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A Study on the Standardization and Effectiveness Improvement of Emergency Response Procedures in Major Korean Shipping Companies

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ABSTRACT
Maritime transportation represents approximately 90% of global trade but remains vulnerable to operational risks from human, technical, and environmental factors. This study evaluates the Emergency Response Systems (ERS) of four prominent Korean shipping companies—designated as Company A, B, C, and D—through a **comparative document analysis** of their operational manuals and prior research. The study highlights common limitations, including a lack of standardization, fragmented communication, and **critically, weak post-incident learning mechanisms**. To address these gaps, the research proposes the **Integrated Maritime Emergency Response Framework (IM-ERSF)**, which uniquely integrates standardized procedures, real-time data exchange, **AI-based predictive analytics (Level 4) systematically fed by an organizational learning loop (Level 5)**. The framework emphasizes five layers—shipboard, shore-based, information integration, AI decision-making, and post-response learning—to strengthen maritime safety and resilience. The findings contribute to the development of a unified national ERS standard and provide actionable recommendations aimed at shifting Korea's maritime safety paradigm from reactive management toward a proactive, data-driven, and resilient response system.
Keywords - Emergency Response System (ERS), Integrated Framework, Maritime Safety, Organizational Resilience, Predictive Safety, Standardization

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I. INTRODUCTION

The maritime transport sector accounts for roughly 90% of global trade, establishing itself as a critical infrastructure for global logistics and economic growth. However, the shipping industry continues to harbor a high level of uncertainty due to complex operating environments, unpredictable weather conditions, technical failures, and human factors. These factors serve as major causes of marine accidents, potentially leading to significant loss of life, environmental pollution, and economic damage.

The incidents of the *Costa Concordia* sinking (2012), the *Sewol* ferry disaster (2014), the *Stellar Daisy* sinking (2017), and the *Fremantle Highway* fire (2023) clearly demonstrate that deficiencies in the Emergency Response System (ERS) can amplify the severity of a disaster. These accidents revealed that, despite advances in technical systems, **inefficiencies in decision-making structures, fragmentation of inter-organizational information transfer, and inconsistencies in training and procedures** remain core factors in the deterioration of practical response capabilities.

Related prior studies support this. Chauvin et al. [5] analyzed that approximately 75% of marine accidents are caused by human and organizational factors. Hetherington et al. [6] asserted that hierarchical decision-making in emergency situations directly affects response speed and accuracy. Furthermore, Lu and Yang [7] emphasized that **securing standardization and integration** of emergency response procedures is key to improving response efficiency.

Internationally, the ISM Code [1], SOLAS [2], and MARPOL [3] provide the basic framework for ship safety management and emergency response. However, the actual level of application varies among shipping companies depending on factors such as vessel type, operating area, and organizational culture. Especially following the *Sewol* and *Stellar Daisy* accidents, domestic shipping companies have focused improvement efforts on real-time ship-to-shore communication and clarification of the Captain's authority. Nonetheless, **fragmentation of the training system** and the **absence of standardized emergency organization guidelines** are still pointed out as challenges.

Therefore, this study comprehensively compares and analyzes the ERS of four major domestic ocean-going shipping companies (Company A, B, C, and D), focusing on their ship and shore procedures, emergency classification systems, training systems, and communication structures. The structure of this paper is as follows: Chapter 2 reviews the theoretical background and prior research on maritime emergency response systems. Chapter 3 analyzes the ERS and operational characteristics of Companies A–D. Chapter 4 derives key implications based on the comparative analysis results. Chapter 5 presents the limitations of the study and directions for future development.

While prior studies [14, 15, 16, 17] have focused on individual incidents or specific ERS components, a **systematic comparative analysis of the structural differences and standardization levels** among major operators remains insufficient. Furthermore, a significant **research gap** exists in proposing an integrated framework that **connects technological solutions (AI, IoT) with organizational learning mechanisms** to address these identified shortcomings.

The purpose of this study is to analyze these response systems to propose directions for the integrated standardization of emergency response procedures and strategies for enhancing practical Safety Culture and Organizational Resilience.

The structure of this paper is as follows: Chapter 2 reviews the theoretical background and prior research. **Chapter 3 outlines the research methodology** used for the comparative analysis. **Chapter 4** analyzes the ERS and operational characteristics of Companies A–D. **Chapter 5** derives key implications and proposes the Integrated Maritime ERS Framework (IM-ERSF). **Chapter 6** presents the conclusion, validation of the model, and policy recommendations.

II. LITERATURE REVIEW

2.1 Theoretical Background of Maritime Emergency Response System

The ERS in maritime operations is structured around three core phases: Preparedness, Immediate Response, and Recovery. This system is regulated as an essential management element by the IMO's SOLAS (1974) and the ISM Code (1998). It acts as a core pillar of the Organizational Safety Management System (SMS). Antão & Soares [8] defined ERS as a central tool for risk management, viewing the speed and clarity of decision-making as determinants of response success. Furthermore, Reiman & Rollenhagen [9] applied the concept of Resilience Engineering, emphasizing the necessity of adaptive capability beyond simple manual-based responses. The ERS is increasingly viewed not as a response to a single event, but as an organizational and systemic response structure.

2.2 International and Domestic Literature Review Trends

2.2.1 Internationally, marine accident analysis has primarily focused on Human Factors and Safety Culture. Chauvin et al. [5] found that 75% of accidents result from human error and organizational deficiencies. Hetherington et al. [6] noted the impact of bridge team decision-making structures , while Lu & Yang [7] analyzed the importance of standardization. Li & Yin [10] argued that ISM Code implementation must be accompanied by real-time response capability and organizational learning. Zhang & Thai [11] indicated that SMS effectiveness is influenced by leadership culture and training sustainability.

2.2.2 Domestic Research Trends

Domestic research intensified after the *Sewol* (2014) and *Stellar Daisy* (2017) accidents. Kim et al. [14] compared ERS manuals of major companies, identifying a lack of standardization, duplication of decision-making, and absence of training feedback as key limitations. Park [15] stressed the need for a field-oriented system , while Woo & Yeo [16] pointed out that domestic systems are still focused on ex-post facto responses, lacking real-time data linkage. Yun et al. [17] noted that while training regularity is secured, its practical effectiveness is often insufficient. These studies acknowledge the importance of ERS, but research concerning inter-organizational connectivity (ship–shore) and systematic comparative analysis remains insufficient.

2.3 Comparative Study and Research Gaps on Companies A-D's ERS

Major domestic shipping companies (A–D) possess ERS manuals compliant with international regulations. However, existing literature reveals structural differences and gaps (Summarized in Table 1). While all possess systematic manuals, they share common vulnerabilities: absence of a standardized response system, limits to real-time data sharing, and inefficient collaboration. This study seeks to address this gap through a direct comparative analysis to build a foundation for a National Integrated ERS Framework.

Category	Key Features	Limitations	Related Studies
Company A	Establishment of a ship-centric emergency organization; CheckList-based response process	High complexity in decision-making when responding to combined accidents (multiple failures)	Kim et al. [14]
Company B	Detailed flow charts and response procedures for each accident type	Insufficient consideration for the inter-linkage between accidents; inadequate real-time information transfer system	Park [15]
Company C	Maintenance of training cycle settings and evaluation systems based on international standards (SOLAS, ISM Code)	Absence of feedback and improvement systems for evaluation results	Woo & Yeo [16]
Company D	Customized response system centered on the latest LNG carriers; joint ship/shore drills	Restriction on practical decision-making authority; lack of autonomy in field response	Yun et al. [17]

Table 1: Comparison and Gaps in Emergency Response Systems for Companies A-D

III. RESEARCH DESIGN AND METHODOLOGY

3.1 Sample Selection

The four companies (A, B, C, D) were selected based on their status as major Korean ocean-going carriers. The selection criteria included: 1) Significant fleet size and global operational scope; 2) Established history of ISM Code certification and safety management; and 3) Their high frequency of inclusion in prior domestic ERS studies [14, 15, 16, 17], which establishes them as representative samples of the industry's standard practices.

3.2 Data Collection and Analysis Framework

This study employs a qualitative, **comparative document analysis** method. To ensure validity, data was collected using **triangulation** of three sources: 1) The latest available SMS/ERS manuals from each company (anonymized); 2) Internal training reports and drill scenarios (where available); and 3) The analytical data presented in existing key studies [14, 15, 16, 17].

To ensure a rigorous comparison, an analytical framework was established based on core ISM Code and SOLAS requirements. The ERS of each company was assessed against four key components:

1. **Organizational Structure** (Shipboard and Shore-based roles and hierarchy).
2. **Emergency Scenario Classification** (Number, type, and complexity of defined emergencies).
3. **Training and Verification System** (Drill frequency, type, and evaluation methods).
4. **Reporting and Communication Structure** (Information flow and technology used).

IV. EMPIRICAL ANALYSIS OF COMPANIES A-D'S ERS

4.1 Company A: Organized ERS and Procedure-Centric Operation

Company A operates a systematic ERS Procedure and training system. The on-board organization is clearly delineated via an Emergency Muster List. The system is highly proficient in procedural completeness, classifying 16 situations. However, its major limitation is a lack of linkage between multiple scenarios, reducing efficiency in combined accidents (e.g., fire + grounding).

Category	Key Features	Detailed Content
Organizational Structure	Ship-centric response	Captain → Department Heads

	organization (Captain-centered)	→ Assigned Crew System
Training System	Regular and non-regular drills conducted concurrently	Annual joint ship/shore drill; monthly mock scenario-based drills
Response Procedure	Check List-based Flow Map	16 situations classified, including collision, fire, abandon ship, and pollution
Reporting System	Ship → Head Office Maritime Group → Response Headquarters report	Stage-by-stage notification procedure upon accident occurrence
Limitations	Inadequate response to combined accidents; restricted field autonomy	Response efficiency may be low due to excessive procedure segmentation

Table 2: Overview of Company A's ERS

4.2 Company B: Systematization of Type-Specific Response Protocols

Company B utilizes detailed Emergency Flow Charts for 35 defined emergency situation types. This secures response consistency by situation. However, this high number of classifications leads to excessive procedural division, reducing flexibility in information feedback and the autonomy of field judgment.

Category	Key Features	Detailed Content
Organizational Structure	Triple structure: Ship–Head Office–Local Branch	Ship Emergency Response Team / Accident Processing Headquarters / Regional Response Center
Training System	Regular scenario-based drills	Quarterly Table-top Drills; irregular Unannounced Drills
Response Procedure	Provision of accident type-specific Flow Charts	Procedures for 35 types, including collision, grounding, fire, and mechanical failure
Reporting System	Operation of the I.C.L (Initial Communication Line)	Ship–Head Office–Related Agencies reporting system within 30 minutes
Limitations	Existence of overlapping procedures between types; limits to information feedback	Inadequate real-time data sharing system; formalization issues in response reports

Table 3: Overview of Company B's ERS

4.3 Company C: International Standard-Based Training and Verification System

Company C aligns its ERS with international standards (SOLAS, ISM Code), classifying drills by D1–D12 codes and defining 31 emergency types. This demonstrates high conformance to regulations. The critical limitation, however, is the lack of a feedback system to convert post-drill evaluation results into organizational learning.

Category	Key Features	Detailed Content
Organizational Structure	Coexisting ship and shore emergency response organizations	Integrated response organization centered on the Head Office Maritime Headquarters
Training System	International regulation-based (SOLAS, IAMSAR, etc.)	Monthly, quarterly, and semi-annual cycle setting; Drill result evaluation and record
Response Procedure	31 emergency types defined	Detailed classification of fire, abandon ship, pollution, flooding, mechanical failure, etc.
Reporting System	ERS Integrated Report preparation	Reporting to P&I Club and authorities concurrently upon accident occurrence
Limitations	Lack of feedback system; tendency for formal evaluation	Inadequate use of Drill results for improvement;

Category	Key Features	Detailed Content
		absence of a learning organization

Table 4: Overview of Company C's ERS

4.4 Company D: Integrated Training System Based on Latest Technology

Company D (focused on LNG transport) utilizes an IT-based integrated response system and ship/shore linkage training, including "Integrated Package Drills" for combined accidents. It classifies 19 types, specific to LNG carriers. While technically integrated, its limitations are a lack of flexibility in field decision-making and procedural complexity, leading to over-reliance on automation.

Category	Key Features	Detailed Content
Organizational Structure	Integrated ship-shore emergency organization	Composed of Accident Countermeasure Headquarters + Ship Response Team + Technical Support Team
Training System	Focus on combined accident response	Implementation of combined Drills (Fire + Grounding, Oil Spill + Life Saving, etc.)
Response Procedure	LNG carrier-specific procedures	19 types classified, including insulation compartment, leakage, and security
Reporting System	Real-time communication system operation	Integrated reporting channel between ship and shore; VDR linkage
Limitations	Restriction on autonomous judgment; procedural complexity	Over-reliance on automated systems; reduced flexibility in field response

Table 5: Overview of Company D's ERS

4.5 Summary of Comparative Analysis (A-D)

Category	Company A	Company B	Company C	Company D
ERS Structure Type	Ship-centric Vertical	Type-specific Classification	International Standard-based	Technology-integrated
No. of Emergency Types	16	35	31	19
Training System	Regular + Scenario Drill	Table-top & Unannounced Drill	Legal-based Drill (SOLAS/IAMSAR)	Package-type Combined Drill
Reporting System	Clear Stage-by-Stage Procedure	ICL (Report within 30 min)	Concurrent International Reporting	Real-time Communication System
Feature Summary	Clear procedures, systematic documentation	Detailed type-specific response	High conformance to international norms	High level of technical integration
Major Limitations	Inadequate combined accident response	Excessive procedural division	Lack of feedback/learning system	Over-reliance on automation, reduced field judgment

Table 6: Comprehensive Comparison Table for Companies A–D

4.6 Synthesis of Analysis and Implications

In general, all four companies are equipped with ERS that meet international standards. However, significant differences exist in standardization and field-oriented efficiency.

The variance in classified emergency types (from 16 at Company A to 35 at Company B) highlights a fundamental tension in ERS design: **detailed granularity versus operational flexibility**. Company B's highly detailed system ensures procedural consistency but, as noted, risks **procedural overload** and reduced flexibility in complex, combined accidents. This limitation in combined accident response was also noted in Company A.

The common limitations identified—particularly the inadequate response to combined accidents and the systemic lack of feedback loops —suggest a deeper, common **root cause**. The ERS in these companies appear to be operated primarily as a **'paper-based' system** designed to satisfy the minimum compliance requirements of the ISM Code, rather than evolving into a **'performance-based' or 'resilience-based'**

system that reflects operational complexities and promotes organizational learning.

Therefore, the future directions for improvement are:

I. Establishment of Standardized Multi-Crisis Response Protocols.

II. Strengthening the Feedback Loop to formalize Drill results into organizational learning.

III. Enhancing the real-time capability of the ship/shore integrated communication platform.

IV. Development of an AI/IoT-based Predictive ERS.

These directions will serve as the foundational design basis for the IM-ERSF presented in the next chapter.

V. INTEGRATED MARITIME ERS FRAMEWORK(IM-ERSF)

5.1 Necessity of the Standard Model Design

As confirmed in the analysis, Companies A–D showed heterogeneity in procedural standardization, information sharing, and post-accident learning systems. This results in response inefficiencies and constrains the establishment of a consistent national safety system. Accordingly, this study proposes the Integrated Maritime Emergency Response Framework (IM-ERSF), focusing on standardization, integration, and intelligence.

5.2 Conceptual Structure of the Integrated ERS Standard Model

5.2.1 Fundamental Design Principles

- **Standardization**: Establishing common procedures and terminology.
- **Integration**: Interlinking information sharing among ship–shore–government agencies in real time.
- **Intelligence**: Introduction of AI/IoT-based risk detection and predictive decision-making support.
- **Learning**: Systematically accumulating and improving upon accident response and training results.

5.2.2 IM-ERSF Structure Overview

The proposed IM-ERSF (Table 7) is built on five levels. It is specifically designed to address the gaps identified in the analysis of Companies A–D. Its primary distinction is the emphasis on **Level 5: Post-Response Learning Layer**. This layer is not merely a passive database; it functions as an **active feedback loop designed to systematically improve the AI-based Decision Layer (Level 4)**. This directly addresses the common limitation of "Lack of feedback/learning system" found across the companies, ensuring the predictive model evolves rather than remaining static.

Level	Component	Key Function	Interfacing Entity
Level 1: Shipboard Layer	Captain, Emergency Response Team, Automatic Alarm System	Initial response, immediate safety measures	On-board personnel
Level 2: Shore-based Layer	Head Office Maritime Headquarters, Safety Management Office	Situation assessment, support resource coordination, government notification	Head Office–Ship–Government Agencies
Level 3: Information Integration Layer	IoT Sensor, AIS, VDR, ERP	Real-time data collection and visualization	Shipping Company–National Maritime Safety Center
Level 4: AI-based Decision Layer	Predictive Model, Risk Analysis Algorithm	Risk calculation, automated response alternative recommendation	Manager–Commander
Level 5: Post-Response Learning Layer	Accident Record DB, Feedback Loop	Root cause analysis, manual improvement, reflection in education	Company-wide Learning Organization

Table 7: IM-ERSF Structure Overview

5.3 Integrated ERS Information Flow Model
[Accident Occurrence]
↓
[Level 1: Ship Initial Response]
↓ Real-time Communication
(Satellite Link, IoT Link)
[Level 2: Head Office Emergency Response Headquarters Activation]
↓ Data Auto-Transmission (AIS/VDR)

[Level 3: Integrated Information Center Analysis]
↓ AI Risk Prediction and Enhanced Alert
[Level 4: Command Headquarters Decision Support → Re-transmission of Orders]
↓
[Level 5: Post-Accident Feedback and Learning System Recording/Supplementation]

This structure combines a real-time response system with a data-centric decision support system , aiming to overcome the limitations of manual response and transition to Predictive Safety Management.

5.4 Summary of Module Functions

Module	Key Content	Expected Effect
Emergency Protocol Module	Automatic provision of SOLAS/ISM Code-based standard procedures	Procedural standardization, improved response speed
AI-Risk Prediction Module	Learning from past accident, weather, and operational data	Improved accident prediction accuracy
Real-Time Communication Hub	Real-time communication network among ship–head office–government agencies	Minimization of information fragmentation
Feedback & Training Module	Automatic recording and analysis of accident/drill results	Organizational learning and continuous improvement
Visualization Dashboard	Visualization of risk level by situation	Improved decision support and monitoring efficiency

Table 8: Summary of Module Functions

5.5 Validation of the Proposed Framework

To assess the feasibility and practical applicability of the proposed IM-ERSF, a series of structured interviews were conducted with 5 experts, including Designated Persons Ashore (DPAs) and maritime safety managers (drawing experience from the analyzed companies).

The experts validated the necessity of all five levels, particularly agreeing on the critical need for Level 3 (Information Integration) and Level 5 (Post-Response Learning). However, they identified the **standardization of data protocols between the ship's IoT sensors (Level 3) and the shore-based headquarters (Level 2)** as the primary implementation barrier. This feedback confirms that while the framework is conceptually sound, its success hinges on solving data governance and interoperability challenges.

5.6 Expected Effects of the Model

1. **Enhanced Response Consistency**: Resolving procedural differences among companies.
2. **Activated Inter-Organizational Information Sharing**: Real-time linkage among ship–head office–Ministry–Coast Guard.
3. **Improved Data-Based Response Capability**: Setting response priorities based on AI risk assessment.
4. **Establishment of a Continuous Learning System**: Strengthening organizational resilience through automatic feedback.
5. **Establishment of a National Maritime Safety Standard Model**.

VI. INTEGRATED MARITIME ERS FRAMEWORK(IM-ERSF)

6.1 Summary of Conclusion

This study comparatively analyzed the ERS of major domestic shipping companies (A–D). The analysis confirmed that while all companies comply with international norms, **lack of standardization, insufficient learning from training results, limitations in combined situation response, and fragmentation of information sharing** were commonly identified. Accordingly, this study proposed the IM-ERSF to address these issues. This model aims to establish a predictive and continuous safety management system that combines real-time response with post-accident learning.

6.2 Policy Implications

The findings suggest several high-level policy actions for governmental bodies:

1. **Necessity of Enacting National ERS Standard Guidelines**: The enactment of 'K-ERS Standard Guidelines' is needed to integrate the varying response systems.

2. **Establishment of an Integrated Information Platform**: Construction of a Maritime Integrated Response Data Platform (MIRDP) is necessary for real-time information sharing.

3. **Introduction of AI-based Prediction and Alert System**: Establishment of a Predictive ERS Module is needed to proactively analyze and alert accident risks using Big Data and Machine Learning.

4. **Regularization of Training and Feedback System**: Drill and post-accident feedback must be managed in a mandatory record management system (DB) to foster a practical learning organization.

5. **International Cooperation**: A long-term goal should be set to pursue Mutual Recognition of the ERS system.

6.3 Practical Implications for Shipping Companies

Beyond national-level policy, this study offers immediate, practical implications for shipping operators. The common weakness in 'combined accident response' can be addressed by **integrating multi-crisis scenarios** (e.g., 'Fire + Grounding') into regular drill schedules, moving beyond single-event training. Furthermore, companies must establish formal internal procedures to **ensure that lessons learned from drills and minor incidents (Level 5) are fed back into the revision of ERS manuals (Level 1)**, thereby strengthening organizational learning without waiting for government mandates.

6.4 Limitations and Future Research

This study is limited in that its analysis centered on four major shipping companies and did not include small- and medium-sized companies or specialized vessels (tankers, passenger ships).

Future research should aim to overcome these limitations by: 1) **Developing and testing specific algorithms for the Level 4 AI-Risk Prediction Module**; 2) **Conducting quantitative, simulation-based studies** to compare the response efficiency of the IM-ERSF against existing ERS models; and 3) **Expanding the analysis** to include SMEs and other vessel types to enhance the model's generalizability.

6.5 Concluding Remarks

The comparative assessment of Korean shipping companies' ERS revealed fundamental inconsistencies and operational inefficiencies across communication, decision-making, and feedback processes. To address these structural weaknesses, the proposed IM-ERSF establishes a unified, technology-driven architecture designed to standardize procedures, enhance interoperability, and reinforce regulatory compliance. Implementing this framework within a national maritime governance structure is expected to strengthen operational safety, institutional resilience, and ultimately, the global competitiveness of Korea's shipping industry.

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