REPORT OF RESEARCH RESULTS

A. Title：

The Near-Miss Risk Assessment of LNG Ships

B. Primary Researcher: Liu, Chung-Ping, Associate Professor

Affiliation: Department of Merchant Marine, National Taiwan Ocean University; No.2, Beining Rd., Zhongzheng Dist., Keelung City 202301, Taiwan (R.O.C.)

Official: ntouimt@ntou.edu.tw

Co-researcher(s): Lai, Chiu-Yu, Assistant Professor

Affiliation: Department of Navigation and Shipping Transportation Management, Taipei University of Marine Technology; No. 212, Sec. 9, Yanping N. Rd., Shilin Dist., Taipei City 11174 , Taiwan (R.O.C.)

Official: amidalalai@gmail.com

C. Summary:

Shipping companies mitigate the financial impacts of major vessel accidents through insurance mechanisms, while insurers rely on maritime safety data to accurately identify risk sources and control marine compensation costs. This research project aims to investigate high-risk operational areas and potential hazard characteristics associated with near-miss incidents on liquefied natural gas (LNG) vessels, thereby strengthening the practical implementation of the International Safety Management (ISM) Code. The dataset consists of 183,352 near-miss records compiled by LNG shipping companies between 2001 and 2023, covering 53 onboard operational and spatial areas. Seasonal variations in correlation patterns are analyzed to identify risk concentration levels and potential hazardous zones across different operational areas. Given the inherently unpredictable nature of near-miss events, which do not result in direct damage to vessels or cargo but may nevertheless expose ships to prolonged substandard conditions, this study employs Grey Relational Analysis to systematically examine the relationships between near-miss locations and their contributing factors. The results indicate that near-miss incidents are predominantly concentrated on decks, in engine rooms, accommodation areas, and galleys, with human operational errors and management deficiencies identified as the primary contributing factors. The findings provide practical implications for shipping companies and insurers by enabling early identification of high-risk operational areas, supporting insurance premium assessment, risk classification, and operational process improvement. Moreover, the results contribute to enhancing the effectiveness of near-miss management mechanisms and reinforcing the operational implementation of the ISM Code, ultimately reducing occupational accident rates and overall operational risks in maritime transportation.

Keywords ： Near-Miss Incidents, LNG Vessels, Grey Relational Analysis, Maritime Safety Management, Human Operational Risk

D. Aim of Research

Near-miss incidents on vessels, although not resulting in direct damage, often reveal underlying high-risk factors within operational processes. An effective near-miss reporting system is a crucial measure for occupational hazard prevention and plays a key role in enhancing maritime safety management and cultivating a safety culture. Given the operational characteristics of LNG vessels and variations in personnel awareness of such incidents, analyzing long-term accumulated near-miss data can facilitate early risk identification, optimize management mechanisms, and support the practical implementation of the ISM Code and overall maritime safety governance.

1. To systematically identify high-risk operational areas and potential hazard characteristics of near-miss incidents on LNG vessels

This study utilizes long-term accumulated near-miss data from liquefied natural gas (LNG) vessels to analyze risk concentration levels, potential hazardous zones, and their seasonal variations across different onboard operational and spatial areas. Although near-miss events do not result in direct

damage, they represent uncertain events that often signal precursors to major accidents. By focusing on near-miss incidents, this research addresses the limitations of conventional accident statistics and aims to enable early identification and proactive prevention of operational risks.

2. To establish a risk–cause correlation framework for near-miss incidents and enhance accident prevention and risk awareness
Given that near-miss events are relatively small in scale yet more traceable in terms of causation, this study employs Grey Relational Analysis to systematically examine the relationships between near-miss locations and contributing factors such as human operational errors and management deficiencies. The integrated analysis of near-miss data facilitates the accumulation of practical risk knowledge, enhances the sensitivity of maritime personnel and management to early risk signals, and provides an empirical basis for the continuous improvement of operational procedures and safety management measures.

3. To support the practical implementation of the ISM Code and decision-making in maritime safety governance and insurance risk management
The findings of this study provide practical support for shipping companies, Designated Persons (DPs), and marine insurers by enabling early identification of high-risk operational areas and latent hazards on LNG vessels. The results can be applied to annual safety management reviews, crew competency and qualification assessments, optimization of near-miss management mechanisms, and insurance risk classification and loss prevention strategies. Through the enhanced application of near-miss management, this study contributes to strengthening the practical effectiveness of the ISM Code, improving vessel seaworthiness, fostering a stronger safety culture, and enhancing overall operational risk control in maritime transportation.

E. Method of Research & Progression

This study employs **Grey Relational Analysis (GRA)** as the core analytical method. GRA, one of the four principal approaches of Grey System Theory, quantifies the relationships among different factors to reveal interactions between parameters and ideal variables. It is particularly suitable for systems characterized by incomplete information or uncertain conditions.
The methodology includes the following steps:

1. **Literature review and data compilation**
An initial literature review was conducted to consolidate previous vessel accident datasets, including Port State Control (PSC) records, near-miss (NM) databases, and studies on ship safety management mechanisms. This provides a knowledge base for analyzing LNG vessel safety management and near-miss incidents.

2. **Quarterly analysis of near-miss data**
Near-miss data from LNG vessels accumulated between 2001 and 2023 were analyzed on a quarterly basis to examine potential deficiencies in ship safety management mechanisms and to assess whether international conventions, PSC inspections, and PSC Concentrated Inspection Campaigns (CICs) influence the occurrence of near-miss events and safety outcomes.

3. **Application of Grey Relational Analysis**
Given that near-miss incidents are unpredictable and their types and occurrence conditions are not fully known, they exhibit characteristics of a grey system. GRA is used to construct quantitative models, compare correlations among parameters, and explore the effectiveness of risk control and hazard awareness within the ISM management framework of LNG fleets. This approach helps enhance the safety culture of crew members, Designated Persons (DPs), and management organizations.

This method is well-suited for analyzing unpredictable events and provides a solid analytical foundation for LNG vessel occupational hazard prevention and near-miss response strategies. Its feasibility and effectiveness in maritime safety and risk assessment have been validated in prior studies.

F. Results of Research

This study focused on near-miss incidents of LNG vessels from a specific shipping company, covering

the period from 2001 to 2023, with a total of 183,352 records. The analysis examined 53 onboard operational or spatial locations, employing Grey Relational Analysis (GRA) across four quarters. Key findings and recommendations are summarized as follows: (Table1, Figure 1~4)

1. **Research Findings and Results**

(1) The occurrence of near-miss events is unpredictable with no clear seasonal or yearly patterns, yet it is closely associated with ship safety management mechanisms (ISM Code, PSC Code 15000 series).

(2) Across all quarters, the highest-risk locations were the working deck and engine room; medium-high risk areas included living quarters; medium risk areas included the galley (Q2 and Q3) and engine control room (ECR) (Q3 and Q4); Q2 also included medium-low risk areas such as workshops and mooring stations.

(3) These results help shipping companies identify key near-miss hotspots, enhance crew risk awareness, improve ship safety management, and provide insurers with a basis for claim assessment and risk evaluation.

2. **Recommendations and Applications**

(1) Collect operational capability data of LNG vessel crews and workplace units to establish crew qualification and competency assessment standards, preventing recurrence of similar events.

(2) Establish dedicated near-miss inspection teams to promptly conduct on-site safety observations and operational demonstrations, evaluate whether ISM standard procedures are impeded, and identify any resource or knowledge gaps, thereby continuously improving management processes.

(3) If the same vessel experiences subsequent near-miss events resulting in significant incidents, conduct a detailed risk cause analysis to prevent reoccurrence.

(4) During annual ISM inspections or ad hoc vessel audits, LNG shipping companies should prioritize high-risk areas and evaluate crew safety awareness and risk recognition, enhancing vessel seaworthiness, maintaining safe navigation in port state waters, and reducing accident incidence.

Overall, this study provides actionable guidance for risk monitoring and safety management, offering high practical value for vessel safety, occupational hazard prevention, and maritime insurance management.

Table 1 Comparison of GRA analysis by quarter

Rank	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1	Deck 0.7757	Deck 0.7913	Deck 0.7676	Deck 0.7774
2	Engine Room 0.7549	Engine Room 0.7384	Engine Room 0.7159	Engine Room 0.7168
3	Accommodation 0.3981	Accommodation 0.4175	Accommodation 0.4863	ECR 0.4085
4	Galley 0.3908	Work Shop 0.4134	Galley 0.4409	Accommodation 0.4029
5	ECR 0.3872	Galley 0.4105	ECR 0.4049	Work Shop 0.3871
6	Others 0.3857	Mooring Area 0.4061	Work Shop 0.3869	Others 0.3833
7	Bridge 0.3854	Bridge 0.3885	Mooring Area 0.3830	Galley 0.3810

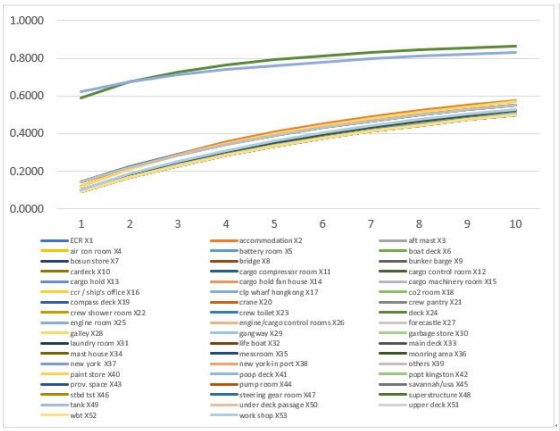

Figure 1: Historical GRA Trend Chart for Quarter 1 of Near Miss Accidents

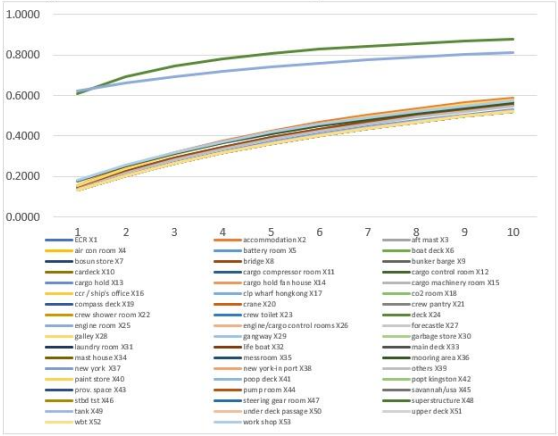

Figure 3: Historical GRA Trend Chart for Quarter 3 of Near Miss Accidents

Figure 2: Historical GRA Trend Chart for Quarter 2 of Near Miss Accidents

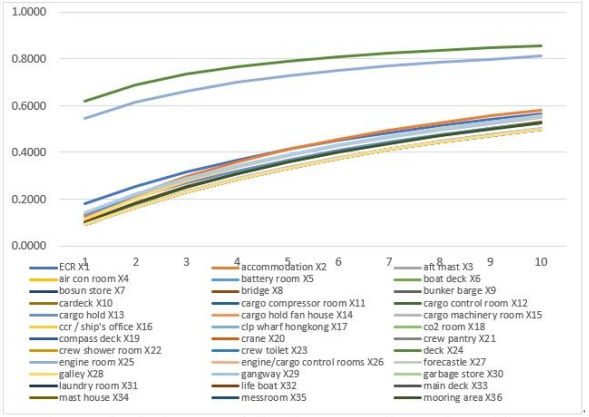

Figure 4: Historical GRA Trend Chart for Quarter 4 of Near Miss Accidents

G. Future Areas to Take Note of, and Going Forward

From the perspective of maritime insurance and risk management, this study emphasizes the analysis of large-scale near-miss data from LNG vessels, highlighting several areas for future attention. First, near-miss data can be further utilized to assess the operational competencies of LNG crew and workplace units, assisting shipping companies in establishing crew qualification and competency assessment standards, thereby enhancing operational skills and safety awareness. Second, it is recommended that LNG fleets establish dedicated near-miss inspection teams to promptly conduct on-site safety observations and operational demonstrations for vessels experiencing incidents, evaluating whether ISM standard operating procedures are impeded or if personnel lack necessary resources or experience. Finally, analyzing the risk causes of near-miss events can support shipping companies in evaluating crew safety awareness and risk recognition during annual ISM inspections, preventing the emergence of substandard vessels or accidents, improving vessel seaworthiness, and maintaining safe navigation in port state waters. Overall, future research and management should focus on **data-driven safety monitoring, real-time risk feedback, and crew competency development** to continuously reduce operational risks in maritime transportation.

H. Means of Official Announcement of Research Results

Our research team will organize and submit the part of results of the research to the Ocean Engineering in next year (2026) and 2026 Aviation and Maritime Conference.