Maritime Pte Ltd.

Effectiveness of the Occupational Safety Mitigation Implemented by the Company

Based on the results of interviews, observations, and document analysis, it can be concluded that the occupational safety mitigation implemented at NW Maritime Pte Ltd is effective in reducing potential hazards and maintaining the operational safety of bunkering activities. This effectiveness is reflected in the implementation of layered risk controls, regular emergency drills, the preparedness of emergency response systems, and the low rate of occupational accidents, with no serious occupational accidents related to bunkering operations identified in recent years. These findings indicate that the success of mitigation measures depends not only on the completeness of procedures and equipment but also on management commitment, safety leadership, crew competence, a near-miss reporting culture, and continuous evaluation mechanisms. Therefore, the mitigation system implemented by the company has functioned as a primary instrument for improving occupational safety while strengthening the safety culture within the operational environment of NW Maritime Pte Ltd.

Analysis of Miles, Huberman and Saldaña Data

The use of the Miles, Huberman, and Saldaña model is considered appropriate for the characteristics of this study, which employs a qualitative approach with a case study of the operational activities of bunker vessels at NW Maritime Pte Ltd. Research data were obtained through in-depth interviews with purposively selected informants, observations of activities and occupational safety conditions aboard the bunker vessels,

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and documentation related to the safety system, work procedures, safety equipment, implementation of bunkering activities, training, inspections, and emergency response. The analysis was conducted to obtain an in-depth understanding of how the occupational safety system is implemented, the actual safety conditions aboard the bunker vessels, the potential hazards arising during bunkering activities, and the effectiveness of the safety mitigation measures implemented by the company. In this qualitative study, data analysis was conducted interactively and continuously until the analysis was completed and data saturation was achieved.

Table 2. Data Condensation

Focus	Interview	Observations	Documentation	Interpretation
Safety system	The informant explained the existence of SOPs and safety procedures	Visible procedures applied in activities	SOP/checklist available	A formal system has been implemented
PPE	The informant stated that the use of PPE is mandatory	PPE use observed	The provisions of PPE are listed in the procedure	PPE compliance is an important part of risk control
Communication	Informant explains communications before and during *the bunker*	Communication observed	*Checklist/records* available	Communication is a *safety* barrier
Potential hazards	The informant identifies several *hazards*	Several risk conditions are observed	Risk assessment supports the identification of	Hazards come from technical, human and environmental factors
Mitigation	The informant explains the drill and control measures	Observed control execution	Drill/inspection *records* available	Mitigation has been done but requires ongoing evaluation

Source: Data Processed by Researcher, 2026

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Table 3. Data Presentation : Hazard Identification & Control Evaluation Matrix at NW Maritime Pte. Ltd.

Location/Activity	Potential Hazards	Risks / Impacts	Access Compliance Procedures	Access Compliance Procedures
Hose Connection	Fuel Leak/ Overpressure	Fire, Pollution, Exposure to Toxic Vapors	*Permit to Work,* Complete Use of PPE	Strict supervision is required on *bolt flange fastening*
Deck Operations (*Mooring/ Unmooring*)	Broken Rope (*Snap-back Zone*)	Serious Injuries (LTI)*/Vital Hazard*	*Snap-back zone* plan on deck	Hazard zone markings need to be clarified; *line handling training*
Pump Room / *Enclosed Space*	Toxic gases/ shortness of breath	Asphyxia, Gas Poisoning H2S/Vapor	*Enclosed Space Entry Permit, Gas Detector*	Routine calibration of multi-gas detectors should be tightened

Source: Data Processed by Researcher, 2026

Conclusion Drawing and Verification

The final stage of data analysis involves drawing conclusions gradually and verifying the validity and credibility of the data through the Miles, Huberman, and Saldaña model. Initial conclusions are formulated based on interview and observation findings but remain tentative and may develop as additional data are obtained. These conclusions are then verified through source triangulation, technique triangulation, member checking, and negative case analysis by comparing information from management, crew, direct observations, and operational records. The verification process also involves reviewing internal documents such as the SMS Manual, Audit Incident Report, logbook, safety checklist, and drill records, as well as clarifying preliminary findings with the HSQE Manager or Port Captain. The final conclusions are formulated comprehensively to address the research questions, including the dominant safety risk profile, the level of compliance with the International Safety Management (ISM) Code and maritime occupational safety standards, and the effectiveness of existing mitigation measures. Ultimately, the conclusions provide a basis for developing

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comprehensive technical, operational, administrative, and safety-culture recommendations to support the achievement of Zero Accident in the bunkering operations of NW Maritime Pte Ltd.

CONCLUSION

This study aimed to analyze occupational safety mitigation on bunker vessels at NW Maritime Pte Ltd using a qualitative research approach with a case study method. Data were collected through in-depth interviews, observations, and document analysis, and were analyzed using the Coding stages combined with the Miles, Huberman, and Saldaña (2020) data analysis model. Based on the research findings, several conclusions can be drawn as follows:

1. Occupational safety mitigation on bunker vessels has been implemented through the Safety Management System (SMS). The implementation includes safety policies, hazard identification, risk assessment, Job Safety Analysis (JSA), Permit to Work, toolbox meetings, the use of Personal Protective Equipment (PPE), safety training, inspections, audits, incident investigations, and corrective and preventive actions.
2. Human factors are the most dominant factors influencing occupational safety. The research findings indicate that human error is influenced by work fatigue (fatigue), lack of concentration, ineffective communication, levels of discipline, and a tendency toward overconfidence. These factors have the potential to increase the risk of accidents if they are not managed systematically.
3. The reliability of technical systems and workplace environmental conditions also determine the effectiveness of safety mitigation. Preventive maintenance of bunker pumps, hoses, valves, piping systems, and safety equipment is an important factor in preventing technical failures. In addition, weather conditions, waves, exposure to fuel vapors, and the condition of the vessel's deck require strict operational controls.
4. Safety culture plays an important role in strengthening the implementation of occupational safety mitigation. This culture is reflected in management commitment, compliance with procedures, near-miss reporting, open communication, and organizational learning from each incident. The stronger the safety culture, the higher the level of crew compliance with safe working procedures.
5. The study developed a conceptual model entitled "Integrated Safety Mitigation Management Model (ISMM) for Bunker Vessel Operations." This model positions safety leadership, risk governance, human resource competence, technical and

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environmental reliability, and continuous improvement as interconnected components for improving occupational safety in bunker vessel operations. The model represents the conceptual contribution of this study in the context of maritime management.

The study found that NW Maritime Pte Ltd has implemented a comprehensive and structured occupational safety system throughout all stages of bunkering, from pre-bunkering preparation and fuel transfer to post-bunkering activities. The system refers to international standards, including the International Safety Management (ISM) Code, International Safety Guide for Oil Tankers and Terminals (ISGOTT), SOLAS, MARPOL Annex I, and the STCW Convention, and is integrated into the company's Safety Management System (SMS) through Risk Assessment, Job Safety Analysis (JSA), Permit to Work, Toolbox Meetings, PPE use, equipment inspections, operational communication, and supervision. Overall, occupational safety conditions aboard the company's bunker vessels are categorized as good and well controlled, supported by adequate safety equipment, effective communication, safety leadership, and an increasingly strong safety culture. However, human factors, particularly complacency during routine activities and the adaptation of new crew members, remain challenges requiring continuous training, supervision, and competency development. The study identified eight major hazard categories: fire and explosion, oil spills, chemical and hydrocarbon vapor exposure, high pressure, slip/trip/fall hazards, human factors, environmental conditions, and mechanical failures, with human factors, fire hazards, and oil spills identified as the most dominant risks.

The occupational safety mitigation implemented by NW Maritime Pte Ltd is considered effective in reducing potential hazards and preventing serious accidents during bunkering operations. Its effectiveness is supported by layered risk controls, regular emergency drills, an effective Emergency Response System, safety inspections and audits, and the use of near-miss events as a basis for organizational learning and continuous improvement. In recent years, no serious occupational accidents related to bunkering activities have been identified, while reported incidents have generally been near misses that were managed without injuries or environmental pollution. Overall, the findings demonstrate that effective safety mitigation requires a holistic integration of international standards, technical reliability, human competence, management commitment, safety leadership, safety culture, and continuous evaluation and improvement.

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IMPLICATION

Theoretical Implications

This study provides theoretical implications for the development of maritime transportation management and maritime safety by reinforcing the view that occupational safety aboard vessels results from the interaction of organizational, human, technical, and environmental factors. Therefore, safety management requires a systems approach rather than an approach focused solely on individual behavior or technology. The findings also support the principles of the International Safety Management (ISM) Code, particularly management commitment, risk identification and control, operational preparedness, emergency response, incident reporting, and continuous improvement. Furthermore, the importance of competence, leadership, communication, and fatigue management reinforces the implementation of the Standards of Training, Certification and Watchkeeping for Seafarers (STCW), which emphasizes competent and safety-oriented human resources.

The development of the Integrated Safety Mitigation Management Model (ISMM) further contributes to maritime safety management by integrating five key dimensions: Safety Leadership, Risk Governance, Human Reliability, Technical and Environmental Reliability, and Continuous Safety Improvement. This integrated framework provides a more comprehensive perspective for understanding and managing occupational safety risks in bunker vessel operations. The model emphasizes that effective safety mitigation is not determined by a single factor but by the interaction and continuous integration of leadership, risk management, human competence, technical and environmental reliability, and organizational learning. Thus, the findings contribute to strengthening the theoretical understanding of holistic safety management within high-risk maritime operations.

Practical Implications

The findings of this study have several practical implications for shipping companies, bunker vessel operators, and other relevant stakeholders. Company management needs to strengthen its commitment to safety by providing adequate resources, maintaining consistent supervision, and demonstrating leadership in implementing a strong safety culture. Continuous training and competency development for crew members should also be enhanced, particularly in hazard identification, operational communication, fatigue management, emergency response, and near-miss reporting. In addition, preventive maintenance programs should be continuously

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improved to ensure that all bunkering equipment remains operationally fit and to minimize the risk of technical failures.

Companies should also strengthen safety evaluation mechanisms through regular inspections, internal audits, incident investigations, root-cause analysis, and appropriate follow-up actions as part of organizational learning and continuous improvement. The use of digital technology, such as electronic incident reporting systems, digital safety checklists, and real-time equipment condition monitoring, can further support the effectiveness of occupational safety risk mitigation. These measures can improve the accuracy and timeliness of safety monitoring while enabling management to respond more quickly to emerging risks. Therefore, the integration of human resource development, equipment reliability, systematic evaluation, and digital technology is essential for strengthening safety performance in bunkering operations.

RECOMMENDATIONS

For NW Maritime Pte Ltd and Similar Shipping Companies

1. Develop a Safety Leadership program for Masters, Chief Officers, Chief Engineers, and management personnel to strengthen the effectiveness of safety leadership in building a strong safety culture.
2. Improve the implementation of Risk Assessment and Job Safety Analysis (JSA) by regularly updating hazard identification in accordance with changes in operational conditions.
3. Optimize fatigue management through consistent regulation of working and rest hours, workload monitoring, and evaluation of factors that may affect crew concentration.
4. Strengthen the near-miss reporting system by developing a reporting culture focused on learning and improvement rather than imposing sanctions.
5. Integrate the safety management system with digital technology to support faster, more accurate, and data-driven decision-making.

For Future Research

1. Conduct research across multiple shipping companies or bunker vessel operators to obtain comparative insights into occupational safety mitigation practices across different operational contexts.

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2. Employ a mixed-methods approach by combining qualitative and quantitative data to enable the statistical testing of relationships among variables within the proposed model.
3. Develop an instrument to measure safety culture maturity and examine its relationship with the company's safety performance.
4. Examine the implementation of digital technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), predictive maintenance, and digital safety management, to improve the effectiveness of occupational safety mitigation on bunker vessels.
5. Test the Integrated Safety Mitigation Management Model (ISMM) across various vessel types, such as tankers, LNG carriers, container vessels, and bulk carriers, to assess its applicability and generalizability within the broader maritime industry.

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