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A Risk Assessment for Accidents of Ship Mooring Operations from Fine-Kinney Method Perspective

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ABSTRACT

Shipboard operations represent a complex environment, characterized by a high degree of risk, which demands a certain level of skill and expertise from those working on them. Despite the implementation of appropriate safety measures for these operations, it is observed that fatalities, injuries, and financial damage continue to occur onboard. When accidents on ships are investigated, it is highlighted that the accident rate caused by ropes in mooring operations is considerable. Mooring operations on ships represent a significant risk to personnel, due to the inherent dangers and the potential severity of the consequences. The study aims to reveal the causes of deaths and injuries caused by accidents during ship mooring operations and to conduct a risk analysis of the operations. The potential risks associated with the operation were identified through a process of consultation with experts and a comprehensive literature review. The Fine-Kinney Method was employed as the risk evaluation method. The results of the expert evaluations indicate that the most significant risks associated with mooring operations of ships are the lack of crew attention and personnel fatigue. Our experts' recommendations for addressing potential risks included adhering to established work hours and avoiding disruptions to the training of personnel.

Keywords: Risk, maritime accident, ship mooring operations, Fine-Kinney method

Fine-Kinney Yöntemi Perspektifinden Gemi Bağlama Operasyonları Kazaları için Bir Risk Değerlendirmesi

ÖZ

Gemi operasyonları, üzerinde çalışanlardan belirli düzeyde beceri ve uzmanlık gerektiren, yüksek derecede risk içeren karmaşık bir ortamı temsil eder. Bu operasyonlarda uygun emniyet tedbirlerinin alınmasına rağmen ölüm, yaralanma ve maddi hasarların yaşanmaya devam ettiği görülmektedir. Gemilerde meydana gelen kazalar incelendiğinde, bağlama operasyonlarında halatlardan kaynaklanan kaza oranının azımsanmayacak düzeyde olduğu belirtilmektedir. Gemilerdeki bağlama operasyonları, doğası gereği barındırdığı tehlikeler ve potansiyel sonuçları nedeniyle personel için önemli bir risk teşkil etmektedir. Çalışmanın amacı, gemi bağlama operasyonları sırasında meydana gelen kazalardan kaynaklanan ölüm ve yaralanmaların nedenlerini ortaya çıkarmak ve operasyonların risk analizini yapmaktır. Operasyonla ilgili potansiyel riskler, uzmanlarla yapılan istişare süreci ve kapsamlı bir literatür taraması yoluyla belirlenmiştir. Risk değerlendirme yöntemi olarak Fine-Kinney Yöntemi kullanıılmıştır. Uzman değerlendirmelerinin sonuçları, gemilerin bağlama operasyonlarıyla ilgili en önemli risklerin mürettebatın dikkat eksikliği ve personel yorgunluğu olduğunu göstermektedir. Uzmanlarımızın potansiyel risklere yönelik tavsiyeleri arasında, belirlenmiş çalışma saatlerine uyulması ve personelin eğitiminde aksaklıklardan kaçınılması yer almaktadır.

Anahtar Kelimeler: Risk, deniz kazası, gemi bağlama operasyonları, Fine-Kinney metod

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1. Introduction

Global maritime transportation involves the operation of over 100,000 ships (URL-1, 2024). As these vessels navigate between ports, they engage in a cyclic process of berthing and unberthing upon completion of their voyages. Mooring, the process of securing a ship to a port or specific location with ship lines, constitutes a critical aspect of maritime operations. The effectiveness and safety of mooring operations are contingent upon various factors including the dimensions and type of the vessel, the characteristics of available mooring lines and equipment, the layout of the terminal necessitating adaptable mooring strategies, and the environmental conditions at the port facility. The maritime industry adheres to numerous standards, guidelines, and recommendations concerning mooring practices, rigs, and equipment. The Maritime Safety Committee (MSC 95) has agreed to revise the SOLAS regulation II-1/3-8 and the associated guidelines (MSC.1/Circ.1175) and to develop new guidelines for safe mooring operations for all ships. The objective is to prevent unsafe and unhealthy work situations during mooring operations (URL-2, 2024).

Despite technological advancements enhancing ship propulsion, control, and navigation, mooring operations largely retain traditional features. Predominantly reliant on ropes and windlasses, mooring systems necessitate substantial human power. Seafarers actively participate in mooring procedures, handling ropes, operating windlasses, and utilizing fixtures such as bollards and swivels. However, this manual involvement exposes seafarers to hazards including fatalities and injuries during mooring activities. Consequently, a thorough examination of mooring processes and comprehensive risk assessments are imperative to mitigate associated dangers. The existing body of literature contains numerous studies which examine various aspects of accidents on ships, including collision, fire, and grounding incidents (Calle et al., 2017; Baalisampang et al., 2018; Chen et al., 2019; Yildiz et al., 2022). In addition to the aforementioned incidents, maritime vessels are also engaged in other operations that are inherently risky. These operations are mainly loading/unloading operations, navigation and mooring operations. A statistical analysis of maritime incidents reveals that accidents involving mooring operations are a significant cause of accidents at sea (Kuzu et al., 2019; Kumar and Singh, 2023). As reported, mooring operation injuries represent the seventh most common cause of personal injury. In addition, The Club's analysis of significant claims found that approximately 5% of all severe personal injuries happened during mooring or towing operations (Crossley, 2023). Major accidents involving mooring equipment in the last 20 years have injured many seafarers and have cost the UK Club over US$34 million (UK Pandi Club, 2009)

The existing literature contains several studies that analyze the operational risks of mooring cargo ships. Hsu (2015) assessed the safety factors of ship berthing operations. Kuzu et al. (2019) performed a systematic risk analysis on the case of a tanker ship mooring operation. Kaushik and Kumar (2023) conducted a risk analysis that assessed the root causes of the parted rope injury during ship mooring operation. Kumar and Singh (2023) carried out a reliability analysis of parted rope injuries and their fundamental causes during ship mooring operations.

As was pointed out above, incidents of mooring lines breaking in port have led to numerous fatalities throughout the years and many more accidents and mooring continues to be a high-risk operation. In addition, there have been significant studies that have highlighted the risks of mooring operations. Against this backdrop, this research aims to identify the risks associated with mooring operations on ships, to prevent injury, death, and other adverse consequences that may result from accidents during maneuvering. As part of this process, there has been a review of fatality and injury incidents that may have occurred during mooring operations. In order to ascertain the incidents that occurred during the maneuver, a comprehensive examination was conducted of the relevant literature and five accident reports (MAIB, 2011, 2013, 2015; KAIK, 2013; UEIM, 2021), which were selected as representative examples. In addition, expert opinions were sought in the risk assessment on the subject. In this context, the incidence of injuries and fatalities resulting from accidents occurring during manoeuvring operations on ships has been evaluated utilising the Fin Kinney risk analysis method. In order to prevent the occurrence of such incidents, experts have implemented risk prevention measures.

The paper is divided into five sections, starting with this introductory section, which examines the risks of mooring operations and presents a literature review on mooring operations on board. The second section is concerned with the cases that were included in the mooring operations accident. The third section describes the development of the Fine Kinney model for a cargo ship mooring operations risks. The research findings and discussion are presented in the fourth section. The conclusion section is a summary of the main findings and suggestions for further research. In conclusion, this research focuses on the risks of mooring operations for seafarers, the findings are expected to assist maritime stakeholders in their efforts to improve mooring safety in maritime shipping.

2. An Overview of Mooring Operations-Accidents

Accidents involving the mooring of ships attract a great deal of attention in many reports. In general, these accidents result in serious injuries, fatalities, and economic losses. Some information on these operations, which are considered to be among the riskiest of all shipboard operations, is presented below.

Mooring incidents represent a significant number of insurance claims, ranking as one of the top seven types of incidents reported by the UK Pandi Club. It can be demonstrated from the available records that mooring is indeed one of the most challenging, intricate, and perilous tasks on board. Such incidents involving mooring have been found to result in leg injuries (23 %), death (14 %), back damage (14 %), and other multiple injuries (UK Pandi Club, 2016). Statistical data from the European Harbour Master's Committee indicates that in all cases of injury related to mooring, 95% are attributable to the use of ropes and wires. 60% of these injuries occur during the mooring process (URL-3, 2020). Furthermore, the Australian Maritime Safety Authority (AMSA) recorded a total of 227 mooring-related incident reports over a five-year period. Of these, 22 percent resulted in injury, indicating a potential risk to personnel involved in maritime operations (AMSA, 2015). The Isle of Man Ship Registry has indicated that mooring operations were the most common activity reported on the accident report forms. It has also been highlighted that mooring operations were the most dangerous activity for seafarers (Isle of Man, 2022). In addition, 5 accident reports which were the subject of in-depth investigations as part of this study are listed below:

Accident Report No 1 (UEIM, 2021): Düzgit Endeavour The tanker named DÜZGİT ENDEAVOUR, with an overall length of 156.10 m, width of 21.7 m and DWT of 15995, was caught by the left foot of the deck cadet on 11 September 2019 at 08:42 while the ship's stern mooring ropes were being carried to the buoy by the mooring boat. He became trapped between the rope given to his boat and the ship's porthole. As a result of the accident, the cadet's left foot was torn off above the ankle and his body was also injured. The following safety factors were found to have caused the accident: Before the accident, the victim did not sufficiently clear the area where the mooring ropes could pose a danger, and the victim's foot stepped on/contacted the mooring ropes pulled by the mooring boat, which started the process leading to the accident.

Accident Report No 2 (MAIB, 2015): On 2 March 2015, a deck officer on the LNG tanker ZARGA, with an overall length of 345m, a beam of 54m and a DWT of 130211, suffered a serious head injury when he was struck by a mooring rope during a mooring operation at the South Hook

LNG Terminal in Milford Haven. The deck officer was positioned on the port shoulder of the ropes with a second sailor in front of him to communicate his orders to the sailor operating the windlass. As the sailor operating the winch attempted to turn the ropes, the winch stalled and repeatedly broke down. About 10 minutes later, the spring rope broke and struck the officer on the head. The officer in charge of the ship's overhead maneuvering team was taken by helicopter for emergency surgery for head trauma.

Accident Report No 3 (MAIB, 2013): On the Capesize bulk carrier WAH SHAN, with an overall length of 289m and a GT of 91165, at about 0712 on 2 October 2012, a sailor was struck by the guide rope while trying to secure the tug's spare rope during the ship's mooring. The seafarer was pronounced dead at 0815. The autopsy report stated that he died from a broken neck. The investigation concluded that the risks associated with securing the tug's towline were not properly considered and that the stern maneuvering team used poor maneuvering practices and was an incompetent team.

Accident Report No 4 (KAIK, 2013): M/V KRISTIN-C, built in 2008, with a DWT of 6799.92 mt, berthed at Dock 1 of Güllük Port on 19 August 2013 at 18:25. After the loading process of the vessel was completed at 09:13 on 21 August 2013, the departure maneuver from the port started at 11:00 with the boarding of the vessel by the harbor pilot. All ropes connecting the ship to the quay were removed one by one and taken onto the ship at 11:10. The stern of the ship is 2-3 meters further from the dock. While the tug gradually increased its pulling power from half to half and continued to tow the ship, at 11:15 the rope used in the towing operation suddenly broke in half and was thrown onto the dock, hitting and seriously injuring the port staff working as mooring men on the pier.

Accident Report No 5 (MAIB, 2011): Fremantle Express, a container ship built in 1995, with an overall length of 188 m, a width of 30 m, and a GT of 23540, was approaching the port of Veracruz on 15 July 2011 when, while releasing the damaged mooring rope at the bow, it backfired and struck the sailor standing on the forecastle. The sailor died. The investigation revealed that The mooring rope had been subjected to a breakaway load due to the ship's reverse motion. The strength of the rope at the time of the accident had been reduced to less than 66% of its original strength. No one in the maneuvering team reported the condition of the damaged rope

3. Methodology

This section provides an overview of the basic principles and processes involved in the Fine Kinney method and introduces the profiles of the experts used in the risk assessment of mooring operations.

3.1. Fine-Kinney Method

The Fine-Kinney risk assessment (FRA) model is a widely utilized quantitative approach for evaluating and prioritizing risks across various domains, including occupational health and safety, agriculture, construction, and maritime operations (Kokangül et al., 2017; Yang et al., 2020; Tang et al., 2021; Ayvaz et al., 2024). Its core tenet is the determination of a risk score by multiplying the parameters of probability, exposure, and consequence (Karahan and Aydoğmuş, 2023; Satıcı and Mete, 2023). Additionally, the FRA model has been employed to assess risks in diverse sectors, such as energy distribution, investment, agriculture, and restoration operations, exemplifying its adaptability and efficacy in identifying and mitigating prospective hazards (Tabak and Büyükakinci, 2023). The method aims to provide a more comprehensive and effective approach to occupational risk assessment and management.

The method was initially proposed by Fine in 1971 from the perspective of mathematical evaluations for hazard control and it was subsequently revised by Kinney and Wiruth in 1976 as a practical risk analysis for safety management (Fine, 1971; Kinney and Wiruth, 1976). The methodology for this risk assessment involves multiplying three parameters: those representing the potential consequences of an accident (C), the likelihood of the hazard event occurring (E), and the probability of a hazardous event (P) (Gul et al., 2018). Risk value (RV) is computed using the following equation:

$$RV = P \times E \times C \quad (1)$$

Likelihood (Probability-P): This is the probability that harm or damage will occur over time, with a range between 0.1 and 10.

Frequency (Exposure-E): Frequency is defined as the repetition of exposure to danger over time, with values between 0.5 and 10.

Severity (Consequence, C): This is defined as the estimated degree of harm that a hazard will cause to people, the workplace or the environment. Violence is rated on a scale of 1 to 100.

The numerical values assigned to the parameters are drawn from the classification tables presented in Table 1, Table 2 and Table 3.

Table 1. The probability scale of Fine-Kinney method

Category of Likehood	Value
Virtually impossible	0.1
Practically impossible	0.2
Conceivable but very unlikely	0.5
Only remotely possible	1
Unusual but possible	3
Quite possible	6
Might well be expected	10

Table 2. The exposure scale of Fine Kinney method

Category of Exposure	Value
Very rare (yearly)	0.5
Rare (a few per year)	1
Unusual (monthly)	2
Occasional (weekly)	3
Frequent (daily)	6
Continuous	10

As illustrated in Table 4, the outcomes of risk value are classified into five categories, ranging from extremely high risk to acceptable risk (Kinney and Wiruth, 1976).

Table 3. The consequences scale of Fine Kinney method

Category of Consequence	Value
Noticeable (minor first aid accident, or > $100 damage)	1
Important (disability, or >$$10^3$ damage)	3
Serious (serious injury, or >$$10^4$ damage)	7
Very serious (fatality, or >$$10^5$ damage)	15
Disaster (few fatalities, or >$$10^6$ damage)	40
Catastrophic (many fatalities, or >$$10^7$ damage)	100

Table 4. The risk level scale of Fine-Kinney method

Risk Situation	Risk Value
Risk; perhaps acceptable	R < 20
Possible risk; attention indicated	20 < R < 70
Substantial risk; correction needed	70 < R < 200
High risk; immediate correction required	200 < R < 400
Very high risk; consider discontinuing operation	400 < R

This application employs three criteria (Fine Kinney risk parameters) for assessment: (P), (E), and (C). To complete the risk assessment for potential hazards identified by the proposed framework, a group of ten maritime transport field experts. The main risks associated with the mooring operation were identified in collaboration with experts and subjected to comprehensive evaluation. Given the disparate weightings of the experts, the risk score derived from their input was recalculated, incorporating their respective weights. The final risk score was obtained by dividing the total result by the number of experts

3.2. Identification and weights of the experts in the method

Expert interviews constitute a highly attractive methodology in the context of data collection, offering researchers the opportunity to bridge the divide between case studies and the comparison of a considerable number of countries based on more general, publicly available data (Dorussen et al., 2005). In the academic field, there is an increasing tendency to accept expert judgments as scientific data, accompanied by the development of procedures to deal with such information

(Cooke and Goossens, 2000). In this study, the expert group was selected to determine risks in mooring operation aboard and to evaluate the potential consequences of an accident, the likelihood of the dangerous event occurring, and the probability of a hazardous event.

In order to ascertain the risks associated with the ship mooring operation, expert opinions, and literature review were employed. Furthermore, the weight factor calculation was utilized to determine the relative quality of expert opinion. The expert's weighting is distinguished by assigning scores ranging from 1 to 5, which indicate profile variations among them (Hsu and Chen, 1996). To determine the weight scores attributed to the experts, Equation (2) was employed (Rajakarunakaran et al., 2015). The expert panel who participated in the survey is shown in Table 5. Experts were categorized based on their rank, service time (years), and level of education.

$$\text{Weighting Score of Expert } (W\mu) = \frac{\text{Total score of the expert}}{\text{In all weight score of experts}} \quad (2)$$

Table 5. Details of the experts and weight scores.

Expert	Rank	Sea Experience	Educational Level	Weight Factor			Total Score	Weight Score
E_1	Chief Officer	5	Bachelor	4	3	3	10	0.1
E_2	Master	≥ 8	Bachelor	5	5	3	13	0.12
E_3	Master	≥ 8	Bachelor	5	5	3	13	0.12
E_4	Junior OOW	*2-3*	Bachelor	2	2	3	7	0.06
E_5	Senior OOW	2-3	Bachelor	3	2	3	8	0.07
E_6	Chief Officer	4	Bachelor	4	3	3	13	0.12
E_7	Senior OOW	*2-3*	Bachelor	3	2	3	8	0.07
E_8	Chief Officer	4	PhD	4	3	5	12	0.11
E_9	Master	6	PhD	5	4	5	14	0.13
E_{10}	Chief Officer	4	MSc	4	3	4	11	0.10
							∑=109	

Weight Factor= If competency; Junior OOW=2, Senior OOW=3, Chief Off. =4, Master = 5.
If sea experience; ≤ 1=1, 2-3=2, 4-5=3, 6-7=4, ≥ 8= 5.
If education level; Bachelor=3, MSc=4, PhD=5

Table 5 indicates that of the 10 experts, three are Masters, four are Chief Officers, two are Senior Officers and one is a Junior Officer. The sea experience of the experts ranges from two years to more than eight years. The educational qualifications of the experts include two Doctorates, one Master's Degree, and seven Bachelor's Degrees. The scores assigned to the risks identified in the mooring operation of the ships were determined by considering the expert weights. For instance, the final risk score calculated for each expert was multiplied by that expert's weight, and the scores obtained from 10 experts were summed to determine the level of risk (see Table 4). Expert opinions were gathered through the use of email, telephone, and face-to-face interview techniques. As a result, the following section presents the scores of the 15 risks identified in the ship's mooring operation

4. Results and Discussion

Fifteen risks of mooring operation identified in this study were developed through a review of the literature (Kuzu et al., 2019; Kaushik and Kumar, 2023) and the opinions of 10 experts and are presented in the table below:

Table 6. Risk evaluation for mooring operation.

No	Operation Place	Source of Threat	Potential Consequence	Average Risk Value	Risk Severity
1	Manoeuvring Stations	Lack of crew attention	Injury or fatality	585.6	Very high risk; consider discontinuing operation
2	Manoeuvring Stations	Fatigue of the crew members	Injury or fatality	526.0	Very high risk; consider discontinuing operation
3	Manoeuvring Stations	Adverse weather conditions	Man overboard, injury	315.0	High risk; immediate correction required
4	Manoeuvring Stations	Parted Rope (appropriate)	Injury or fatality	134.1	Substantial risk; correction needed
5	Manoeuvring Stations	Inadequacy communication	Parted rope	109.9	Substantial risk; correction needed
6	Manoeuvring Stations	Inappropriate rope	Fatality or injury due to the parted rope	94.8	Substantial risk; correction needed
7	Manoeuvring Stations	Inappropriate rope	Damage due to the parted rope	80.2	Substantial risk; correction needed
8	Manoeuvring Stations	Slippery surface	Injury or fatality (hitting the head)	60.9	Possible risk; attention indicated
9	Manoeuvring Stations	Excessively long rope	Ropes entagled	60.6	Possible risk; attention indicated
10	Manoeuvring Stations	Malfunction of the windlass control lever	improper manoeuvre due to inability command to the rope	57.2	Possible risk; attention indicated
11	Manoeuvring Stations	Malfunction of the windlass control lever	Injury due to the loss of rope command	53.5	Possible risk; attention indicated
12	Manoeuvring Stations	Multiple ropes tied to a single bollard	No let go the rope	39.2	Possible risk; attention indicated
13	Manoeuvring Stations	Multiple ropes tied to a single bollard	Damage	34.4	Possible risk; attention indicated
14	Manoeuvring Stations	Structures located on the manoeuvre stations' ground	Injury or fatality	18.2	Risk; perhaps acceptable
15	Manoeuvring Stations	Observation hawse	Injury (hitting the head)	10.7	Risk; perhaps acceptable

Table 6 indicates that the highest risk score in the mooring operation of the ships is No:1 risk, with 585.6 points. This is followed by No:2 risk, with 526.0 points, and No:3, with 315.0 points. The three lowest scores are No:13, No:14, No:15 (34.4, 18.2, and 10.7 points, respectively). The two highest risks, in terms of risk severity, are the “lack of crew attention (No:1)” and “fatigue among the crew (No:2)”. These two risks are classified as “very high risk” and therefore require consideration of discontinuing operation. The two lowest risks are the “structures located on the maneuver stations ground - injury or fatality (No:14)” and “observation hawse- injury (hitting the head) (No:15)”. These two risks are categorized as “Risk; perhaps acceptable”.

It is of paramount importance to examine the risks of injury or fatality due to personnel fatigue and lack of attention. Given the operating conditions of the ships, their voyage frequency and workload, it is an expected fact that experts consider these situations important within the framework of the mooring operation. In recent years, there has been a notable acceleration in the operation of ports, with ships being operated with a reduced number of personnel. These factors collectively contribute to the phenomenon of crew fatigue. There are also many studies revealing the fatigue in question (Oldenburg et al., 2010; Dohrmann and Leppin, 2017; Zhao et al., 2020).

In addition to the risk assessment phase, experts were requested to propose "corrective and preventive actions" for the identified risks. In light of the findings, the experts have put forth the following recommendations, particularly with regard to the three highest-scoring risks:

Corrective and preventive actions for 1st item (Lack of crew attention-Injury or fatality) are as follows: It is recommended that personnel rest before undertaking the maneuver. Furthermore, it is important to ensure that working and rest hours are accurately implemented. Finally, personnel with attention problems should be assigned to the maneuver area as little as possible.

Corrective and preventive actions for 2nd item (Fatigue-Injury or fatality) are as follows: Crew working hours must comply with the MLC. Furthermore, it is crucial that training on the use of PPE be provided. The importance of personnel training must be emphasized. Finally, our experts have stated that the work should be stopped and immediate measures should be taken if there is fatigue in the crew.

Corrective and preventive actions for 3rd item (Fatigue-Injury or fatality) are as follows: It is not recommended that personnel work on the deck in adverse weather conditions. Prior to undertaking any manoeuvre, it is essential that a situation assessment meeting is held. Furthermore, it is crucial that all personnel are trained in the event of a man overboard (MOB) situation. MOB drills must be conducted regularly and with the utmost realism. Finally, the situation must be included in the emergency action plan.

5. Conclusion

The present study identifies and assesses the risks that may arise in the context of ship mooring operations, with the objective of determining the relative levels of risk associated with specific items. The findings of the study reveal that items lack of crew attention, fatigue and adverse weather condition represent the most significant risks, while items “structures located on the maneuver stations ground - injury or fatality” and “observation hawse- injury (hitting the head) ”exhibit the lowest levels of risk. The experts in this study proposed corrective and preventive measures for the highest-risk score substances. These measures focused on ensuring that the working hours of personnel complied with the MLC agreement, with particular emphasis on the importance of ensuring adequate crew resting hours and avoiding operations in the event of identified risks.

It is expected that this study will make a significant contribution to the field of maritime transport in terms of mooring operations. Further studies on mooring operations, on different ship types, in various areas of operation will produce significant results in findings.

Author contribution

Öztürk, O.B: Visualization, Conceptualization, Literature review, Data collection, Data processing, Data Analysis, Methodology, Investigation, Writing and Editing, Critical review.

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Conflict of Interest Declaration

The author(s) declare(s) that they have no conflict of interest.

Ethical standards

No Ethics Committee Approval is required for this study.

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