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The Impact of Crew Resource Management on Safety Climate: Evidence from the Maritime Industry

By

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Abstract

This study empirically investigates the impact of Crew Resource Management (CRM) practices on safety climate r CRM and safety climate dimensions. The analysis, based on descriptive statistics and multiple linear regression, revealed within the maritime industry, a sector characterized by operational complexity and high-risk exposure. Data were collected through a cross-sectional survey of 641 seafarers across various vessel types, using validated scales fo that higher levels of CRM implementation are significantly associated (p <0.01) with more favorable perceptions of the overall safety climate and its key dimensions, including communication, mentoring, values, and systems. Among CRM subdimensions teamwork, situational awareness, and decision-making emerged as the strongest predictors of a positive safety climate. These findings reinforce CRM's role as a core component in mitigating human error and shaping crew perceptions of safety in high-reliability maritime environments. Theoretically, the study contributes empirical evidence to the growing body of literature that emphasizes non-technical skills in enhancing safety performance. Practically, it provides actionable guidance for maritime organizations to prioritize training and development in critical CRM competencies. Furthermore, the results support the institutionalization of CRM practices within maritime operations and regulatory frameworks, encouraging industry stakeholders—including shipping companies and international bodies such as the IMO—to treat CRM as an essential element of safety culture, rather than as isolated procedural training.

Keywords: *Crew Resource Management, Safety Climate, Maritime Operations, Teamwork, Situational Awareness*

INTRODUCTION

As the backbone of global commerce, the maritime industry facilitates over 80% of world merchandise transport, underpinning economic stability and supply chain continuity (UNCTAD, 2024). Yet this critical sector operates within inherently high-risk environments where operational complexity, volatile conditions, and human interactions create persistent safety challenges. Many maritime accidents, with potentially devastating consequences for people, the economy and the environment often stem from human error communication failures or mental overload (Sembiring et al., 2025). In this context, safety transcends regulatory compliance to become a strategic imperative demanding systematic optimization of human performance.

Crew Resource Management (CRM) has emerged as a vital human factors framework to address these vulnerabilities. Initially pioneered in aviation it provides structured methodologies to develop four core non-technical skills: teamwork (synchronized task execution), situational awareness (real-time hazard recognition), decision-making (formulate different approaches) and leadership practices (authority distribution) (Hanzu-Pazara et al., 2008; FjeldandTvedt, 2020). Within maritime operations, CRM specifically addresses the cognitive and social precursors of accidents by promoting shared mental models for managing navigational challenges, establishing collaborative decision-making protocols during critical operations, and implementing cross-monitoring mechanisms to detect and prevent human errors.

Despite its critical role in mitigating human error, there remains a significant gap in understanding how CRM practices influence broader organizational constructs—particularly safety climate. Defined as the collective

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perceptual lens through which crews interpret management's safety prioritization versus operational demands, safety climate manifests through four organizational dimensions: safety climate manifests through four dimensions: communication (peer-initiated safety discussions), mentoring (peer-to-peer safety guidance), values (peer adherence to safety during operational challenges), and systems (peer monitoring of safety procedures and equipment). While CRM theoretically engages these dimensions—for instance, teamwork reinforces communication and information transparency, while leadership practices shape management values—no empirical evidence quantifies how specific CRM competencies convert into climate perceptions, which CRM dimensions most strongly predict safety climate subcomponents, or whether maritime's regulatory hierarchy neutralizes certain CRM-climate pathways.

This study therefore empirically investigates the CRM-safety climate nexus through a cross-sectional survey of 641 maritime professionals. Utilizing multiple regression analysis, it examines how distinct CRM dimensions (teamwork, situational awareness, decision-making, and leadership) predict both global safety climate perceptions and their subcomponents (communication, mentoring, values, and systems). The research makes three primary contributions: First, it reconceptualizes CRM as a cultural catalyst rather than merely a training protocol, demonstrating its capacity to reshape the socio-technical foundations of maritime safety. Second, it identifies which non-technical CRM skills yield the highest safety climate returns, providing evidence-based guidance for resource allocation. Third, it delivers actionable frameworks for regulators, classification societies, and shipping companies to embed CRM principles into policy design, safety management systems (SMS), and organizational practices—ultimately bridging the gap between human factors theory and maritime operational realities.

2. CONCEPTUAL FRAMEWORK

2.1. Crew Resource Management

CRM is a structured and operational management approach that aims to optimize the use of all available resources—particularly human capital and technical systems—to enhance performance in high-stakes environments (Yousefi and Seyedjavadin, 2016). As defined by the European Union Aviation Safety Agency (EASA), it is designed to ensure the safe and efficient conduct of flight operations through the coordinated use of procedures, equipment, and human resources (EASA, 2017: 3). The origins of CRM can be traced back to NASA's human factors research in the 1980s, which revealed that deficiencies in teamwork and communication were central contributors to aviation accidents (Marshall, 2010). Initially referred to as "Cockpit Resource Management," the term later evolved into "Crew Resource Management" to reflect a broader team-based orientation (Helmreich et al., 1999; Muñoz-Marrón, 2018). Today, CRM encompasses both cognitive skills—such as decision-making and situational awareness—and social competencies, including leadership and teamwork (Saaed et al., 2019; Redjem et al., 2025; Allard et al., 2020).

CRM serves as a strategic framework for mitigating human-factor risks within the maritime sector's dynamic and unpredictable operational environment. The increasing complexity of modern ship operations necessitates developing core non-technical competencies to prevent systemic failures (Allard et al., 2020; Wahl and Kongsvik, 2018). Within this framework, leadership functions as a critical catalyst for safety culture. Maritime leaders must extend beyond crisis decision-making and task delegation (Helmreich and Kanki, 1993) to foster inclusive processes that integrate diverse crew perspectives, thereby cultivating mutual trust and psychological safety essential for operational resilience (Wiener et al., 1993).

This leadership function directly enables effective teamwork—operationalized through maritime-specific variants like Bridge Resource Management (BRM) and Engine Room Resource Management (ERM). Empirical analyses confirm that over 40% of navigational accidents originate from teamwork failures, particularly breakdowns in coordination, communication, or assertiveness (Grech et al., 2019). Robust teamwork further correlates with enhanced safety climates and reduced operational risks, underscoring its systemic value (O'Connor and Flin, 2003; Theotokas and Progoulaki, 2020).

Closely interdependent with teamwork is communication, which sustains coordination and shared mental models across crew members. Ambiguous or untimely communication persists as a root cause of maritime incidents (Schröder-Hinrichs et al., 2012), as effective information exchange ensures mutual comprehension rather than mere data transfer. This process is foundational to maintaining situational awareness (SA)—a hierarchical construct involving continuous perception of vessel status and environmental variables, comprehension of their implications, and projection of emergent risks (Hansen and Nazir, 2024). SA enables proactive hazard identification and mitigation, making its preservation critical during high-risk operations (Helmreich and Kanki, 1993; Allard et al., 2020).

Concurrently, decision-making integrates these competencies during high-stress scenarios. Seafarers must synthesize real-time data, procedural knowledge, and experiential judgment to execute rapid yet informed choices (Klein, 1998). Maintaining cognitive control under pressure determines emergency response efficacy, directly impacting incident outcomes (Orasanu and Fischer, 1997). These non-technical skills collectively constitute CRM's preventive core, formalized through mandatory training programs (e.g., Maritime Resource Management) under the STCW Convention (Picpican, 2025).

Recent technological shifts have further transformed CRM pedagogy. Digitalization and automation necessitate symbiotic human-machine collaboration under the Joint Cognitive System paradigm, requiring adaptive mental models for human-technology coordination (Berner et al., 2016). Contemporary initiatives thus employ resilience engineering principles—such as scenario-based simulations in

*Corresponding Author: **Betül GEZGEN.**

hybrid learning environments—to enhance adaptability during crises (Baldauf et al.,2012; Griffioen et al., 2021). As bibliometric analyses indicate (Türkistanlı, 2023), this evolution will accelerate with AI and IoT integration, further embedding resilience and collaborative cognition into CRM's future framework.

2.2. The Link Between Crew Resource Management and Safety Climate

As the indispensable artery of global supply chains, the maritime sector facilitates over four-fifths of worldwide merchandise movement, rendering operational safety a non-negotiable imperative for human and environmental protection. Consequently, fostering a robust safety climate—defined as employees' shared perceptions of the relative priority of safety within organizational policies, procedures, and practices at a given time (Zohar, 1980; Flin et al., 2020)—is fundamental to the sector's sustainability. CRM which enhances non-technical skills (teamwork, leadership, decision-making, situational awareness) among maritime personnel, is a critical intervention for improving safety performance (Hetherington et al., 2006; Wahl and Kongsvik, 2018). Understanding the relationship between CRM practices and the specific dimensions of safety climate—communication, mentoring, values, and systems—is therefore strategically essential for enhancing maritime safety.

To contextualize safety climate, a distinction from related concepts is necessary. Safety entails the protection of human life, assets, and the environment from harm (Dhillon, 2016; Raheemy et al., 2025). Safety culture represents the organization's enduring, underlying values, beliefs, and assumptions about risk and prevention (Ustaömer and Şengür, 2020), emerging prominently post-Chernobyl. In contrast to enduring safety culture, safety climate manifests temporally through observable management and peer actions, reflecting the perceived priority of safety within operational contexts (Cox and Flin, 1998).

This climate is manifested through four interconnected dimensions that collectively shape how safety is perceived and enacted on board. First, communication reflects the quality and openness of safety-related information exchange among crew members, influencing the flow of critical information during routine and emergency operations. CRM trains crews in clear, assertive, and closed-loop communication protocols (e.g., standardized phraseology, challenge-and-response), directly mitigating procedural confusion and fostering psychological safety (Zara et al., 2023; Saleem and Malik, 2022). This behavioral framework enhances the perceived quality and openness of safety communication within the climate, complementing formal maritime methods (manuals, signage, training).

Mentoring encompasses the informal peer support and guidance that promote adherence to safety practices and foster a culture of shared responsibility. CRM fosters peer-to-peer safety advocacy by training junior crew to voice concerns and senior crew to actively solicit input. This creates psychological safety for consultation (Griffin and Neal, 2000), promoting proactive safety dialogue and informal mentoring aligned with Reason's (1997) "informed culture," though formal frameworks remain regulator-driven (e.g., IMO).

Values pertain to crew members' perceptions of how safety is prioritized relative to operational or commercial pressures, signaling the organization's genuine commitment to safe conduct. CRM reinforces collective responsibility through training scenarios demonstrating leadership commitment to safety (Zohar, 2002) and crew empowerment to "speak up." By visibly prioritizing safety over operational pressures (e.g., schedule adherence), CRM shapes shared perceptions of organizational values, a core climate indicator (Ostrom et al., 1993; Clarke, 2000).

Lastly, systems represent the perceived effectiveness and implementation of formal Safety Management Systems (SMS), which structure and institutionalize safety procedures. CRM acts as the human-factors enabler of the SMS (ISM Code mandated). It bridges procedural requirements and practical execution by ensuring crews can implement SMS protocols through coordinated action, dynamic resource allocation, and effective communication during emergencies (Solagaistua Pineda and Padilla Cruz, 2025; Xi et al., 2022). This enhances perceived SMS relevance and effectiveness.

CRM training strategically influences each dimension, creating a synergistic relationship that elevates safety performance. Empirical findings indicate that effective implementation of CRM practices is linked to a reduction in human-error-related accidents (Hetherington et al., 2006; Grech et al., 2008). In this study, the relationship between CRM and safety climate is analyzed through regression analysis to explore how key CRM components—such as teamwork, situational awareness, and decision-making — influence employees' perceptions across various safety climate dimensions. The results reveal a significant and positive association, highlighting the potential of CRM to reinforce safety-related attitudes and behaviors. This insight contributes to a better understanding of how human factor strategies like CRM can be integrated with technical systems to foster sustainable safety performance in maritime operations.

3. METHODOLOGY

3.1. Research Aim and Model

Determining whether perceptions of CRM and safety climate differ according to both individual (socio-demographic) and occupational factors is critically important for improving safety performance. On the other hand, the relationship between CRM and safety climate holds strategic significance for reducing operational risks and promoting safe behaviours, particularly in the maritime sector where human factors are prominent. Within this context, the hypotheses developed for this research aim to identify the factors influencing shipboard personnel's perceptions of CRM and safety climate, and to analyze the direction and strength of the relationship between these two variables. Accordingly, the validity of the following hypotheses was tested:

*Corresponding Author: Betül GEZGEN.

H1: Shipboard personnel's perception of CRM and its sub-dimensions exhibits statistically significant differences based on socio-demographic and occupational variables.

H2: Shipboard personnel's perception of safety climate and its sub-dimensions exhibits statistically significant differences based on socio-demographic and occupational variables.

H3: There are positive and significant relationships between the sub-dimensions of CRM (Leadership, Decision Making, Situational Awareness, Teamwork) and the overall level of safety climate.

H3a: There is a significant positive relationship between the CRM dimension of Leadership and safety climate.

H3b: There is a significant positive relationship between the CRM dimension of Decision Making and safety climate.

H3c: There is a significant positive relationship between the CRM dimension of Situational Awareness and safety climate.

H3d: There is a significant positive relationship between the CRM dimension of Teamwork and safety climate.

The research model and hypotheses are summarized in **Fig. 1**.

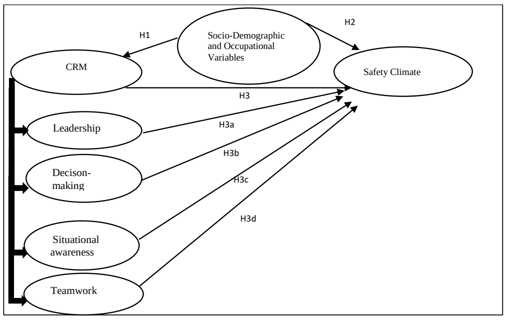

Fig. 1 Research Hypothesis and Model

Source: Authors

3.2. Data Collection Process and Instruments

This study employed a quantitative survey methodology utilizing structured questionnaires to assess CRM competencies and safety climate perceptions. The study utilized two validated instruments as primary measurement tools. Safety climate was assessed using the 12-item *Co-workers' Safety Climate Scale* developed by Brondino et al. (2012), which captures four core dimensions of peer-related safety attitudes. Sample items such as *"Team members discuss incident prevention"* were rated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), reflecting the extent of perceived safety-oriented behaviors among colleagues. In parallel, CRM was measured using a 33-item scale adapted from Saeed (2015), encompassing key non-technical skill domains: leadership, teamwork, situational awareness, and decision-making. Items included statements like *"Sharing information among all team members,"* rated using the same 5-point Likert format. Importantly, respondents were asked to evaluate the behaviors of management teams in the CRM scale and peer behaviors in the safety climate scale, rather than providing self-assessments—thereby reducing self-report bias and enhancing contextual validity.

Data from 641 seafarers were analyzed in IBM SPSS-28. Initial analysis involved descriptive statistics: frequency distributions (counts/percentages) for categorical variables and measures of central tendency/dispersion (means, SDs, min/max) for continuous variables. Subsequent normality assessment via Kolmogorov-Smirnov test revealed non-normal distribution ($p < .05$), prompting adoption of non-parametric methods. For group comparisons, Mann-Whitney U tests analyzed two-group differences while Kruskal-Wallis H tests addressed multi-group comparisons. Spearman's rank-order correlations assessed associations between scale dimensions.

Critically, to test the hypothesized predictive relationship where CRM dimensions function as independent variables and safety climate as the dependent variable (as specified in H3), multiple regression analysis was performed. This analytical approach specifically evaluated whether CRM subdimensions (Leadership, Decision-Making, Situational Awareness, Teamwork) significantly predicted variance in safety climate scores. Throughout all inferential analyses, a 95% confidence interval ($\alpha = .05$) maintained statistical rigor, with regression diagnostics confirming robustness of the model despite non-normality through appropriate data transformation procedures.

4. FINDINGS

4.1. Descriptive Findings Regarding Participants

The study comprised 641 shipboard personnel, with demographic analysis revealing notable distributions across key variables. Regarding age distribution, the 26-35 years cohort represented the largest segment (n=219, 34.2%). In terms of gender composition, males predominated significantly (n=590, 92.0%), while educational attainment analysis indicated that 195 participants (30.4%) held university/higher education degrees. Concerning professional experience, the majority subgroup consisted of personnel with 4-6 years of service (n=166, 25.9%). Positional distribution showed 215 participants (33.5%) serving in engine officers (Chief Engineer/Engineer/Electro-Technical Officer). Finally, vessel type analysis identified tanker operations as the most prevalent work environment (36.0% of total sample).

4.2. Findings Related to Crew Resource Management

The results of the analysis conducted to determine whether the mean scores of the participants on the CRM scale differed according to socio-demographic characteristics are presented in Table 1.

*Corresponding Author: **Betül GEZGEN.**

Table 1 Differences in CRM Perceptions Across Socio-Demographic Variables

Socio-demographic variables		Mean	Standard Deviation	Test Statistics	p
Age	Age ≤ 25	3.85	0.55	$\chi^2(3) = 106.09$	**< .001**
	26-35	4.21	0.57		
	36-45	4.19	0.54		
	Age ≥ 46	4,03	0.37		
Gender	Male	4.12	0.52	z=-3.27	**< .001**
	Female	3.81	0.79		
Marital Status	Married	4.18	0.52	z=-6.19	**< .001**
	Single	3.99	0.56		
Education	Secondary or lower	4.30	0,48	$\chi^2(4) = 88.83$	<.001
	Vocational school	4.06	0.58		
	Military School	4.09	0.42		
	University/College	3.96	0.60		
	Postgraduate	3.99	0.49		

Source: Authors

**Note: Total N = 641. Kruskal-Wallis test for age/education; Mann-Whitney U for gender/marital status.*

*Statistical significance: p < .05.**

Analysis of variance in Crew Resource Management (CRM) perceptions across socio-demographic variables revealed statistically significant differentiations. Age emerged as a significant factor (Kruskal-Wallis $\chi^2(3) = 106.086$, $p< .001$), with pairwise comparisons confirming substantially lower CRM scores among personnel aged ≤25 years (M = 3.85, SD = 0.55) relative to all older cohorts. The 26-35 age group demonstrated peak CRM perception (M = 4.21, SD = 0.57), suggesting optimal non-technical skill development during early career stabilization. Conversely, the attenuated scores in the ≥46 cohort (M = 4.03, SD = 0.37) may reflect either diminished team engagement intensity or challenges in adapting to contemporary CRM paradigms.

Gender-based analysis indicated significantly higher CRM perceptions among male seafarers (M = 4.12, SD = 0.52) versus female counterparts (M = 3.81, SD = 0.79; Mann-Whitney U = -3.265, p= .001). However, this finding necessitates cautious interpretation given the pronounced gender asymmetry within the sample (92% male, n = 590), precluding definitive conclusions regarding inherent gender differences in CRM competency.

Marital status significantly influenced CRM evaluations (Mann-Whitney U = -6.189, p< .001). Married personnel reported markedly higher scores (M = 4.18, SD = 0.52) than single colleagues (M = 3.99, SD = 0.56), potentially indicating enhanced collaborative aptitude derived from the responsibility-sharing dynamics characteristic of marital partnerships.

Educational attainment revealed a counterintuitive pattern (Kruskal-Wallis $\chi^2(4) = 88.829$, $p <.001$). Secondary education holders demonstrated the highest CRM perception (M = 4.30, SD = 0.48), while university (M = 3.96, SD = 0.60) and postgraduate (M = 3.99, SD = 0.49) cohorts reported comparatively lower evaluations. This discrepancy potentially reflects: (1) heightened critical assessment capacities among advanced-degree holders regarding CRM implementation gaps, or (2) differential evaluation standards wherein vocational (M = 4.06, SD = 0.58) and military-trained (M = 4.09, SD = 0.42) personnel may prioritize operational pragmatism over systemic critique.

The results of the analysis conducted to determine whether the participants' average scores on the CRM scale differed according to their professional information are presented in Table 2.

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Table 2Differences in CRM Perceptions Across Occupational Variables

Occupational Variables		Mean	Standard Deviation	χ^2(df)	p
Experience	≤1	3.82	0,47	$\chi^2(4) = 106.50$	<.001
	1-3 Years	4.05	0,70		
	4-6 Years	4.23	0,53		
	7-9 Years	4,24	0,44		
	≥10	4,11	0,45		
Position	Engine Officers	4,14	0,52	$\chi^2(5) = 153.45$	<.001
	Deck Officers	3,85	0,61		
	Deck Ratings	4,26	0,64		
	Engine Ratings	4,29	0,54		
	Service Staff	4,32	0,31		
	Interns	3,85	0,39		
Vessel Type	Warship	4,07	0,42	$\chi^2(5) = 51.24$	<.001
	Tanker	4,19	0,50		
	Container	4,18	0,35		
	Yacht/Boat/Other	3,85	0,69		
	Factory Ship	4,14	0,53		
	Bulk/Reefer	4,05	0,59		

Source:Authors

Kruskal-Wallis test applied for all occupational variables. Statistical significance threshold: α = 0.05.*

Work experience significantly differentiated CRM perceptions ($\chi^2(4) = 106.50$, p<.001). Personnel with ≤1 year experience scored substantially lower (M = 3.82, SD = 0.47) than all other groups. Peak scores occurred in mid-career cohorts (4-6 years: M = 4.23, SD = 0.53; 7-9 years: M = 4.24, SD = 0.44), suggesting non-technical skills optimize after foundational competency development. The attenuation in ≥10 year personnel (M = 4.11, SD = 0.45) may reflect reduced team interaction due to specialized roles.

Positional differences were pronounced ($\chi^2(5) = 153.45$, p< .001). Interns (M = 3.85, SD = 0.39) and Deck Officers (M = 3.85, SD = 0.61) reported significantly lower CRM perceptions than Engine Ratings (M = 4.29, SD = 0.54) and Service Staff (M = 4.32, SD = 0.31). This polarity reflects structural constraints: Deck Officers' authority limits collaborative engagement, while Interns' observational role restricts practical learning. Conversely, operational personnel (Deck Ratings: M = 4.26, SD = 0.64; Engine Ratings: M = 4.29, SD = 0.54) demonstrated heightened CRM integration, likely due to frequent cross-functional collaboration demands.

Vessel type significantly influenced CRM perceptions ($\chi^2(5) = 51.24$, p < .001). Personnel on non-standardized vessels (yachts/boats/other: M = 3.85, SD = 0.69) scored markedly lower than those on commercial vessels (Tankers: M = 4.19, SD = 0.50; Containers: M = 4.18, SD = 0.35). This gap reflects: (1) less formalized CRM protocols in non-commercial operations, (2) higher crew transience disrupting cohesion, and (3) multi-tasking diluting role-specific engagement. Military vessels showed intermediate scores (M = 4.07, SD = 0.42), indicating regimented but less participatory team structures.

4.3. Findings Related to Safety Climate

The results of the analysis conducted to determine whether participants' average scores on the safety climate scale differ according to their socio-demographic characteristics are presented in Table 3.

Source: Authors

Kruskal-Wallis test for age/education; Mann-Whitney U for gender/marital status. Statistical significance: α = 0.05.*

Analysis of safety climate perceptions revealed significant age differences (Kruskal-Wallis $\chi^2(3) = 38.86$, p <.001). Personnel aged ≤25 reported markedly lower scores (M = 4.06, SD = 0.68) than older cohorts (26-35: M = 4.31; ≥46: M = 4.27), suggesting early-career personnel may experience weaker organizational integration into safety practices.

No significant gender differences emerged (Mann-Whitney z = -1.62, p = .105), though small sample size for females (n≈51) warrants caution in interpretation. Married personnel reported higher safety climate perceptions (M = 4.27, SD = 0.55) than singles (M = 4.18, SD = 0.62; z = -3.05, p = .002),

*Corresponding Author: **Betül GEZGEN.**

potentially reflecting risk-aversion associated with familial responsibilities.

Educational attainment showed significant but nuanced effects ($\chi^2(4) = 14.72$, $p = .005$). Pairwise comparisons confirmed lower perceptions among vocational school graduates (M = 4.19, SD = 0.53) versus secondary education holders (M = 4.30, SD = 0.57), while higher-educated groups (university: M = 4.20; postgraduate: M = 4.20) demonstrated consistent but moderate scores. This pattern may indicate occupational role influences outweigh pure educational effects in safety climate evaluation.

The results of the analysis conducted to determine whether participants' average scores on the safety climate scale differ according to their occupational characteristics are presented in Table 4.

Table 4Differences In Safety Climate Perceptions Across Occupational Variables

Occupational Variables		Mean	Standard Deviation	X²	p
Experience	≤1	4.05	0.60	$\chi^2(4)$ = 49.45	<.001
	1-3 Years	4.20	0.78		
	4-6 Years	4.29	0.52		
	7-9 Years	4.35	0.46		
	≥10	4.26	0.50		
Position	Engine Officers	4.25	0.54	$\chi^2(5)$ = 48.32	<.001
	Deck Officers	4.20	0.75		
	Deck Ratings	4.26	0.63		
	Engine Ratings	4.32	0.64		
	Service Staff	4.33	0.34		
	Interns	4.08	0.54		
Vessel Type	Warship	4.33	0.54	$\chi^2(5)$ = 29.05	<.001
	Tanker	4.32	0.53		
	Container	4.33	0.35		
	Yacht/Boat/Other	4.03	0.78		
	Factory Ship	4.20	0.55		
	Bulk/Reefer	4.17	0.63		

Source: Authors

*****p<0.05

Safety climate perceptions significantly differed by work experience ($\chi^2(4) = 49.45$, $p < .001$), with personnel having ≤1 year experience reporting the lowest scores (M = 4.05, SD = 0.60). This suggests inexperienced personnel may not yet fully internalize safety protocols.

Positional differences were significant ($\chi^2(5) = 48.32$, $p < .001$). Interns scored substantially lower (M = 4.08, SD = 0.54) than all other positions, indicating limited risk internalization in entry-level roles. Engine Ratings (M = 4.32) and Service Staff (M = 4.33) demonstrated peak safety climate integration.

Vessel type significantly influenced perceptions ($\chi^2(5) = 29.05$, $p < .001$). Personnel on yachts/boats/other small vessels reported markedly lower scores (M = 4.03, SD = 0.78) versus standardized vessels (Warships: M = 4.33; Tankers: M = 4.32; Containers: M = 4.33), reflecting weaker institutionalization of safety protocols in non-commercial operations.

4.4. Findings on the Relationship Between CRM Perceptions and Safety Climate

The results of the correlation analysis conducted to determine whether there is a relationship between CRM and safety climate are presented in Table 5.

*Corresponding Author: **Betül GEZGEN.**

Table 5 Relationship Between CRMPerceptions and Safety Climate

	Safety Climate	Communication	Mentoring	Values	Systems
CRM(Total)	.509	.480	.477	.557	.210
Teamwork	.526	.460	.440	.538	.263
Leadership	.519	.452	.473	.552	.143
Situational Awareness	.562	.451	.471	.488	.358
Decision-making	.497	.459	.461	.494	.163

Source: Authors

*p < .001 (two-tailed)

Spearman correlation analysis revealed statistically significant positive relationships between all CRM dimensions and safety climate factors (p < .001). CRM demonstrated moderate-to-strong associations with overall safety climate (r = .509), safety communication (r = .480), safety mentoring (r= .477), and safety values (r = .557), though its relationship with safety management systems was comparatively weaker (r = .210). These results indicate that enhanced CRM implementation corresponds with elevated safety climate perceptions across most domains.

Teamwork exhibited robust correlations with core safety climate dimensions, particularly overall safety climate (r = .526) and values (r = .538), suggesting that collaborative dynamics significantly reinforce safety culture foundations. The weakest association emerged with systems (r = .263), implying procedural frameworks may not fully capture team-based safety behaviors. Leadership showed significant predictive relationships, most notably with values (r = .552) and overall climate (r = .519). Its limited association with systems (r= .143) suggests formal protocols may not adequately reflect leadership-driven safety practices.

Situational awareness demonstrated the strongest overall correlation with safety climate (r = .562), indicating operational vigilance serves as a primary catalyst for safety culture development. Its moderate association with safety management systems (r = .358) further highlights the role of real-time risk assessment in procedural compliance. Decision-making showed consistent but modest correlations across dimensions (range: r= .163 to .497), with its weakest linkage to safety management systems (r= .163). This pattern suggests cognitive processes in high-risk environments may not directly translate to formal safety documentation.

A notable divergence emerged in the relationship between CRM dimensions and systems (range: r = .143 to. 358), indicating procedural safety frameworks may not fully align with team-based operational practices. This systematic disconnect warrants organizational attention to bridge formal protocols and lived safety experiences.

The results of a regression analysis conducted to determine whether CRM has an effect on safety climate are presented in Table 6.

Table 6 Effect of CRM on Safety Climate

	Model Summary		Anova		Coefficients	
	R	R^2	F	Sig	ß	Sig
CRM	.822	.676	1334.18	.001	.879	<.001

Source: Authors

(Dependent Variable: Safety Climate) p <.001

A positive and statistically significant effect of CRM on safety climate was found (β = .879, p <.001). CRM explains approximately 68% of the variance in safety climate.

The results of a regression analysis conducted to determine the individual effects of CRM subdimensions on safety climate are presented in Table 7.

<table>
<tr><th rowspan="2"></th><th colspan="2">Model Summary</th><th colspan="2">Anova</th><th colspan="2">Coefficients</th></tr>
<tr><th>R</th><th>R^2</th><th>F</th><th>Sig</th><th>ß</th><th>Sig</th></tr>
<tr><td>Teamwork</td><td rowspan="4">.845</td><td rowspan="4">.714</td><td rowspan="4">397.08</td><td rowspan="4">.001</td><td>.312</td><td><.001</td></tr>
<tr><td>Leadership</td><td>.002</td><td>.974</td></tr>
<tr><td>Situational Awareness</td><td>.435</td><td><.001</td></tr>
<tr><td>Decision-making</td><td>.187</td><td><.001</td></tr>
</table>

Table 7 Effects of CRM's subdimensions on safety climate

Source: Authors

(*Dependent Variable: Safety Climate*) p < 0.01

Multiple regression analysis examining the predictive capacity of CRM subdimensions on safety climate revealed a

*Corresponding Author: **Betül GEZGEN.**

statistically significant overall model ($F(4, 636) = 397.08$, $p < .001$), accounting for 71.4% of the variance ($R^2 = .714$). Situational awareness emerged as the strongest predictor (β = .435, p< .001), indicating its critical role in shaping safety perceptions, followed by teamwork (β = .312, p< .001) and decision-making (β = .187, p < .001). Leadership demonstrated no significant predictive value (β = .002, p= .974), suggesting its influence may be mediated through other CRM components or organizational factors. These findings highlight situational awareness as the primary catalyst for safety climate enhancement, while revealing a notable disconnect between formal leadership structures and operational safety outcomes in maritime contexts. The substantial explained variance underscores CRM's collective efficacy, though the non-significance of leadership warrants investigation into potential moderating variables like organizational hierarchy or authority dynamics that may attenuate its direct impact. The findings related to the hypotheses tested in the study are summarized in Table 8.

Table 8 Hypothesis Testing

Hypothesis	Result
H1-Socio-demografic and occupational variables→CRM	Partly Accepted
H2-Socio-demografic and occupationalvariables →Safety climate	Partly Accepted
H3-CRM→ Safety climate	Accepted
H3a- Leadership→Safety climate	Accepted
H3b-Decision-making→ Safety climate	Accepted
H3c-Situation awareness→ Safety climate	Accepted
H3d-Teamwork→Safety climate	Accepted

Source: Authors

5. CONCLUSIONS

This study aimed to examine the influence of Crew Resource Management (CRM) practices on safety climate in the maritime sector through quantitative analysis. The findings indicate that CRM is a statistically significant and positive predictor of safety climate on board ships. Among the CRM dimensions examined, teamwork, situational awareness, and decision-making emerged as key contributors to the development of a robust safety climate. Conversely, the leadership dimension did not exhibit a statistically significant effect.

This result calls for a more nuanced interpretation. In highly regulated and hierarchical work environments like maritime operations, leadership is often perceived not as a behavioral competency, but as a formal role governed by rank and international maritime conventions (e.g., STCW). This perception may limit the visibility of leadership behaviors that contribute to safety culture, while placing greater emphasis on collaborative, task-oriented competencies such as communication, situational awareness, and decision-making. In his doctoral research, Saeed (2015) analyzed the application of non-technical skills by deck officers in crisis scenarios and found that while leadership was acknowledged as important, greater reliance was placed on competencies like situational awareness and decision-making in real-time operations. Furthermore, his study found that Human Element, Leadership and Management (HELM) training only marginally improved overall non-technical skills performance, suggesting the need to revisit how leadership is conceptualized and taught in maritime training programs.

The current study's findings are also supported by earlier literature. Hetherington, Flin, and Mearns (2006) identified human error as a major contributor to maritime accidents and proposed CRM as a critical intervention to reduce such risks. Grech et al. (2008) emphasized the role of CRM in enhancing safety by targeting human performance factors. In addition, Flin et al. (2000; 2008) underscored the central importance of non-technical skills—particularly decision-making, situational awareness, and communication—in supporting operational safety.

In support of these conclusions, existing empirical research further highlights the significance of non-technical competencies and systemic factors in shaping safety outcomes. For example, Brondino, Pasini, and da Silva (2013) demonstrated that safety climate is a multidimensional construct influenced by the interplay of individual, team-level, and organizational factors. Their findings reinforce the need for a holistic approach to safety that extends beyond compliance and focuses on cultural and behavioral elements—an approach that aligns with this study's emphasis on CRM subcomponents. Similarly, Saeed (2015) provided empirical evidence that deck officers facing emergency scenarios place heavy reliance on dynamic decision-making and situational monitoring, further validating the central role of CRM elements in ensuring effective safety performance.

In conclusion, the study affirms the utility of CRM as a powerful framework for cultivating a strong safety climate within maritime operations. The results suggest that training programs and organizational strategies should place greater emphasis on non-technical skills—particularly teamwork, situational awareness, and decision-making—while also reevaluating traditional notions of leadership in shipboard contexts. Future research could benefit from longitudinal

*Corresponding Author: **Betül GEZGEN.**

studies exploring how CRM competencies evolve with experience and how organizational culture and regulatory frameworks influence the behavioral expression of leadership at sea.

In addition to its core findings, the study revealed that perceptions of CRM practices and safety climate significantly varied across demographic and occupational variables. Specifically, factors such as years of experience, professional rank, and vessel type were found to influence both CRM and safety climate scores. These findings are consistent with the suggestions of Wahl and Kongsvik (2018), who argued that CRM training programs should be tailored to individual characteristics and professional experiences. The differentiated effects of age and educational level observed in the current research further underscore the need for targeted educational and managerial strategies that align with the specific needs of diverse crew members.

Another critical insight emerging from this study is that safety climate is not solely shaped by technical systems or procedural compliance but is also fundamentally constructed through human-centered management strategies. As emphasized by Clarke (2000) and Guldenmund (2000), core components such as organizational values, leadership behaviors, and communication processes play a vital role in shaping perceptions of safety. The present findings reinforce this perspective by demonstrating how CRM practices contribute positively to safety climate through these behavioral and cultural dimensions, particularly within the context of maritime operations.

Overall, the study demonstrates that CRM not only enhances individual performance but also fosters the development of a broader safety culture and climate in maritime organizations. In this context, it becomes strategically important to expand training programs that focus on non-technical skills, strengthen leadership capacity at the organizational level, and adopt communication-oriented management practices. Managers in maritime organizations should actively facilitate regular and open communication with crew members to promote the internalization of safety culture. They should also design training programs tailored to the specific needs of crew members, aiming to enhance their non-technical competencies. Objective performance evaluations must be conducted to identify areas for improvement, with updated training initiatives provided accordingly. Furthermore, managers should encourage reporting of safety concerns and incidents to support proactive risk management.

Ultimately, strong leadership, continuous training, effective communication, participatory management, regular performance assessments, and robust risk management systems are essential components for achieving safe and efficient maritime operations.

5.1. Limitations and Future Researches

Despite the meaningful findings, several limitations of this study should be acknowledged. First, the primary data collection tool was a self-report questionnaire, which inherently carries the risk of response bias, such as social desirability or self-perception distortions. However, in the present study, efforts were made to mitigate these risks through precise framing of the items. For example, the CRM-related items were explicitly designed to assess participants' perceptions of their managerial teams rather than themselves, while the safety climate items focused on the behavioral patterns of peers and coworkers. This design choice aimed to reduce self-evaluation bias and improve the objectivity of responses.

Another limitation lies in the conceptual nature of CRM and safety climate, both of which are subject to the influence of broader organizational culture and national cultural values. While the current study did not explicitly measure or control for these cultural factors, it is important to acknowledge that such variables may affect how CRM practices and safety norms are interpreted and enacted across different settings. Furthermore, although the sample included seafarers from various types of vessels, the study did not delve into the unique operational characteristics and organizational climates of each vessel type. This omission may limit the generalizability of the findings to specific subgroups or shipboard contexts. Furthermore, the study was geographically confined to a particular region, which may constrain the applicability of its conclusions to other cultural or operational environments. Future research conducted in different geographic and cultural contexts would provide valuable comparative insights and contribute to a more nuanced understanding of CRM and safety climate dynamics across the global maritime industry.

Future studies are encouraged to explore the effects of CRM practices on safety climate across different vessel types and working conditions in greater detail. Such research would provide a more comprehensive understanding of how operational contexts influence the implementation and outcomes of CRM strategies. In addition, the development of national-level CRM programs is essential—not only to support future research but also to improve maritime safety training and recruitment processes. Specifically, tools and simulation-based assessment systems capable of identifying candidates' competencies and inclinations toward CRM-related skills during the selection, evaluation, and training phases of new captains and crew members would offer significant value.

Moreover, future studies should aim to include greater representation of female seafarers, enabling gender-based subgroup analyses that can shed light on the role of diversity in CRM dynamics and safety climate perceptions. To contribute more robustly to the literature, researchers may also consider incorporating potential mediating and moderating variables such as organizational commitment, leader–member exchange (LMX), and perceived stress levels into models examining the CRM–safety climate relationship.

Beyond quantitative methods, qualitative approaches—such as in-depth interviews or focus group discussions—could be employed to gain a more nuanced understanding of employees' lived experiences and interpretations of CRM practices. Finally, there remains a significant gap in the

*Corresponding Author: **Betül GEZGEN.**

literature concerning the role of national and international maritime regulations in shaping CRM practices and safety climate. Addressing this issue through future research would provide important insights into the broader institutional and policy frameworks that govern safety management in the maritime industry.

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