Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 45 No. 1
January 2024

Promoting Sustainable Practices at Chittagong Port and Outer Anchorage, Bangladesh: A Comprehensive Analysis of Maritime Support Services and Accident Reduction

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Abstract
The maritime sector plays a vital role in facilitating the transportation of goods and services across countries. In Bangladesh, the Port of Chittagong serves as the primary port and generates significant revenue. However, there has been an increase in accidents at seaports, raising concerns among stakeholders. This study focuses on reducing accidents within Chittagong Port and its outer anchorage in Bangladesh. Three hypotheses were formulated to examine their relationship with accident reduction. A descriptive survey research design was adopted for this study, comprising a sample size of one hundred (100) employees from the Chittagong Port. The results of this study revealed noteworthy outcomes. First, there was a significant relationship between operational risk management and accident reduction, as evidenced by an r-value of .858, with a p-value of less than .005. This underscores the importance of effective risk management strategies for mitigating accidents. Second, this study demonstrated a significant relationship between maritime safety and accident reduction, with an r-value of .611. This highlights the paramount role of maritime safety in minimizing employee accidents. Finally, the study revealed a significant relationship between simulation training and assessment and accident reduction, with an r-value of .810. This underscores the value of simulation-based training programs in equipping employees with the knowledge and skills necessary to reduce accidents.
Keywords: Operational Risk Management; Maritime Support services; Simulation Training and Assessment.

1. Introduction

The maritime sector is essential for global transportation and promotes seaborne trade. Seaborne trade reached a staggering 11 billion tons in 2018[1–4]. Seaports are integral to national development and economic prosperity. Economists view maritime transportation as increasingly significant compared to other modes of transportation worldwide, primarily because of globalization and growing demand in the marine sector. Achievements in this sector would not have been possible without considering capacity enhancement, as it directly affects operational safety, efficiency, and overall processes in seaports[5–7].

Marine incidents can lead to human casualties, environmental harm, and economic loss. Most of these accidents are characterized by their low likelihood but substantial consequences, underscoring the importance of assessing risks associated with maritime activities. It is widely acknowledged that factors such as organizational aspects, working conditions, and navigational environments significantly contribute to maritime accidents[8–10]. Despite the integration of advanced technologies, such as e-navigation and onboard information systems, on modern ships, human factors continue to play a significant role in causing maritime accidents[11–15]. The International Maritime Organization (IMO) only started giving considerable attentioto human factors much later than other transportation modes such as aviation or railways [16,17]. The maritime sector began exploring the impact of human and organizational factors (HOFs) on accidents following the capsizing of the Herald of Free Enterprises in 1987[18,19]. Since then, accident investigations have increasingly focused on human factors to enhance maritime safety. Statistics have revealed that human failures and errors are responsible for approximately 80% of maritime accidents, making them a critical aspect of accident prevention. Human factors in maritime accidents often intertwine with other relevant factors, including working conditions, physical and natural surroundings, procedures, technology, training, organization, management, and individual

elements, such as fatigue and mental state. Notably, half of the marine accidents occurred in ports and terminals in 2022[20–22].

The Port of Chittagong is the primary port in the People's Republic of Bangladesh, located on the right bank of the Karnafuli River, approximately nine nautical miles from the Bay of Bengal shoreline, and is widely regarded as the country's premier seaport[23]. During 2011-2012, Chittagong Port handled over 41 million metric tons of cargo, including 1.34 million TEUs, accounting for approximately 92% of the total maritime trade in Bangladesh. In addition to this significant economic contribution, Chittagong ports are responsible for more than two-thirds of marine accidents among ports in Bangladesh [24,25]. According to Khaled et al. [26], 1981-2013, 76.92% of accidents take place there. Notably, 57.96% of the accidents were due to collision and grounding, and these accidents were caused by human error, accounting for 75.36% of all casualties, while environmental factors and technical errors contributed to approximately 8.7% and 15.94% of the accidents, respectively.

The increase in accidents presents a serious risk to the safety of mariners because many ships congregate in crowded anchorages while waiting for lighter-age operations. Accidents not only cost lives and property but also hinder employee performance and prompt some to go for other, less dangerous jobs[27]. Therefore, the Chittagong Port is the vital lifeline of Bangladesh's maritime trade; hence, its rising accident rate must be addressed immediately to protect its workers, passengers, and the continuous flow of marine commerce. To reduce accidents and improve the safety and productivity of the maritime environment, this study examined the interactions between operational risk management, maritime safety, simulation training, and assessment.

2. Literature review

The United Nations Conference on Trade and Development (UNCTAD) highlighted the substantial growth in the maritime industry in recent decades, with global cargo volumes reaching an impressive 10.7 billion tons in 2020[28,29]. This remarkable expansion, primarily centered in Asia, underscores the importance of adapting and advancing environmental and safety measures within the maritime sector as maritime trade continues to thrive, and it becomes increasingly evident that rapid growth necessitates simultaneous advancements in safety and sustainability. The surge in shipping activities driven by the movement of goods correlates with a notable increase in maritime accidents. These accidents carry far-reaching consequences, including substantial economic losses, injuries, fatalities, and environmental degradation, underscoring the urgent need for enhanced safety and environmental safeguards in the maritime domain[30–33].

Significant efforts have been invested in maritime safety, ship design, technological advancements, regulations, and risk management in recent decades, driven by the need to mitigate substantial losses, which account for approximately 70% of the incidents in the shipping industry. However, despite these advancements, the complexity of maritime accidents underscores the need for further research to enhance safety measures and reduce accident rates. Maritime accidents are frequently the result of a series of intricate events or processes involving multiple stakeholders, and their outcomes can be devastating [34–36]. Throughout the existing literature, a consistent theme emerges human error is consistently identified as the predominant contributing factor to maritime accidents. According to data from the European Maritime Safety Agency (EMSA), the period from 2014 to 2020 saw human factors play a significant role in maritime accidents, with a staggering 89.5% of incidents attributed to the human element[37,38]. Notably, European waters witnessed an annual average of 4,128 ships involved in maritime accidents during this period[39–41].

Few studies have been conducted to evaluate and analyze the contribution of human error to maritime accidents at Chittagong Port. In 2018, Al-Shammari and Oh [42] investigated the influence of human error on the collision between an oil tanker (Kiafan) and a bulk carrier (Unison Star) in 2017. This case study demonstrates that numerous factors play a significant role in influencing the occurrence of human errors.

Many of these errors can be attributed to technologies, working conditions, and organizational elements that often fail to adequately account for the capabilities and limitations of the individuals who interact with them. Consequently, human errors can be substantially mitigated by placing greater emphasis on enhancing the quality of crew training and capability development initiatives. Furthermore, the implementation of regulations aimed at managing and minimizing human errors should be a central part of these efforts. Another study by Khaled et al. [26] investigated the collision and grounding risks in the Chittagong Port. A few parameters were considered to execute the research, including visual detection, navigational aid detection, human factors, technical reliability, and local factors. Furthermore, this study provides a probability for grounding causation, estimating 0.000934. This implies the likelihood of a grounding accident occurring for every 1000 vessels that are managed or dealt with. The statistics of collision accidents in Chittagong Port are shown in Figure 1.

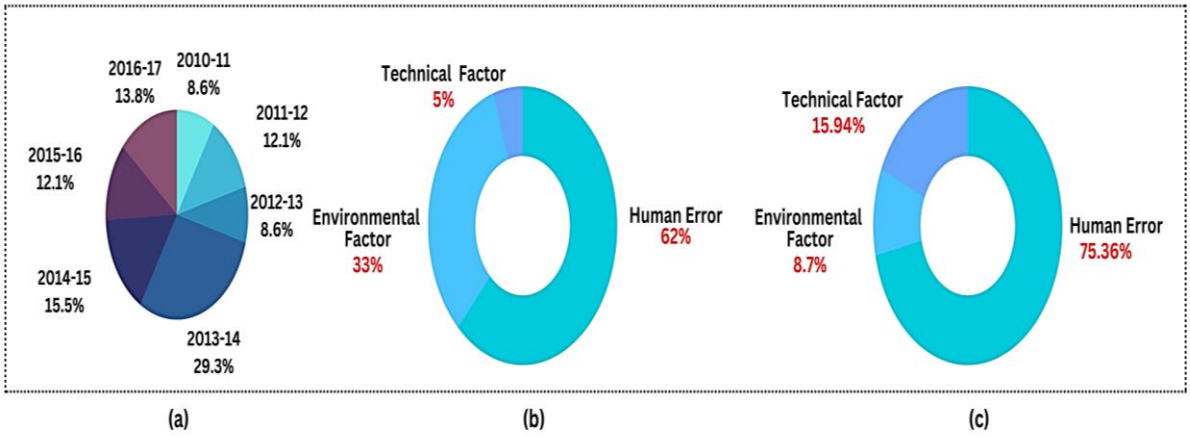

Figure 1. (a) Collision per 1000 handled vessels in Chittagong port (b) Factors of accidents in Bangladesh (1981-2013) (Overall Bd) (c) Factors of accidents in Bangladesh (1981-2013).

Furthermore, Quraishi [43] provided figures in his master's thesis, indicating that the most common type of accident in this context is a collision, accounting for 62.6% of the total accidents. Of the 604 accidents, 366 were collisions. On the other accident types are illustrated in Figure 2.

Another research done by Abdullah et al. [44] investigated navigational safety in the Chittagong Port and anchorage. This research provided some recommendations, such as a proper traffic control system. In the outer anchorage area, it is crucial to enforce strict regulations regarding the maximum allowable draught (the depth of water that a vessel can safely navigate) and the number of vessels present at any given time. Awal's [45] research delves into the characteristics of marine vehicle accidents in Bangladesh, offering valuable insights into this critical issue. Through a comprehensive statistical analysis, Awal et al. discerned that several prominent causes underpin these accidents. The foremost among them were collisions involving ships, trawlers, and country boats, highlighting the prevalence of such incidents in Bangladesh's maritime landscape. Additionally, the loss of stability attributed to Nor'westers emerged as a significant factor contributing to accidents in this context. This study demonstrated that cargo vessels are mostly involved in collision accidents, accounting for more than 80% of the total accidents, as shown in Figure 3. Furthermore, the analysis of the monthly accident distribution yielded noteworthy insights, as shown in Figure 4.

hand, grounding contributes only 1.5% of the total number of accidents. The less frequent accident types include fires (0.7 %) and bottom ruptures (0.3 %). The percentage of occurrences of the remaining

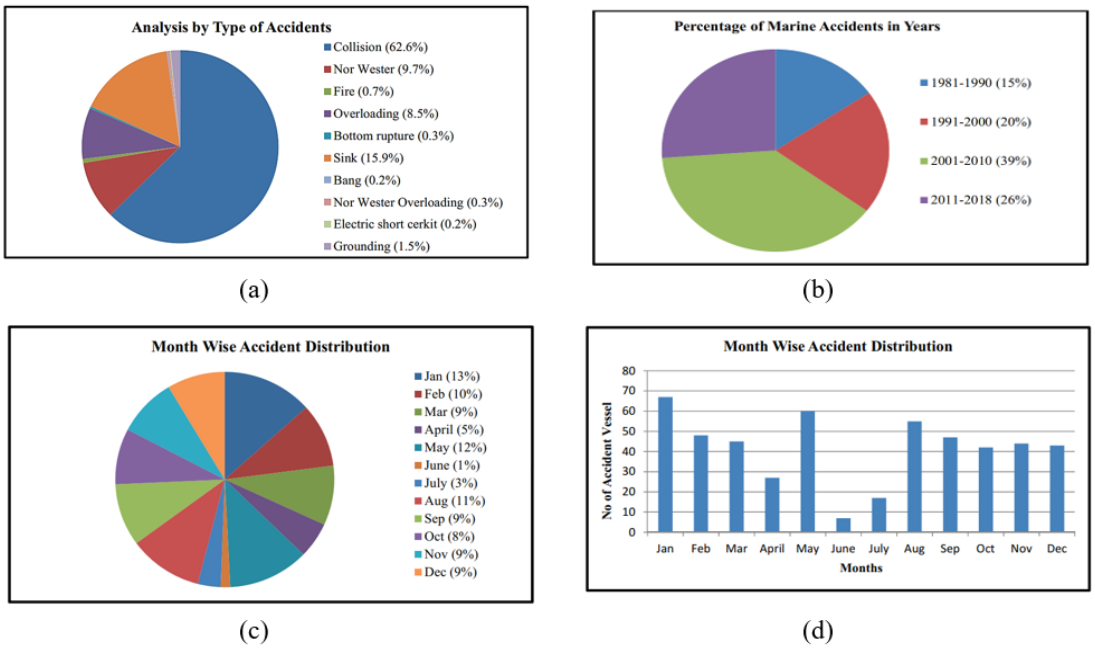

Figure 2. (a) Analysis of accident type percentage (b) percentage of maritime accidents (yearly), (c) percentage of maritime accidents (monthly), and (d) number of accidents (monthly).

Beyond these primary causes, Awal's study also brought to light several other factors that play a role in these accidents, including collisions 39%), excessive current 9%), physical failure 4%), adverse weather and overloading 44%), and others 4 %). Furthermore, accidents resulting from the loss of stability owing to the rushing of passengers, overloading of vessels, and grounding incidents were identified as recurring themes. However, the research gap in this area is typified by a conspicuous lack of comprehensive evaluations that concurrently address problems about the linkages between assessment, simulation training, marine safety, and operational risk management. Existing studies have focused mostly on accident reasons, such as collisions, overloading, poor traffic management, and grounding.

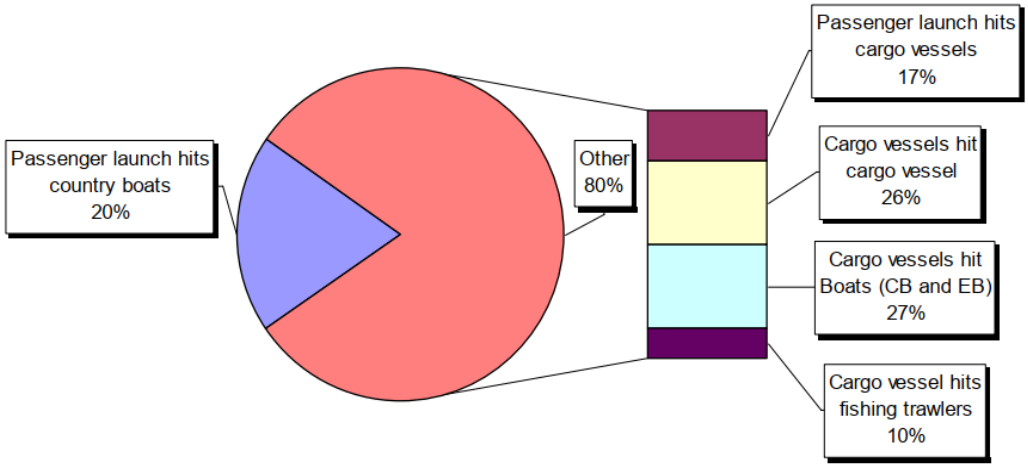

Figure 3. Accident by collision ratio.

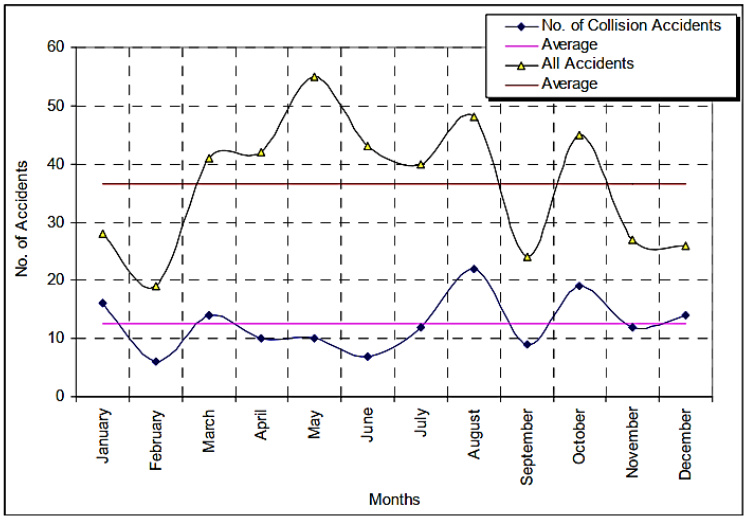

Figure 4. Monthly accident distribution

3. METHODOLOGY

A descriptive survey design was employed to gather information and analyze the relationships between the variables. The sample consisted of 100 employees selected from Chittagong Port, Bangladesh, from a total employee population of 160. The sample size was determined based on Krejcie and Morgan's sample size table [46]. Before distributing the questionnaires, the researcher sought permission from port management, as this was the first study of its kind in the maritime sector questionnaire. The data collected for testing the hypotheses were analyzed using the Pearson Moment Correlation Coefficient.

3.1. Research hypotheses

The following is the hypothesis of this study: RH1: Effective operational risk management is expected to have a positive impact on reducing accidents in Chittagong Port and outer anchorage in Bangladesh. RH2: The implementation of robust maritime safety measures is anticipated to contribute to a decrease in accidents at the Chittagong port and outer anchorage in Bangladesh. RH3: Using simulation training and assessment is hypothesized to be positively correlated with accident reduction in the Chittagong port and outer anchorage in Bangladesh.

in Port Bangladesh. The researcher received an approval letter from the port management, allowing the questionnaire to be distributed. Questionnaires were distributed to employees within one week using a simple random sampling technique. Three hypotheses were formulated to guide this study. It is worth noting that the respondents were employees who had been involved in accidents within the port, providing valuable insights for answering the

3.2. Conceptual Framework of the Study

The present study investigated the correlation between support services and accident reduction in Chittagong Port and outer anchorage in Bangladesh. This study examined three independent variables: operational risk management, maritime safety, and simulation training and assessment. The dependent variable was the accident reduction. The conceptual framework of this study is illustrated in Figure 5.

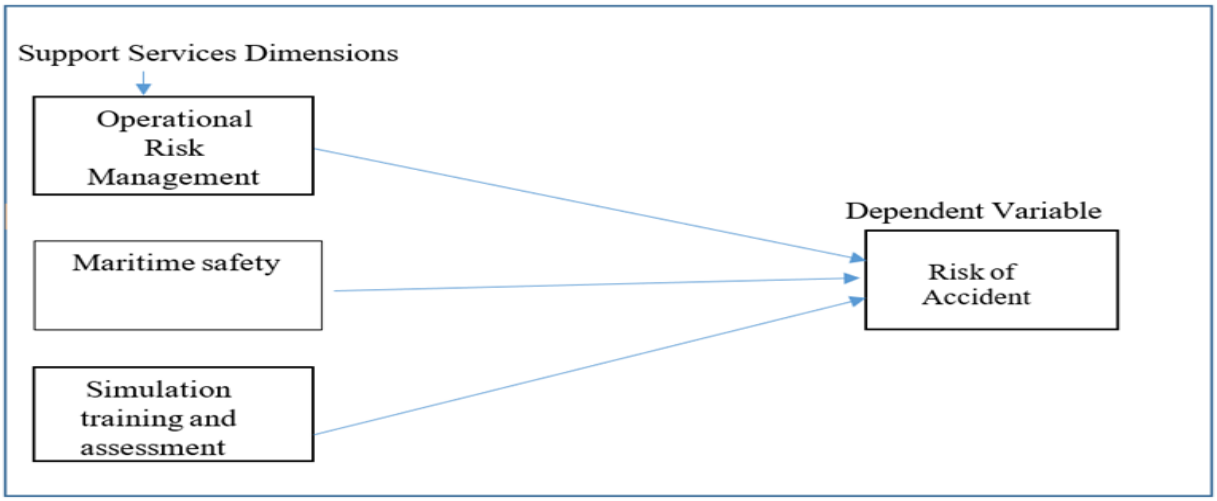

Figure 5. Conceptual Framework of the Study

3.3. Survey Design

This study incorporates three variables: operational risk management, maritime safety, and simulation training and assessment. The quaternaries were divided into four parts. The first part included the respondents' demographic information, including gender, age, experience, and qualifications. The second part focuses on maritime safety and consists of six items. The third part addressed operational risk management and comprised seven items. The final part assessed employee performance with six items, while simulation training and assessment also included six items. Hence, 18 items were used across all three variables. Descriptive statistics were used to analyze the respondents' demographic information. Three hypotheses were formulated for the study and analyzed using the Pearson Moment Correlation Coefficient. Please refer to the table for a breakdown of instrumentation items.

S/No	Item Code		Measurement Items
Maritime Safety			
1	MSS1		The monitoring, inspection, and evaluation departments have helped reduce staff in accidents.
2	MSS2		The health and safety service in my maritime industry has helped reduce accidents.
3	MSS3		The maritime industry's training and safety setup has helped staff.
4	MSS4		The safety committees in the maritime industry have helped staff to reduce accidents.
5	MSS5		The counseling department of the maritime industry has helped me a lot.
6	MSS6		The orientation department has improved my productivity in the maritime industry.
Operational Risk Management			
7	OPRIMA 1		The maritime industry is aware of the strengths and weaknesses of risk management systems.
8	OPRIMA 2		A risk management center set up in the maritime sector has reduced accidents.
9	OPRIMA 3		The maritime industry has regular training programs for staff in risk management.

10	OPRIMA 4		The department provides checklists or written guidelines for safely performing dangerous tasks or operations.
11	OPRIMA 5		Employees receive a copy of the safety manual(s) for your department's operations.
12	OPRIMA 6		Our department has written policies/procedures related to safety management.
Simulation Training and Assessment			
13	STA 1		Maritime simulators can be used for absolute sensing of the actual situation on the ship.
14	STA 2		Simulator teaching for the avoidance of collision assists in navigation.
15	STA 3		The training period for all deck competency certificates tends to be minimal once simulators are used.
16	STA 4		Simulation training has enhanced maritime staff productivity in the maritime industry.
17	STA 5		The maritime industry conducts training on simulation regularly.
18	STA 6		Have you received any specific training courses, seminars, or similar educational activities on the simulation?
20	STA 7		To what extent did you find specific training, courses, and seminars on simulation you received within your maritime education helpful for your performance?
21	STA 8		The workshops and seminars organized by the maritime sector are relevant to the organization's needs.

Table 1. Instrumentation Items

4. Result and discussion

4.1 Result of Demographic Information

A total of 100 respondents participated in the study, of whom 70 (70.0%) were male and 30 (30.0%) were female, indicating a higher representation of males in Chittagong Port, Bangladesh. Regarding age distribution, the analysis revealed that the age group between 20-30 years accounted for 16 respondents (16.0%) were between 31-40 years of age, followed by 32 respondents (32.0%). The age group between 41-50 years consisted of 29 respondents (29.0%), while the age group between 51-60 years included 23 respondents (23.0%). Notably, the age group of 31-40 years had the highest frequency among the respondents. The educational qualifications of respondents were also examined. The analysis showed that 10 respondents (10.0%) had diplomas, 35 (35.0%) held bachelor's degrees, 44 (44.0%) had master's degrees, and 11 (11.0%) had PhDs.

Additionally, the distribution of respondents, based on their overall experience in the maritime sector, was examined. The analysis revealed that 34 respondents (34.0%) had 1-10 years of experience, 19 (19.0%) had 11-20 years of experience, 34 (34.0%) had 21-30 years of experience, and 13 (13.0%) had 31-40 years of experience. Among these, respondents with 21-30 years of experience had the highest frequency. In terms of designations, the analysis showed that 23 respondents (23.0%) were executives, 31 respondents (31.0%) were technical supervisors, 24 respondents (24.0%) were senior officers, and 22 respondents (22.0%) were junior staff. Technical supervisors had the highest frequency of designations, with 31 respondents. These findings provide valuable insights into the demographics and characteristics of the respondents involved in the study, allowing for a better understanding of the sample composition and representation at the Chittagong Port.

4.2. Results of Correlation Analysis

Ho1: Relationship between operational risk management and accident reduction in Chittagong Port and outer anchorage, Bangladesh

A Pearson product-moment correlation was conducted to examine the association between operational risk management (ORM) and accident reduction in Chittagong Port and the outer anchorage in Bangladesh. To determine the strength of the relationship, Chua [47] proposed a guideline for interpreting correlation coefficients. According to this guideline, correlation coefficients ranging from .91 to 1.00 or - .91 to -1.00 indicate a robust correlation, .71 to .91 or -.71 to -90 suggest a strong relationship, .51 to .70 or -.51 to -.70 signify an average or medium relationship, .31 to .50 or -.31 to -50 indicate a weak relationship, .01 to .30 or -.01 to -30 represent a very weak relationship, and a coefficient of .00 indicates no correlation.

In the present study, a strong correlation was observed between operational risk management and accident reduction, with a correlation coefficient of r = .858 (n = 100, p < .005) shown in Table 2. This positive correlation suggests that, as the level of ORM increases, the likelihood of accident reduction also increases. These findings support previous research, indicating that operational risk management should be implemented comprehensively [48]. Moreover, better implementation of ORM in Chittagong Port would lead to a positive outcome in terms of reducing accidents and improving employee productivity within the system. Furthermore, the internalization of ORM strategies is a critical factor in successfully reducing accidents within port organizations, thereby contributing to the knowledge of the maritime sector.

Overall, the correlation analysis demonstrates a strong positive relationship between operational risk management and accident reduction in Chittagong Port and the outer anchorage in Bangladesh, highlighting the importance of implementing effective ORM strategies to enhance safety and productivity in the maritime industry.

Table 2. Correlation between operational risk management and Accident Reduction

		Accident reduction	**Hypothesis**
Operational Risk Management	Pearson Correlation	.858**	H1 Supported
	Sig. (2-tailed)	.000	
	N	100	

**. Correlation is significant at the 0.01 level (2-tailed).

Ho2: Relationship between maritime safety and accident reduction in Chittagong Port and outer anchorage, Bangladesh

A Pearson product-moment correlation analysis was performed to examine the association between maritime support services and accident reduction in Chittagong Port and the outer anchorage in Bangladesh. The results revealed a moderate correlation between maritime safety and accident reduction, with a correlation coefficient of r = .611 (n = 100, p < .005) shown in Table 3. This positive correlation indicates that, as the maritime safety level increases, there is a corresponding increase in accident reduction. These findings suggest that implementing maritime support services in Bangladesh can effectively reduce accidents. This aligns with previous research [49,50], which highlights the importance of maritime support as a fundamental pillar of seaports. Such support services can enhance employee motivation and job satisfaction, leading to a decrease in the number of accidents. This insight contributes to knowledge and understanding of the maritime sector.

In summary, the correlation analysis indicates a moderate positive relationship between maritime support services and accident reduction in Chittagong Port and the outer anchorage in Bangladesh. The results emphasize the significance

of implementing effective maritime safety measures and support services to promote a safer working environment and enhance the overall operational performance in ports.

Table 3. Correlation between maritime safety and accident reduction

		Accident reduction	Hypothesis
Maritime safety	Pearson Correlation	. 611**	
	Sig. (2-tailed)	.000	H2 Supported
	N	100	

**. Correlation is significant at the 0.01 level (2-tailed).

Ho3: Relationship Between Simulation Training and Assessment and Accident Reduction in Chittagong Port and Outer Anchorage, Bangladesh

In this study, a Pearson product-moment correlation analysis was conducted to examine the relationship between simulation training and assessment and accident reduction in the Chittagong Port and outer anchorage in Bangladesh. The analysis yielded a strong positive correlation between these variables, with a correlation coefficient of r = .810 (n = 100, p < .005) shown in Table 4. This indicates that as the value of the simulation training and assessment increases, there is a corresponding increase in accident reduction. The results suggest that implementing simulation training and assessment programs in ports can contribute to enhanced accident reduction. This finding aligns with previous research conducted by[51], who emphasized that simulation training and assessment provide valuable guidance for employees to improve their performance when handling actual job tasks. Additionally, Nazir, Overgaard, and Yang [52] highlighted that simulation training and assessment not only serve as a guide but also help identify and correct any abnormalities in job processes, leading to increased productivity within the system. Therefore, the implementation of simulation training and assessment programs in an organization can minimize accidents and contribute to the overall knowledge and understanding of the maritime sector.

In conclusion, the correlation analysis revealed a strong positive relationship between simulation training and assessment and accident reduction in the Chittagong Port and outer anchorage in Bangladesh. These findings emphasize the importance of incorporating effective simulation training and assessment programs to improve safety measures, reduce accidents, and enhance overall port performance.

Table 4. Correlation between simulation training and assessment and accident reduction

		Accident reduction	Hypothesis
Simulation Training and Assessment	Pearson Correlation	. 810**	
	Sig. (2-tailed)	.000	H3 Supported
	N	100	

**. Correlation is significant at the 0.01 level (2-tailed).

5. Conclusion

This study aimed to investigate the correlation between maritime support services and accident reduction in Chittagong Port, Bangladesh. A conceptual framework was developed based on existing leadership theories and the relevant literature. The results confirmed significant positive relationships between operational risk management, maritime support services, simulation training and assessment, and accident reduction. The study also found that employees' experiences at Chittagong Port highlight the impact of support services on hindering their performance.

As such, this study emphasizes the potential to improve employee performance through the provision of support services. Given the rapid changes in the maritime sector, it is crucial to provide extensive support services to enable employees to fulfill their duties while reducing accidents within the organization. Furthermore, employees expressed that with the provision of these three services, accidents in Chittagong Port could be reduced. As the world undergoes rapid changes, including in the maritime sector, it is essential to equip employees with the knowledge and skills necessary for effective use of new technologies. Support services, along with training mechanisms, can significantly improve employee effectiveness and prevent accidents.

The findings of this study add to the existing body of knowledge in the maritime sector, reinforcing the crucial role of support services. The practical implications of this study recommend the establishment of comprehensive support services as a robust strategy for reducing accidents and enhancing employee performance. Furthermore, the study underscores the necessity of adopting a comprehensive approach to support services in Bangladesh and underscores the importance of comprehensive interventions for improving organizational performance. In summary, the empirical evidence presented in this study supports the importance of comprehensively implementing support service dimensions to achieve significant success in accident reduction. Organizations in the maritime sector must adopt a comprehensive approach to support services and make necessary improvements to enhance safety and overall performance.

Funding: This study received no specific financial support.

Institutional Review Board Statement: Not applicable.

Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Competing Interests: The authors declare that they have no competing interests.

Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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