STRENGTHENING SAFETY LEADERSHIP IN INDONESIA'S MARITIME SECTOR

***Elif Nur Ercan*[1], *Dimas Harris Sean Keefe*[1], *Saeyeon Roh*[2], *Jin-Woong Yoo*[3], *Hyunmi Jang*[1*]**

[1]*Graduate School of International Studies, Pusan National University, ROK*

[2]*Plymouth Business School, University of Plymouth, UK*

[3]*Hertfordshire Business School, University of Hertfordshire, UK*

Corresponding Author

ABSTRACT

Purpose: This study aims to explore and analyze the structural relationships among the key determinants influencing safety leadership behaviors in the Indonesian maritime industry. Amid increasing safety concerns and complex maritime conditions in Indonesia, this research seeks to provide a comprehensive understanding of how various individual, behavioral, and environmental factors interact to shape leaders' safety behaviors.

Design/methodology/approach: An exploratory research design is employed, utilizing the Fuzzy-DEMATEL method to investigate the causal relationships among safety leadership factors. Data is collected through an online survey targeting maritime industry managers and officers with safety-related decision-making experience. The survey applies a pairwise comparison format to assess the influence levels among determinants such as safety attitude, safety knowledge, safety motivation, AI knowledge, and safety culture.

Findings: The findings revealed the critical pathways and hierarchical influence structures among the determinants of safety leadership behaviors. The study provides empirical evidence on how advanced technologies, particularly AI applications, and organizational safety culture collectively enhance or hinder safety leadership. The results offer valuable insights into which factors should be prioritized to strengthen safety leadership practices in the Indonesian maritime sector effectively.

Practical implications: The study's outcomes are expected to support the development of practical strategies and policies aimed at improving safety leadership in maritime operations. By identifying the most influential factors, maritime organizations can implement targeted interventions to enhance safety performance and prevent accidents.

Originality/value: This research contributes to the literature by applying a systems-thinking approach through Fuzzy-DEMATEL to safety leadership, a methodology that has been scarcely used in the maritime context. It also introduces the integration of AI-related factors into safety leadership analysis, offering novel perspectives for both academia and industry. The methodology and analytical framework can be adapted for broader applications in similar high-risk sectors.

Keywords: Safety leadership; Maritime safety; f-DEMATEL; Reciprocal determinism; Safety compliance; Communication; AI knowledge; Safety policy; Indonesia; Maritime governance

1. Introduction

Indonesia, as the world's largest archipelagic nation, occupies a highly strategic position between the Pacific and Indian Oceans, and along several major international maritime trade routes (Rochwulaningsih et al., 2019). With over 17,000 islands and the second-longest coastline in the world, the management of maritime safety and operational efficiency has become a prerequisite for sustainable development in the maritime sector. Nonetheless, due to the limited application of safety management systems aligned with international standards, frequent safety incidents have occurred (Bowo et al., 2024; Wahid et al., 2023), such as the sinking of KM Sinar Bangun in Lake Toba in 2018, which resulted in significant loss of life (Waskito et al., 2024). To ensure safety standards and improve overall safety performance, safety leadership should therefore be addressed in the Indonesian context, where previous studies have predominantly emphasised the strategic role of leaders (Arif and Kurniawan, 2018).

Compared to other leadership styles, safety leadership specifically highlights a leader's safety-enhanced behaviour and the way leaders engage with followers to achieve safety goals (Kim et al., 2021), making it a suitable concept in the current maritime context to prevent accidents and elevate safety standards (Hasanspahić et al., 2021). However, despite recognition of the vital role leaders play in reinforcing safety in the maritime industry, a critical gap remains in understanding the diverse determinants of safety leadership and how these can be operationalised within the Indonesian maritime sector (Putra et al., 2024).

In the extant literature, safety leadership has been linked to several key determinants, including safety culture, policy, and motivation (Lu and Yang, 2010; Ta et al., 2022). This study employs Bandura's theory of reciprocal determinism, which posits that individual behaviour is influenced by the continuous interaction among personal, environmental, and behavioural dimensions (Bandura, 1978). Through these dynamic interactions, leadership capabilities can be progressively developed and enhanced (Ross, 2014). Accordingly, reciprocal determinism is adopted in this study as the conceptual lens to examine how these interconnected dimensions contribute to the emergence of effective safety leadership in high-risk operational settings.

In the Indonesian maritime sector, institutional fragmentation and overlapping jurisdictional responsibilities, particularly involving agencies such as Bakamla and the Sea and Coast Guard, have led to operational inefficiencies and hindered the development of safety leadership at the individual level (Darmawan et al., 2022; Suparto and Admiral, 2022). Although national authorities are instrumental in shaping safety leadership policies through strategic vision, the actual implementation often relies on individual actors within organisations. In response, many shipping companies have begun strengthening internal leadership strategies to improve overall safety performance (Putra et al., 2024). Nevertheless, the lack of a unified command structure and the limited coordination between public and private sectors continue to constrain regulatory enforcement efforts and inhibit the broader advancement of safety leadership practices (Suparto and Admiral, 2022).

Therefore, two different research questions arise: 1) What are the key determinants of safety leadership in the Indonesian maritime sector, and 2) how can safety leadership be implemented through these determinants? Hence, this study aims to identify key determinants of safety leadership and their interactions in the Indonesian maritime sector for actualising the safety leadership of individuals.

This quantitative study utilises the fuzzy Decision-Making Trial and Evaluation Laboratory (*f*-DEMATEL) method as one of the Multi-Criteria Decision-Making (MCDM) methods, which can analyse and prioritise the complex relationships among variables influencing safety leadership (Wu and Lee, 2007). The f-DEMATEL method is also effective in identifying causal links among different dimensions, such as personal, environmental and behavioural aspects, to actualise a certain leadership style (Yoo et al., 2025).

In summary, this quantitative study employs the f-DEMATEL method to identify the key determinants of safety leadership and analyse their interrelationships within the Indonesian maritime sector. Grounded in the theoretical lens of reciprocal determinism, the study highlights factors across three dimensions: personal, environmental, and behavioural. The aim is to enhance safety leadership and address the current gaps in its development within the Indonesian context.

2. Determinants of Safety Leadership

2.1 Indonesian Context

Indonesia's maritime environment presents significant safety risks due to its vast archipelagic geography, traditional sea practices, and varying infrastructure quality (Effendi, 2025). Frequent accidents, such as ship fires, drownings, and port injuries, are especially common in small multipurpose ports and traditional routes, largely due to inadequate safety measures, poor enforcement, and limited applicability of international standards (Wahid et al., 2023). Many incidents involve passengers falling, vehicle collisions, or injuries from mooring lines, which are linked to substandard infrastructure and the absence of standardised protocols. Although safety initiatives exist, they remain limited, particularly in addressing port-size-specific challenges and the integration of safety leadership strategies (Putra et al., 2024; Santospriadi et al., 2023).

Beyond safety policies and systems, building a strong maritime safety culture is seen as a strategic priority that can shape leadership styles within organisations (Yoo et al., 2025). Initiatives such as national awareness campaigns, enhanced maritime education, and the integration of occupational safety and health (K3) into training academies are vital for developing safety-oriented leaders (Ekawati, 2024). Additionally, expanding research and data-driven policymaking is essential for understanding and actualising safety leadership in practice (Arif and Kurniawan, 2018; Putra et al., 2024).

2.2 Reciprocal Determinism Theory

According to Bandura (1978), human behaviour can be regarded as the result of dynamic interactions among three key dimensions, such as personal factors, environmental elements and behavioural patterns or factors. Thus, based on this theory, it is implied that a certain leadership is not shaped in isolation and can be steadily developed through continuous interactions among three key dimensions (Ross, 2014). While Bandura's theory underlines a psychological aspect, emergent reciprocal influence addresses people's interactions (Sims and Manz, 1984; Watson and Scribner, 2007). In the leadership development context at work, mutual influence and interactions become a key principle (Yang et al., 2025).

Digitalisation has been deemed a transformative force in Indonesia's maritime sector, aiming to reinforce service quality and global competitiveness (Iman et al., 2022). Various technological initiatives have been introduced in shipping and port operations, including the implementation of electronic delivery orders, Artificial Intelligence (AI), and integrated logistics platforms. These innovations can aim at modernising Indonesia's maritime infrastructure and aligning it with global standards for smart port development and safety leaders (Arif and Kurniawan, 2018; Safuan and Syafira, 2024). Therefore, personal elements, including safety attitude, knowledge, and AI knowledge for safety, can interact with environmental or behavioural factors. It is likely that when actualising a certain leadership, factors for personal dimension can interact with factors of environmental dimension, including safety culture, policies and motivational systems (Yoo et al., 2025).

2.3 Personal Dimension

Based on the theoretical lens of reciprocal determinism, this study posits that safety attitude, knowledge and AI knowledge for safety can be key determinants of safety leadership in the maritime context, particularly in the Indonesian context.

Safety Attitude

The safety attitude of leaders in maritime plays vital role in improving in their leadership approach. It can act as the psychological facilitator that determines whether safety leadership is reactive and compliance-based or proactive, learning-centered, and enduring. The research shows that positive safety attitudes among leaders develop their leadership style by improving reporting culture, introducing systemic thinking, and making decisions for safety based on evidence-based practices (Hjellvik & Sætrevik, 2020). Building on previous research that established self-reported safety behaviour as a predictor of safety outcomes, another study shows perspective into the psychological mechanisms underlying these relationships. The research investigated "friendly leader", "mentoring", "multiculturalism" and "teamwork" themes that how these factors influence each other, and it showed that except multiculturalism they have positive impact. (Casareale et al., 2021).

Moreover, leaders' safety attitudes have a great impact on pilots' line behaviour, as hazardous attitudes are the major source of risky behaviour. Positive safety leadership involves promoting psychological wellness, balanced risk perception, and regular safety training to counter hazardous attitudes. Study showed that overconfidence in hazard assessment may undermine risk perception, and therefore leaders ought to facilitate realistic assessment and continual learning (Xu et al., 2021).

Safety Knowledge

Studies underlines that safety knowledge in leaders is not just regulatory literacy; it is a driver of preparedness, motivation, awareness, and crew behaviour. Leaders who possess and actively apply safety knowledge can embed preparedness into the fabric of ship operations, align safety culture with practice, and ensure crew are motivated and aware in emergencies (Kuncowati et al., 2023). Gundi´ c et al. (2021) discuss the development of generic competencies through additional education programs that very important for addressing technological growth and changes in ship organization. Complementing the safety culture is recognized with numerous studies mentions its implications for safer shipping operation competencies outlined by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). Finally, Shipboard leaders enhance safety by integrating safety values into procedures while employing soft influence tactics such as coaching and role modelling, research showed these tactics could foster sustained safety behaviours through relational knowledge and interpersonal communication (Veltsin et al., 2025).

AI Knowledge

The potential of AI-driven risk management and analytics in transforming maritime safety leadership at both operational and organizational levels. At the ship level, Large Language Models (LLMs) and machine learning (ML) systems support captains and officers by reducing miscommunication, automating safety reporting, and enhancing situational awareness through anomaly detection and decision cues (Arslanoglu et al., 2023; Miller et al., 2025) . Studies show that AI-enabled analytics can predict safety climate and crew perceptions, allowing leaders to intervene with targeted coaching, adjusted workloads, and more effective drills. According to Lee and Lee 2024, the RA4MAIS paradigm assists executives in managing risks in human-AI interactions while also assuring accountability and operational safety. However, it is still in early stages of development and requires additional empirical validation to demonstrate its efficacy in real-world, complicated marine contexts. Several studies have shown that, AI tools at headquarters enhance safety culture by enabling multilingual communication, policy dissemination, and compliance auditing for fleet managers and HSE leaders (Wu et al., 2025; Lee and Lee et al., 2024). Aligning AI risk management with international frameworks encourages proactive governance for maritime autonomy, ensuring that safety continues into future operations.

2.4 Environmental Dimension

Based on the theoretical lens of reciprocal determinism, this study posits that safety culture, policy and motivational system can be core determinants of safety leadership.

Safety Culture

Safety culture serves as a foundational determinant of how leaders at both the ship and headquarters levels perceive, prioritize, and act upon safety in maritime operations. For ship-based leaders, such as captains and officers, a robust safety culture fosters relationship-oriented leadership behaviours, including coaching, role modelling, and collaborative consultation (Kim & Gausdal, 2020; Hasanspahić et al., 2021). This alignment enhances situational awareness and nurtures a just culture, where errors are treated as opportunities for collective learning rather than grounds for punishment. Such an environment reduces unsafe behaviors, promotes accurate risk assessment, and reinforces proactive safety engagement (Casareale et al., 2021; Hasanspahić et al., 2021; Kim & Gausdal, 2020; Sætrevik & Hystad, 2021). Conversely, fragmented or punitive cultures erode trust, discourage transparent communication, and elevate operational risks, thereby undermining safety performance (Hasanspahić et al., 2021; Olsen et al., 2020). Given their direct involvement in daily operations, ship-based leaders must internalize and embody safety values to translate organizational policies into consistent, high-quality practices (Choo et al., 2024; Hasanspahić et al., 2021; Kim & Gausdal, 2020).

For headquarters-based leaders, the influence of safety culture is less immediate but equally significant. Through policy formulation, resource allocation, and targeted training programs, they establish the structural and cultural foundation that enables consistency in safety performance across fleets (Atikasari et al., 2022; Bautista-Bernal et al., 2023; Hasanspahić et al., 2021). Strong alignment between strategic priorities at headquarters and operational realities onboard enhances clarity, communication, and mutual trust, whereas misalignment often leads to inconsistent safety practices and diminished organizational resilience (Hasanspahić et al., 2021; Jung, 2021). Moreover, headquarters leaders play a pivotal role in fostering a culture of continuous improvement, transparent dialogue, and innovation in safety practices, reinforcing safety as a shared and enduring organizational value (Bautista-Bernal et al., 2023; Jung, 2021).

Safety Policy

Safety-relevant policies developed by maritime firms or regulatory authorities are pivotal in shaping leadership behaviors and operational decision-making across organizational levels. For ship-based leaders, including captains and officers, safety policies function not only as operational guidelines but also as behavioral frameworks that guide communication, coordination, and problem-solving (Choo et al., 2024; Hasanspahić et al., 2021; Kim & Gausdal, 2020). When effectively implemented, these policies support the application of safety management systems, promote compliance with regulatory standards, and enhance teamwork and information sharing. Policies that are grounded in a just culture create an environment in which errors are treated constructively, facilitating shared learning and collective accountability (Choo et al., 2024; Hasanspahić et al., 2021; Kim & Gausdal, 2020; Olsen et al., 2020). Evidence further suggests that transformational and relationship-oriented leadership styles reinforce safety participation and compliance, whereas passive or avoidant leadership increases the likelihood of unsafe behaviors and operational incidents (Casareale et al., 2021; Chen et al., 2021; Yuen et al., 2020).

For headquarters-based leaders, the influence of safety policies is more strategic but equally significant. These leaders design coherent frameworks, allocate resources, and ensure that policies are consistently applied across diverse operational contexts (Buchari & Victoria, 2021; Chen et al., 2021; Febriansyah et al., 2020; Hopcraft et al., 2022; Turedi & Ozer-Caylan, 2021). Effective policies are those that bridge the gap between regulatory expectations and shipboard realities, fostering trust and effective communication between onshore managers and ship-based personnel. By cultivating a climate of continuous learning and innovation, headquarters leaders can empower ship-based leaders to internalize safety standards, enhance operational resilience, and strengthen a proactive safety culture throughout the organization.

Safety Motivation

Safety reward systems in maritime organizations significantly shape leadership behaviours at both operational and strategic levels, influencing how safety is valued, communicated, and enacted across the organization. For ship-based leaders, such as captains and officers, reward systems directly affect daily interactions with their crews. Timely and meaningful recognition, particularly through symbolic or collective rewards, fosters morale, strengthens teamwork, and enhances adherence to safety procedures (Hasanspahić et al., 2021; Houette & Mueller-Hirth, 2021). When these systems align with transformational and transactional leadership approaches, they enable leaders to motivate their teams while reinforcing compliance through structured and constructive feedback (Hasanspahić et al., 2021; Kim et al., 2020). Consistent application of rewards reduces role ambiguity and strengthens perceptions of fairness, creating an environment where safe behaviours are encouraged, expected, and appreciated. Conversely, inconsistent or absent feedback undermines clarity, weakens motivation, and can lead to reduced engagement with safety protocols (Liu et al., 2022).

For headquarters-based leaders, reward systems function at a more strategic level. These leaders are responsible for designing frameworks that balance material incentives, symbolic recognition, and collective achievements to align with organizational priorities (Casareale et al., 2021; Houette & Mueller-Hirth, 2021). Clear communication of reward criteria, coupled with leadership development initiatives, ensures that ship-based leaders can apply these systems effectively (Casareale et al., 2021; Hasanspahić et al., 2021; Liu et al., 2022). Furthermore, involving employees from both shipboard and shore-based operations in the design and refinement of reward systems promotes a sense of ownership, enhances the relevance of incentives, and fosters a cohesive organizational culture where safety motivation becomes a shared and sustainable value (Casareale et al., 2021; Houette & Mueller-Hirth, 2021).

2.5 Behavioural Dimension

Likewise, through the theoretical lens of reciprocal determinism, this study posits that safety communication, compliance and AI application by leaders can be key determinants of safety leadership in the Indonesian context.

Safety Communication

The main causal factor in maritime accidents is miscommunication. Safety Communication has been repeatedly emphasized in the literature moreover highlighting that leadership plays important role in operational clarity in maritime communication. Gabedava and Hu (2025) demonstrate that up to 80% of accidents are attributable to human error, with nearly half linked to communication breakdowns. Their linguistic analysis of the *Stena Feronia* collision and the *Hamburg* grounding show how vague instructions, delayed responses, and misinterpretations of authority escalated risks. Standardized language practices, such as Standard Marine Communication Phrases (SMCP), and linguistically informed safety training are recommended to reduce ambiguity and enhance clarity.

Rey Charlo (2023) provides historical evolution by showing that maritime safety communication has evolved from early wireless telegraphy to the Global Maritime Distress and Safety System (GMDSS) and this progress show how institutionalized communication standards have consistently improved safety outcomes. Yet, research highlight that technology alone is insufficient: effective communication requires training, standardization, and leadership commitment to fostering an environment where seafarers feel psychologically safe to report concerns (Gabedava and Hu, 2025; Charlo, 2023). Thus, in the Indonesian context, leaders must act not only as users of established communication systems but also as facilitators of open, standardized, and trust-based dialogue within multicultural crews.

Safety Compliance

Safety leadership lies in safety compliance, which involves devotion to established rules, checklists, and international conventions. Safety compliance is a critical determinant of maritime safety leadership, ensuring that international regulations and company procedures are consistently applied in practice. While compliance is often framed in terms of human discipline, recent studies show that it can be strengthened both technologically and organisationally. Recent study demonstrate this through their KM-DWA model for Maritime Autonomous Surface Ships (MASS), which embeds COLREGs rules, situational awareness, and tiered safety distances into navigation algorithms (Song et al., 2024). Similarly, Durlik et al. (2025) highlight how real-time AI agents reinforce compliance by integrating collision avoidance, anomaly detection, emission control, and fail-safe operations into vessel systems, ensuring rule-adherent decision-making even in dynamic environments.

From an organisational perspective, research on container terminals in Taiwan shows that safety climate, employees' self-efficacy, and the perceived cost of non-compliance all significantly influence compliance behaviours (Yen et al., 2022). Importantly, the concept of non-compliance cost mediates the link between safety climate and compliance, underlining the value of aligning cultural and economic incentives with safety codes. Together, these studies suggest that safety compliance in the Indonesian maritime sector leaders play a crucial role in bridging regulations with both human and AI-supported practices, ensuring compliance is not treated as a formality but as an integrated behavioural norm.

AI Application

According to Peifer et al. (2022), owing to a massive growth in data, the application of AI has become a key part of the reinforcement of leadership implementation. Through the AI application, such as AI-driven predictive analytics, maritime leaders can enhance their strategic thinking, risk assessment and decision-making, which in turn improves organisational safety performance. If leaders can utilise predictive analytics (i.e., AI application), they can avoid potential safety hazards before they occur (Simion et al., 2024).

In the Indonesian context, the adoption of AI and other emerging technologies, such as the Internet of Things (IoT), blockchain, and augmented reality, has also been explored as a means of optimising supply chain management and vessel traffic control (Tseng et al., 2025). These technologies are expected to reduce human error, enhancing real-time decision-making and managing container handing processes. Nonetheless, their integration has been challenged by limitations in physical infrastructure, a shortage of skilled personnel, and policies (Safuan and Syafira, 2024). Thus, in addition to supportive policies, it is necessary to design training programs for applying AI-driven predictive analytics for maritime leaders, which can enhance safety leadership approaches (Simion et al., 2024). Hence, the successful AI application can be a core determinant of safety leadership in this study.

Overall, Table 1 summarises the safety leadership determinants in this research.

Table 1. Safety leadership determinants

V1-9 will be used in the analysis

Dimension	Variable	Meaning	Relevant source
Personal	Safety attitude (V1)	Prioritising safety as a core value	Stiles et al. 2018; Ta et al. 2022
	Safety knowledge (V2)	Understanding safety rules and procedures	Ayouz et al. 2025; Stiles et al. 2018; Ta et al. 2022
	AI knowledge (V3)	Understanding AI-based risk management and analytics	Durlik et al. 2024; Miller et al. 2025
Environment	Safety culture (V4)	Shared beliefs and values about safety	Lu & Yang 2010; Stiles et al. 2018; Ta et al. 2022
	Safety policy (V5)	Defined responsibilities for safety	Lu & Yang 2010; Ta et al. 2022
	Safety motivation (V6)	A safety incentive (motivational) system	Lu & Yang 2010
Behavioural	Safety communication (V7)	Open communication for safety with colleagues and followers	Lu & Yang 2010; Stiles et al. 2018
	Safety compliance (V8)	Adhering to safety rules and procedures	Lu & Yang 2010; Pilbeam et al. 2016
	AI application (V9)	Using AI-driven predictive analytics to detect and manage risks	Durlik et al. 2024; Peifer et al. 2022; Simion et al. 2024

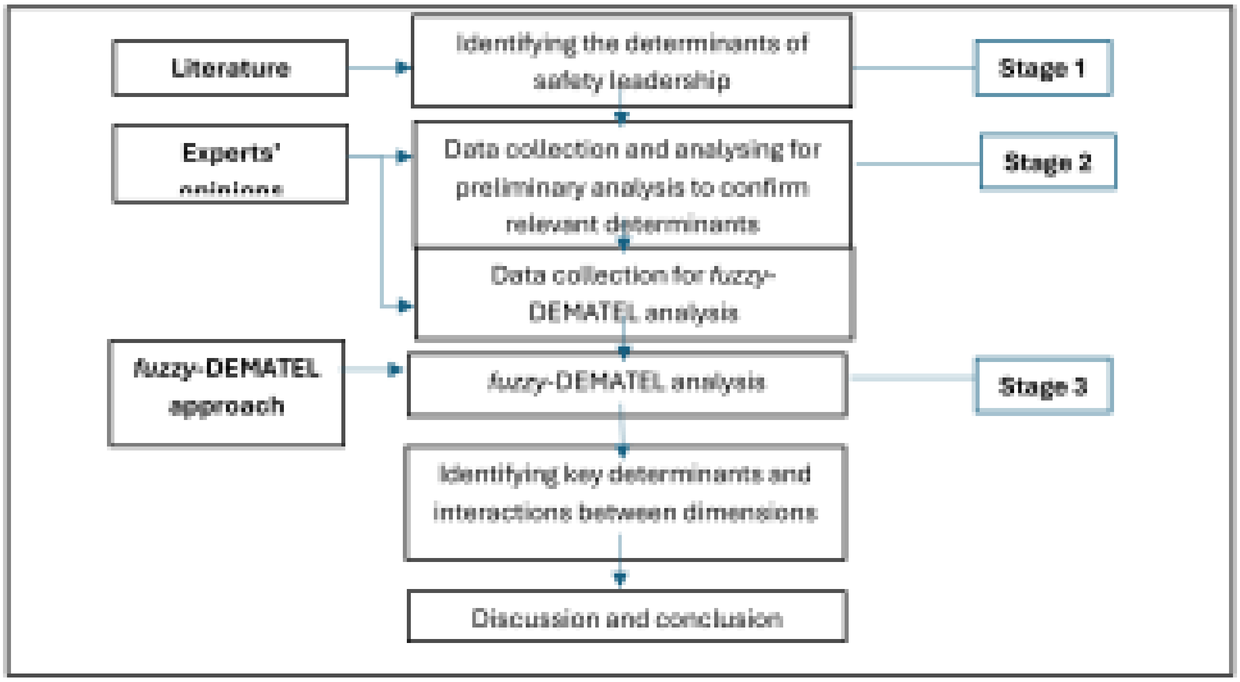
3. Methodology

3.1 Sample and Process

Prior to conducting the *f*-DEMATEL analysis as stage 3, the determinants of safety leadership within the maritime context are identified and confirmed in stages 1 and 2. Figure 1 for the framework for research methodology covers stages 1, 2 and 3 for the *f*-DEMATEL approach.

In the first stage, core determinants of safety leadership are extracted from the existing literature (See Figure 1).

Figure 1. Framework for methodology



In the second stage, 9 elements as identified in Table 1 were furnished to 85 experts in Indonesia's maritime sector to assess their relevance to safety leadership determinants in the Indonesian context. As the MCDM method, including *f*-DEMATEL, relies on experts' opinions to develop practical viewpoints, this study has utilised the non-probability sampling method to collect survey data (Gandhi et al., 2016). Moreover, regarding data collection for preliminary analysis as stage 2 and *f*-DEMATEL analysis as stage 3, this study has been approved by the Institutional Review Board (IRB) of the university for ethics in August 2025.

To assess and confirm if 9 elements are related to safety leadership determinants as a preliminary analysis, 5-Likert Scale was utilised. A mean value greater than 3 was regarded as relevant to safety leadership determinants (Yoo et al., 2025). The results indicated that all 9 elements have had mean values above 3, determining their suitability for inclusion in Stage 3.

Table 2 provides the preliminary analysis for stage 2.

Table 2. Preliminary analysis

Dimension	Variable	Value
Personal	Safety attitude	4.53
	Safety knowledge	4.40
	AI knowledge	3.98
Environment	Safety culture	4.44
	Safety policy	4.41
	Safety motivation	4.96
Behavioural	Safety communication	4.36
	Safety compliance	4.55
	AI application	4.10

In the third stage of the f-DEMATEL analysis, likewise, 85 experts participated in the survey. While previous studies on maritime safety and safety leadership have mainly focused on the perspectives of seafarers or ship-based personnel, this study has collected data from both seafarers (78 experts) and office-based personnel (7 experts), considering the importance of integrated viewpoints for enhancing safety leadership. In that case, the risk of maritime disasters can be practically reduced (Casareale et al., 2021).

Regarding 85 maritime professionals (i.e., experts), over 90 per cent of participants have more than 5 years of experience in deck, engineering or operational roles for safety. Therefore, they were considered maritime safety experts for the purpose of this research. The description of research participants is depicted in Table 3.

Table 3. Description of research participants

Category		Frequency	Per cent (%)
Gender	Male	85	100
	Female	0	0
	Total	85	100
Age	20s	4	4.7
	30s	34	40
	40s	32	37.6
	50s	14	16.5
	60s	1	1.2
	Total	85	100
Work location	Ship-based	79	92.9
	Headquarters-based	6	7.1
	Total	85	100
Ship-based personnel	Captain	16	20.2
	Chief officer	13	16.5
	Second officer	10	12.6
	Third officer	1	1.3
	First engineer	19	24.1

	Second engineer	10	12.6
	Third engineer	4	5.1
	Other	6	7.6
	Total	79	100
Office-based personnel	Department head	1	16.7
	Senior officer	1	16.7
	Junior officer	2	33.3
	Officer	2	33.3
	Other	0	0
	Total	6	100
Years of professional experience (experts)	More than 15 years	30	35.3
	10-15 years	26	30.6
	5-10 years	23	27.1
	Less than 5 years	6	7.1
	Total	85	100
Areas of expertise	Engineering	47	55.3
	Deck	33	38.8
	Leadership	3	3.5
	Operational management	2	2.4
	Total	85	100

3.2 *F*-DEMATEL technique

This research employs the *f*-DEMATEL technique to analyse complicated interrelationships among diverse factors from personal, environmental and behavioural dimensions. Compared to the traditional DEMATEL method or technique, the *f*-DEMATEL technique can integrate fuzzy logic to address ambiguity and uncertainty in expert judgements (Mangla et al., 2018). This technique is useful for understanding complicated problems involving diverse interrelated elements or dimensions. By considering fuzzy numbers, the use of the *f*-DEMATEL technique can help decision-makers or business leaders avoid the ambiguity of assessments. In addition, this technique can help identify critical elements of leadership determinants, causal relationships among elements and understand their complex interactions, which can facilitate structured decision-making for business leaders (Yoo et al., 2025). Although the DEMATEL technique was recommended to be used for maritime safety, leadership styles or approaches based on experts' judgements are rarely discussed (Demirci et al., 2023). Moreover, as the concept of safety leadership can be developed by understanding relationships between different dimensions, the use of *f*-DEMATEL is appropriate for this study (Choo et al., 2024).

The *f*-DEMATEL technique contains several steps as below:

1) As a first step, a group of experts (i.e., maritime professionals) is gathered.
2) To construct a fuzzy pairwise comparison matrix, the pairwise comparisons are acquired through the feedback of experts, utilising the scale provided in Table 4 (Mangla et al., 2018).
3) To develop the fuzzy average direct relation matrix (A), given by the expression as follows:

$$aij = \frac{1}{k\sum x_{ij}} \quad (1)$$

Where k is the number of experts, and i and j are the criteria to be compared.

To obtain crisp values, the defuzzification utilising the weighted average method is executed.

4) Develop the normalised initial direct relation matrix (D) by means of subsequent Equations (2) and (3).

$$m = \min\left[\frac{1}{\max\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\sum_{i=1}^{n}|a_{ij}|}\right] \quad (2)$$

$$D = m \times A \quad (3)$$

Where m is used to normalise the values in the matrix (A).

5) Develop the total-relation matrix by using Eq. (4) as provided below:

$$T = D\,(I - D)^{-1} \quad (4)$$

Where I: Identity matrix, T: Total relation matrix. $T = [t_{ij}]_{n \times n}$

6) Determine the summation of row (R) and the summation of columns (C) by using Eq. (6) and Eq. (7) as given below:

$$R = \left\{\sum_{j=1}^{n} t_{ij}\right\}_{n \times 1} \quad (5)$$

$$C = \left\{\sum_{i=1}^{n} t_{ij}\right\}_{1 \times n} \quad (6)$$

R refers to the net effects provided by one critical factor, say (i), to the other critical factor (j), and C represents the net effect received by critical factor (j) from the other critical factor (i).

7) A cause-and-effect diagram is created using two values, such as the sum of influences given and received (R+C), and the difference between them (R–C). If a factor's R–C value is positive, it can be classified as a cause. Otherwise, if the value is negative, it is classified as an effect.

Table 4. Fuzzy pairwise comparison scale

Linguistic variable	Preference score	Corresponding TFNs
No effect (No)	0	(0, 0, 0.25)
Very low effect (VL)	1	(0, 0.24, 0.50)
Low effect (L)	2	(0.25, 0.50, 0.75)
High effect (H)	3	(0.50, 0.75, 1.0)
Very high effect (VH)	4	(0.75, 1.0, 1.0)

TFN: Triangular Fuzzy Numbers.

4. Findings

F-DEMATEL was applied to identify interrelationships among determinants and critical factors for safety leadership. Table 5 presents the defuzzified average values regarding the direct influence of one criterion on another.

Table 5. Fuzzy initial direct relation matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9
V1	0.04	0.88	0.73	0.85	0.86	0.87	0.85	0.87	0.76
V2	0.87	0.04	0.77	0.85	0.87	0.88	0.85	0.88	0.77
V3	0.79	0.8	0.04	0.79	0.79	0.8	0.8	0.79	0.81
V4	0.87	0.87	0.8	0.04	0.87	0.87	0.87	0.89	0.79
V5	0.85	0.85	0.81	0.87	0.04	0.88	0.87	0.87	0.81
V6	0.87	0.86	0.8	0.86	0.86	0.04	0.86	0.86	0.8
V7	0.87	0.88	0.8	0.87	0.86	0.87	0.04	0.88	0.8

V8	0.87	0.88	0.82	0.87	0.87	0.88	0.87	0.04	0.79
V9	0.8	0.79	0.82	0.78	0.78	0.78	0.8	0.8	0.04

Following this, Table 6 presents the normalised version of the initial direct relation matrix, utilising equations (2) and (3) above.

Table 6. Fuzzy normalised direct relation matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9
V1	0.01	0.13	0.11	0.12	0.12	0.13	0.12	0.13	0.11
V2	0.13	0.01	0.11	0.12	0.13	0.13	0.12	0.13	0.11
V3	0.11	0.12	0.01	0.11	0.11	0.12	0.12	0.11	0.12
V4	0.13	0.13	0.12	0.01	0.13	0.13	0.13	0.13	0.11
V5	0.12	0.12	0.12	0.13	0.01	0.13	0.13	0.13	0.12
V6	0.13	0.12	0.12	0.12	0.12	0.01	0.12	0.12	0.12
V7	0.13	0.13	0.12	0.13	0.12	0.13	0.01	0.13	0.12
V8	0.13	0.13	0.12	0.13	0.13	0.13	0.13	0.01	0.11
V9	0.12	0.11	0.12	0.11	0.11	0.11	0.12	0.12	0.01

In Table 7, utilising equation (4), this matrix reflects the total influence of each criterion on the others, which can provide a comprehensive insight into the safety leadership determinants.

Table 7. Fuzzy total direct relation matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9
V1	4.81	4.93	4.61	4.88	4.89	4.94	4.90	4.95	4.60
V2	4.96	4.88	4.66	4.92	4.94	4.98	4.94	4.99	4.65
V3	4.70	4.72	4.33	4.67	4.69	4.73	4.69	4.73	4.42
V4	5.01	5.03	4.72	4.87	4.99	5.04	5.00	5.05	4.70
V5	5.00	5.01	4.70	4.97	4.87	5.03	4.99	5.03	4.69
V6	4.97	4.99	4.68	4.94	4.95	4.89	4.96	5.00	4.67
V7	5.01	5.03	4.72	4.98	4.99	5.04	4.89	5.05	4.70
V8	5.03	5.04	4.73	4.99	5.01	5.05	5.01	4.95	4.71
V9	4.69	4.70	4.42	4.66	4.67	4.71	4.68	4.72	4.31

In Table 8, the vertical axis (R–C) represents the cause or effect group. Meanwhile, the ranking of the determinants of safety leadership is based on the (R+C) values, where prominence can be demonstrated by the sum of R and C.

Therefore, when considering the order of importance, safety compliance (V8), safety motivation (V6), and safety communication (V7) are regarded as three key determinants of safety leadership. Moreover, except for safety attitude (V1), safety knowledge (V2) and safety motivation (V6), all other elements belong to the cause group.

Table 8. (R + C) and (R – C)

Variables	R	C	R + C	Rank based on R + C	R – C	Cause/Effect
Safety attitude (V1)	43.507	44.18	87.687	7	-0.67	Effect
Safety knowledge (V2)	43.901	44.30	88.201	6	-0.40	Effect
AI knowledge (V3)	41.692	41.57	83.262	8	0.12	Cause
Safety culture (V4)	44.413	43.89	88.303	4	0.52	Cause
Safety policy (V5)	44.288	44.01	88.298	5	0.28	Cause

Safety motivation (V6)	44.057	44.42	88.477	2	-0.36	Effect
Safety communication (V7)	44.409	44.06	88.469	3	0.35	Cause
Safety compliance (V8)	44.522	44.47	88.992	1	0.05	Cause
AI application (V9)	41.571	41.46	83.031	9	0.11	Cause

5. Discussion

5.1 Theoretical Implications

This study contributes to the literature on maritime safety leadership by applying Bandura's (1978) theory of reciprocal determinism to the Indonesian context. Whereas prior research has often emphasized either the strategic role of leaders or the significance of safety culture in isolation, this study provides a more holistic perspective by examining the dynamic interactions among personal, environmental, and behavioral dimensions. By employing the fuzzy DEMATEL method, the research empirically identifies not only the determinants of safety leadership but also their causal–effect relationships, thereby advancing safety leadership from a unidimensional construct to a multidimensional and network-based concept.

A key theoretical insight is that safety compliance, safety communication, and safety motivation emerged as the most critical determinants of safety leadership. This finding shifts the focus from the traditionally dominant role of safety culture toward behavioral determinants that exert direct influence on leadership development. Rather than supporting a linear "culture–attitude–behavior" model often assumed in the literature, the results highlight the importance of behavior-centered mechanisms in shaping effective safety leadership, which is consistent with Kim's (2017) weighted safety leadership model demonstrating how leaders' concrete behaviors, such as compliance and communication, carry differential influence across organizational levels.

Furthermore, this research enriches ongoing scholarly debates about the integration of technological knowledge, such as AI-based competencies, into leadership theory. Although AI knowledge and AI application were not ranked as the most influential determinants, their classification within the "cause group" suggests that technological capabilities act as enabling conditions for the effectiveness of other leadership determinants. This perspective also aligns with Hasanspahić (2021), who found that human relations and teamwork satisfaction are fundamental to safety leadership and sustainable operations in shipping, reinforcing the behavioral and relational mechanisms identified in this study.

5.2 Practical Implications

From a practical standpoint, the findings highlight clear priorities for policymakers and practitioners seeking to strengthen safety leadership in Indonesia's maritime sector. First, the prominence of safety compliance (V8) underscores the necessity of reinforcing strict adherence to established rules and procedures. Beyond routine enforcement, leaders should embody compliance themselves, acting as role models whose behavior sets the standard for their crews. Such visible commitment can enhance trust and credibility while embedding compliance into the organizational safety culture.

Second, safety communication (V7) must be strengthened as a two-way process between ship-based leaders and headquarters-based managers. Transparent reporting of hazards and consistent dissemination of policies are essential to reduce misalignment between shipboard realities and onshore directives. Leveraging digital communication platforms and multilingual tools can further improve clarity, timeliness, and inclusiveness in safety-related exchanges.

Third, the importance of safety motivation (V6) points to the need for well-designed reward and recognition systems. Both material incentives and symbolic rewards—such as collective acknowledgments of safe practices—can foster a stronger sense of ownership and reinforce long-term engagement with safety objectives. By integrating motivational frameworks across ship-based and shore-based operations, organizations can sustain a cohesive safety culture where safe behaviors are consistently encouraged and rewarded.

In addition, the findings suggest that industry leaders and policymakers should not only enforce compliance but also invest in capacity building through training programs that integrate safety knowledge with emerging digital tools. As maritime operations become increasingly data-driven, leaders who are able to combine traditional safety competencies with AI-assisted decision-making will be better positioned to anticipate risks and adapt to evolving challenges. Hence, practical reforms must focus not only on policy alignment and communication channels but also on building the next generation of digitally competent maritime leaders who can lead in both traditional and technologically advanced environments.

6. Limitation

Although this study provides valuable insights into the determinants of safety leadership in Indonesia's maritime sector, several limitations should be acknowledged. First, the research relies on expert judgments obtained through surveys, which may introduce subjective bias despite the use of the fuzzy DEMATEL technique to reduce uncertainty. The findings therefore reflect the perspectives of experienced maritime professionals but may not fully capture the views of junior officers, cadets, or non-technical personnel, whose experiences could also influence safety leadership dynamics.

Second, the study's sample is limited to Indonesian maritime experts, which raises questions of generalizability. While Indonesia is the world's largest archipelagic nation and provides an important case study, the unique institutional and cultural context may limit the applicability of findings to other maritime nations or industries. Future studies could extend this research to cross-country comparisons or inland shipping contexts to validate and refine the framework.

Third, although technological determinants such as AI knowledge and AI application were included, the study did not conduct empirical testing of specific AI-based tools in real operational environments. Consequently, the results highlight their potential but cannot confirm their actual effectiveness in enhancing safety leadership practices. Longitudinal and mixed-method approaches would be useful to assess how technological integration interacts with leadership over time.

7. Conclusion

This study investigated the determinants of safety leadership in the Indonesian maritime sector by applying the fuzzy DEMATEL method within the framework of reciprocal determinism theory. Nine determinants were identified across three dimensions—personal, environmental, and behavioral—and their interrelationships were systematically examined. The findings revealed that safety compliance, safety motivation, and safety communication are the most critical determinants, while environmental and technological factors largely function as causal enablers. These results underscore that safety leadership is not a function of individual traits alone but rather emerges from complex interactions between individual capabilities, organizational systems, and behavioral practices.

The study offers theoretical contributions by expanding safety leadership research toward a multidimensional, interaction-based model, and practical implications for policymakers and practitioners aiming to reduce maritime accidents and enhance resilience. Specifically, embedding compliance as a cultural norm, strengthening two-way communication, and implementing motivational reward systems are pivotal steps for developing safety-conscious leaders. At the same time, investing in digital competencies and AI-based risk management will be essential for preparing the next generation of maritime leaders.

In conclusion, the research provides a structured pathway for enhancing safety leadership in Indonesia's maritime industry and offers insights that may also be relevant to other high-risk sectors and emerging economies. By integrating policy, practice, and technology, safety leadership can be transformed from a reactive compliance-based approach into a proactive, learning-centered framework that supports sustainable maritime development.

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Appendix
Appendix 1. Fuzzy linguistic scale (adapted from Mangla et al. 2018)

Linguistic variable	Preference score	Corresponding TFNs
No effect (No)	0	(0, 0, 0.25)
Very low effect (VL)	1	(0, 0.24, 0.50)
Low effect (L)	2	(0.25, 0.50, 0.75)
High effect (H)	3	(0.50, 0.75, 1.0)
Very high effect (VH)	4	(0.75, 1.0, 1.0)

TFN: Triangular Fuzzy Numbers.