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Ranking the Factors Applied in Simulation Training Leading to Better Traffic in Alexandria Port Using AHP

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ABSTRACT

Purpose: *There is a risk of collisions in daily life and these risks are doubled in the shipping industry. The focus of this study is to identify the factors that lead to ships' collisions by prioritizing them. These factors are vessel traffic, marine pilots, fairway traffic, navigation aids, and ship berthing.*

Methodology: *The data were collected from 30 experts and decision-makers in the maritime industry. The Analytic Hierarchy Process (AHP) method analyzed the data to know the preferences.*

Findings: *The results revealed that vessel traffic is the first item that causes ships' crashes, then marine pilots, fairway traffic, navigation aids and ship berthing, respectively.*

Key-words:
ships' collisions, vessel traffic, fairway traffic, navigation aids, ship berthing, marine pilot simulator.

1. INTRODUCTION

Currently, the majority of the world's products is transferred by the ocean which is more than 90 percent. About 8 million tons of products were carried every year by container ships, tankers, and bulk carriers (Fruth and Teuteberg, 2017). In year 2013, ship shipping was increased to 9.5 billion tons, while in 2015 this process has been raised to 20.5 million twenty-foot equivalent units (TEUs), regardless of the economic crisis that occurred in 2009. The maritime industry increased twice in comparison with the global commercial local goods (Harrison and Boske, 2017). In the last decades, the maritime industry became a vital way of connection and transportation all around the world. By increasing maritime traffic, the world endured this suboptimal growth that has increased risk (Sousa, 2018).

The increase in shipping industry is positively correlated with the rising in world's request, thus it is a well-established truth that most marine transportation is relatively frequent. In other words, particular points of interest (POIs) are connected to only a restricted number of roadways such as ports or stationary locations (Willett et al., 2018).

With every maritime traffic increase, there is an increase in ship crashes, privateering offensive, and terrorism threats. Although the updated computer-based systems and the new navigational technology are frequently placed on vessel crossings, a large proportion of accidents still occur (Willett et al., 2018). Since traffic is going on, collisions between vessels are the main functional hazard in the maritime industry. Although updated computer-based systems and new navigational technology are frequently placed on vessel crossings, a large proportion of accidents still occurs (Hou et al., 2020; Van Gelder et al., 2020).

More than 80% of maritime transportation accidents and collisions are said to be due to human factors, according to various marine accident surveys. Therefore, the influence of human factors on these accidents is continuing to be crucial (Hou et al., 2020). According to that, many prior studies started to search for different reasons that affect the safety of the navigation and lead to ships' collisions, which are represented in; vessel traffic where some of the literature review were dedicated to understand the semi-continuous spatial statistical analysis using ais data for vessel traffic flow characteristics (Kim, 2021); marine pilots as some of the previous studies contributed to analyzing the term of maritime pilot training and certification, besides conducting a comparative study between several countries regarding marine pilot (Kalulu, 2018); fairway traffic where some of the literature review investigated the Ship collision frequency estimation in port fairways in order to understand the fairway traffic through conducting a case study (Weng and Xue, 2015); navigation aids where a specific portion of the literature review contributed to understanding the effects of urban form and navigational aids on wayfinding behavior and spatial cognition (Yu et al., 2021); and finally ship berthing as several previous studies were dedicated to solving continuous berth allocation problems (Yuan et al., 2017).

Based on these studies, the current research aimed to investigate the role of these five factors (Vessel Traffic (VT), Marine Pilot (MP), Fairway Traffic (FT), Navigation Aids (NA) and Ship Berthing (SB)) on the ships' collisions and apply analysis of Analytic Hierarchy Process (AHP) method to know the ranking of each of these five variables. According to that, the contribution of the study is represented in testing different factors that affect ships' safety as well as trying to rank them according to their strength. This point represents the main contribution as there are no previous studies that have merged these five factors before or have measured their effect on maritime safety.

This paper is divided into seven sections, where each section achieves a particular purpose of the research. Starting with section one, it presents the introduction of this paper. Section two presents the literature review, where previous studies that had examined the same variables are discussed. Section three is research methodology. Section four presents the data analysis and the outcomes of the AHP. Section five shows the discussion of the concluded results. Moreover, section six is the conclusion of the research, where the benefit of the current research is shown. Ending with the seventh section, which represents the limitation of this research and the suggestions for the future research.

2. LITERATURE REVIEW

The relationships between the research variables are examined in the parts that follow. This study sought to ascertain how to prioritize the preferences of maritime traffic based on the simulation models that impacted the security and risk level in the maritime industry. Five key variables are presented to determine the optimal service standard that the port should adhere to to achieve a safer navigational path. These factors are; Vessel Traffic (VT), Marine Pilot (MP), Fairway Traffic (FT), Navigation Aids (NA) and Ship Berthing (SB). Therefore, the relationship between these factors and the way to safer way of navigation are shown in the next subsections.

Vessel Traffic

By describing how the freight field is one of the oldest fields in traffic. Nowadays maritime traffic has become one of the major fields in traffic at extremely high pressure for efficacious and secure functions on land not in the harbor functions. With increasing requests, there is a development in technology in all fields generally and in the maritime industry especially. Vessel Traffic Service (VTS) is one of the newest technological services in the maritime industry to raise the safety and efficiency of harbor functions. A support service for cargo ships passing by ports or over challenging terrain is called VTS (Praetorius and Hollnagel, 2014). Numerous forms of VTS have been implemented in recent years to increase safety, especially in areas with high traffic density and vital maritime settings (Yang et al., 2023). In locations with peak traffic intensity, the VTS has been found to have a favorable impact on both administrative surveys and project evaluations (Praetorius and Hollnagel, 2014). VTS is accepted as one of the aspects that could affect the safety of navigation based on the aforementioned points.

Different studies discussed this point, such as; Park and Bang (2016), Hoogendoorn et al. (2019), Qiu et al. (2020), and Srše et al. (2021) proved a strong correlation between the improvement of vessel traffic service and maritime traffic and safety. In addition, Hoogendoorn et al. (2019) assured that the amount of vessel traffic was positively related to vessel traffic. Qiu et al. (2020) revealed that vessel number and speed were the most effective factors in vessel traffic services and the adoption of rotational shifts can help in maritime traffic. Similarly, Srše et al. (2021) indicated a relationship between the vessel sizes, the hazard distance, and the traffic flow standard deviation. These can be used to develop a broad model of vessel traffic flow as well as to judge the architecture of hypothetical rivers and the safety of navigation. Accordingly, the current study can assure of the importance of VTS on maritime traffic and its benefits that are related to vessel amount, speed and size as well as the hazard distance.

On the other hand, Dahlman et al. (2015) aimed to study how vessel traffic systems engaged integrity and dynamic traffic movements and how these services uplifted traffic fluency. Results showed that the VTS domain is highly complicated and that the two systems that were simulated have quite diverse services to identify the impact on the systems' monitoring, response, and anticipatory capabilities. When making plans for and carrying out modifications inside the VTS domain, it is crucial to keep this in mind. Although VIS has many benefits for maritime safety, it still represents a complicated system that requires lots of training in order to deal with it.

Real-time multi-vessel collision assessment, which integrates a multi-vessel collision risk index model and Density-Based Spatial Clustering of Applications with Noise (DBSCAN) for locating groups of encountering vessels was investigated by Jin et al. (2017). The results showed how effectively and efficiently encounter vessels within each cluster can be identified and ranked according to their collision risk, allowing operators to prioritize encounter vessels for further risk assessment automatically. This framework can thereby lessen the number of fatalities and property losses while enhancing the security and safety of vessel traffic transportation.

Studies also mentioned artificial intelligence and it supports the safety of navigation in the presence of VIS. Ye et al. (2019) and Goh et al. (2019) had mentioned this point, where Ye et al. (2019) indicated that when VIS is compared to the current Traffic Signal Revealing System, the average waiting time for vessels is reduced by roughly 22 minutes. By shortening travel times, this will boost the waterway's capacity while also greatly enhancing the effectiveness and precision of the scheduling of ship traffic. While Goh et al. (2019) revealed the importance of traffic pattern knowledge for a variety of domain applications and how it is a requirement for the increasingly common knowledge-based forecasting methodologies. The results also highlighted how crucial it is to research maritime traffic and how artificial intelligence may be used to address it. Regarding this point, it is important to mention that artificial intelligence is a significant factor that will support the navigation process but at the same time, the human pilot role should not be neglected.

Marine Pilot

Today's pilots provide one of the most critical services to the maritime business. It is nevertheless crucial for ships traveling to high-risk waters to have a pilot on board. Today's pilots combine the latest cutting-edge nautical technology with their extensive local expertise. The rate of technological development makes it challenging for pilots to stay up to date with such cutting-edge equipment. New ship designs necessitate new maneuvering techniques, yet marine pilots are obliged to operate them without prior training, putting them and others in danger. These changes necessitate specialized knowledge, ongoing attention, and extremely complex decision-making (Kalulu, 2018). According to this, it is important to investigate the role of pilots in marine safety and how to prepare them to ship safely and avoid collisions.

Many studies have mentioned the importance of training and simulators in making marine pilots able to perform efficiently. Sellberg and Lundin (2017) and Sellberg (2018) demonstrated how instructions given during the simulation build on an instructor's capacity to discern how the ongoing activities in the simulator align with learning objectives. According to Sellberg (2018), the instructional goal of tying together the general and particular navigational conditions was upheld throughout all training phases, from briefing through scenario to debriefing. The findings highlighted the necessity of both in-scenario instruction and post-simulation debriefing to improve learning in a profession. The results also demonstrate how technology in the model environment enables instructors to monitor, correct, and assess students' progress toward learning goals on a continual basis.

In the same manner, Kalulu (2018) compared and contrasted Namibia's marine pilot training and certification scheme with Denmark's, as well as with international standards and best practices and revealed that there are variations in the education and training systems as well as in the rules, practices, structures, operations, and administration of the two pilotage jurisdictions. To improve the safety of persons and property at sea and in ports, the findings also indicated the need for international standards for maritime education and certification. These standards will promote the development of critical skills required for high performance and marine environment protection.

Moreover, Mateichuk et al.'s (2020) objective was to establish an efficient "Ship's Captain / Pilot" relationship that will guarantee the vessel can maneuver as effectively as possible while taking all hazards, dangers, and warnings into account. The experimental study's findings on how to efficiently foster interactions between "The Ship's Captain and the Pilot" using training technologies will aid in operationalizing fixes for problems with ship handling training and improve captains' capabilities.

The above studies have shown very clearly the importance of the simulators and training that are provided to pilots as well as the importance of training these pilots on new technology and how to use it in an effective way that represents an added value that guarantees a very safe shipping journey.

Another point related to marine pilots has been discussed in the study of Orlandi and Brooks (2018), where the study aimed to determine how 10 marine pilots' physiological and mental workloads were affected by ship handling maneuvers. From the electrocardiogram, heart rate and heart rate variability were determined. Eye tracking was used to measure pupil dilation. As berthings became more challenging and the pilots performed them in foreign ports, workload levels grew. This study concluded that the workload must be put in consideration as a main factor that affects marine pilots and their performance.

Fairway Traffic

The main purpose of fairway infrastructure is to make river navigation both safe and profitable. The fairway, along with other elements like locks, is essential to the construction of the fairway. It can be described as a specific section inside a riverbank that must be preserved by the relevant competent fairway authority (Rusu, 2015). Waterway parameters are set forth in international treaties to enable inland navigation based on the same standards. The canal system belongs to the public and must be established and maintained in accordance with these international conventions and accords by national fairways administrations (Erceg, 2018). Higher demands are placed on the capacity and safety level of coastal fairways due to the transportation sector's rapid growth and the ongoing growth of marine traffic flow (Zhou et al., 2015). Thus, the identification of fairway infrastructure and traffic represents a significant factor of navigation whether in rivers or open seas.

Studies have investigated fairway traffic and many issues that affect its safety. Weng and Xue (2015) assured that nighttime ship collision frequency was observed to be much greater than daytime ship collision frequency. Hirdaris et al. (2020) showed that remote piloting might be a safe choice on a few fairways under controlled circumstances.

Zhou et al. (2015), Cho et al. (2020a) and Cho et al. (2020b) had mentioned the importance of fairway size, as the studies showed that for a particular port quality of service, fairway size is associated with the safety level, and that the bigger the capacity of the fairway, the lower the safety level. Additionally, according to Cho et al. (2020a), the safety distance between the ship's path and structural stiffness was found to be 0.18 times for two-way traffic and 0.23 times for one-way traffic.

Also, Cho et al. (2020b) indicated that traffic distribution for each port can be taken into account while building river bridges. A similar issue is made by Park et al. (2022), who stated that it would be ideal to employ a design strategy that takes collision and stranded risk models into account when constructing new fairways or assessing those that already exist.

Another idea is discussed by Liu et al. (2022), which is related to identifying the best turnaround zone and fairway usage patterns at the same time to reduce terminal stress. A multi-objective optimization model's two optimization variables are the minimal overall scheduling time and the total waiting time. Results indicated that the entire scheduling time and the total waiting time for vessels are, respectively, reduced by around 20 minutes and an hour when compared to the operation phase. The practical approach improved turning zone and fairway accessibility in addition to substantially boosting safety and effectiveness.

Navigation Aids

The effective operation of navigational aids is another crucial element that is essential to the safety and ease of navigation of fairways following a storm (ATONs). ATONs are usually found on water and aid boats and seamen in navigating the waters. Equipment like this includes day beacons, minor lights/beacons, and buoys with or without lights. Some of these ATONs may sustain damage during extreme weather conditions (Brock et al., 2013). However, such sophisticated technology can burden navigators more and jeopardise the safe operation. To give navigators alternate data for a safer operation, advanced IT-based navigation systems are also being developed. It is vital to investigate the current drawbacks of various types of navigation equipment and prospective remedies from the navigators' point of view because it cannot be assumed that all sensor arrays offer navigators pertinent knowledge (Kwon et al., 2016).
The navigational aids represent important support that guarantee the safety of shipments. This point is studied by previous research, where different navigational aids are investigated. The Automatic Identification System (AIS) was studied by Wilhoit et al. (2014) as a cyber-physical system (CPS) that is utilized by ship pilots and authorities as an observer and navigation aid to prevent ship crashes. Findings showed how to use AIS to connect all transmitters deployed on ships and other maritime structures, including lighthouses, buoys, AIS gateways, vessel traffic services, and aircraft used for search and rescue (SAR) missions.

Artificial intelligence was also studied by Soares et al. (2014), in which the main goal was to study the navigation and collision provenance of ship handling using artificial intelligence, the results revealed that the vessel model using navigation tools profitably prevented one ship from crashing, while the other did not. This result shows the importance of navigational aids in providing safety and preventing collisions.

Through the incorporation of information display, Hareide and Porathe (2019) sought to improve the navigator's situation awareness (SA). It was proved that to enable safe navigation, it might decrease the navigator's cognitive effort while he or she is necessitated to keep vigilant awareness of what is happening outside the window. But before Maritime Augmented Reality (M-AR) is operationalized, the Technology readiness level (TRL) must be raised, and additional analysis must be done before choosing the design and the data that should be displayed in AR. Accordingly, the vigilant awareness and technological readiness awareness represent two main factors that offer safety.

Dahlman et al. (2022) aimed to study an Advanced Intelligent Maneuvering that can be used as alert during traffic to avoid ships' crashes and the benefits of navigation overall. The findings proved that participants view the decision support system as a tool for advice in visualizing potential traffic scenarios, a task that is currently problematic for most navigators.

Ship Berthing

The procedure of berthing a ship is difficult due to the growth of large ships, in particular, VLCC, cargo ships, and large container boats. Berthing energy is produced when a ship and a port structure make contact, and berthing velocity is its primary component. Additionally, berthing is a procedure in which the distance and speed gradually drops to zero for the safety of the ship and the port, whereas the needed unberthing speed is lower once the ship has left the fender. As a result, port management, pilots, and captains now prioritize keeping berthing safe. The surrounding area of the vessel must be precisely calculated regarding the berthing speed and the distance of approach during berthing. To help safe the safety of the vessel and the port, it is crucial to research ship location and surveillance close to the coastline (Chen and Li, 2021).

Hsu (2015) identified many factors that provide safety to ship berthing at harbor piers, which are worker concentration, the state of fixed support, emergency reaction, harbor strategy of improving decision-making, and berth lengths. Nguyen and Im (2019) aimed to study how to maintain ship berthing by using technology and the outcomes demonstrated that using advanced technology makes the ship's berthing support system perform effectively. On the other hand, Kang and Park (2016) examined the conditions of the ships using the final spot for more hazardous products than they could adapt. The findings revealed that a ship with a maximum limit that was three times that of the maximum berth capacity was moored at the berth. This study put a focus on the importance of capacity.

Cho et al. (2020) estimated the danger threshold of a hazardous berthing speed when the ship approached the port using a machine learning algorithm. During testing utilising the receiving operator's normal curve, the most dangerous range of berthing speed had the biggest region beneath the curve, demonstrating that the threat spectrum was properly graded. It is therefore possible to securely berth a ship because the generated models can categorise and anticipate the risk range of unsafe berthing velocity before entering a port. This is a reference to these derived models' significance. Similar to this, Anning et al. (2021) assessed the risk of berthing dangerous cargo boats. According to the results, even though the problematic container ship threat has a considerably lower likelihood under normal conditions, it still cannot be ignored and needs to be handled because of its high relative risk. According to this study, environmental and human variables play the largest roles in hazardous shipping accidents.

Cho et al. (2022) found a correlation between the type of pilot and ship berthing, identifying three categories of pilots: cautious, efficient, and hazardous. A substantial difference between the cautious and dangerous kinds was also revealed by the analysis of variance.

3. RESEARCH METHODOLOGY

To fulfill the study's purpose and goals, the data collected has been the initial step. In this study, data were gathered from experts and decision-makers in maritime industry to determine ship navigation safety in order to generate a study on the factors that affected ship's safety by prioritizing these elements. It is crucial to focus on these factors to know what the safety system lacks from experts' and decision-makers' perspectives to relieve the ship's crashes. A number of 30 experts and decision-makers in maritime industry made the sample size. This sample strategy aims to equip representatives' sample to know their opinion in ship navigation safety, then analyzing and organizing these opinions from the highest important to the least important by converting them into a number by AHP method. The methods and resources used to collect research data are detailed in the data analysis section.

4. DATA ANALYSIS

This section shows the applied AHP analysis, where data are collected from 30 experts and decision makers to identify the service attribute of a port for ship navigation safety. The analysis is presented in the following sub-sections.

Selection of the Port's Service Attribute for Safer Way of Navigation

Five factors are analyzed to identify the best service attribute that the port must follow to reach a safer way of navigation. These factors are Vessel Traffic, Marine Pilot, Fairway Traffic, Navigation Aids and Ship Berthing. Each of these factors contains a number of codes, which are shown in Table I. The following factors and codes are used in the analysis.

Table I: Factors of Port's Service Attribute for Safer Way of Navigation

Construct	Service Attribute
Vessel Traffic	VT1: The effectiveness of VTC regulators in responding to vessel enquiries
	VT2: The ability of VTC to communicate in English
	VT3: The VTC regulator warns ships of the time and location of the pilot pickup
	VT4: The VTC provides information about weather, traffic, and geographical features of the port
Marine Pilot	MP1: The marine pilot indicates an appropriate location to embark
	MP2: The marine pilot has a professional piloting ability
	MP3: The ability of marine pilot to communicate English language
	MP4: The service attitudes of the marine pilot
Fairway Traffic	FT1: The fairway and anchorages are occupied by fishing boats.
	FT2: The management of vessel traffic in the fairways
	FT3: The procedures used by small boats to prevent collisions with inbound and outbound vessels
	FT4: The measures taken by the port administration to stop small boats from blocking fairways

Construct	Service Attribute
Navigation Aids	NA1: The layout of the anchorages and fairways
	NA2: The harbor's landmarks and lighthouses
	NA3: The lighted buoy used to indicate the difference between the inbound and outbound lanes
Ship Berthing	SB1: the quantity of tugboats needed to help berth and unberth the ships
	SB2: The horsepower of the tugboat helps vessels in berthing and departing
	SB3: The tugboat driver's qualifications to help vessels berth and leave
	SB4: The measures mooring boats take to help vessels berth and depart

Ranking the Preference of the Main Five Factors

The ranking is identified through making a pairwise comparison matrix, decision matrix and the weight of the five factors. The values of the factors constructed from the responses are shown in Table II.

Table II: Values of Main Factors

Dimen-sions	VT	MP	FT	NA	SB
VT	1.00	0.26	0.34	0.45	0.68
MP	3.84	1.00	0.99	1.69	2.39
FT	2.92	1.01	1.00	1.12	2.06
NA	2.22	0.59	0.89	1.00	1.52
SB	1.47	0.42	0.48	0.66	1.00
SUM	11.46	3.28	3.70	4.92	7.66

From Table II the criteria weight (CW) and weighted sum vector (WSV) are calculated, where they are used to calculate the consistency of the numbers that are checked by calculating the ʎmax Random Consistency value (RC), Consistency Index (CI), and Consistency Ratio (CR) as shown in Table III.

Table III: CW and WSV Values of the Main Five Factors

CW	WSV
0.55	2.73
1.98	9.72
1.62	8.29
1.25	6.31
0.80	4.04

ʎmax= (WSV1/CW1) + (WSV2/CW2) + (WSV3/CW3) + (WSV4/CW4) + (WSV5/CW5) / no. of criteria
= ((2.73/0.55) + (9.72/1.98) + (8.29/1.62) + (6.31/1.25) + (4.04/0.80)) /5 = 5.0155491
CI= (ʎmax – no. of criteria) / (no. of criteria – 1)
= (5.0155491-5)/4 = 0.0038773
CR= CI / Random Consistency Index
= 0.0038773/1.12 = 0.0034708

It is concluded that CR value is < 0.1. Thus, the values are acceptably consistent. After that the pairwise comparison of the five factors is done as shown in Table IV. From Table IV that indicates pairwise comparison, the decision matrix is obtained. MP is the first in ranking followed by FT. The third rank is NA, while the fourth is SB and the final rank is VT.

Table IV: A Pairwise Comparison Matrix for Main Five Factors

	GM	W
VT	0.49	8.81%
MP	1.73	31.25%
FT	1.47	26.59%
NA	1.12	20.31%
SB	0.72	13.04%
Sum	5.53	100.00%

Ranking the Preference of Vessel Traffic

The ranking is identified through making a pairwise comparison matrix, decision matrix and the weight of vessel traffic. The values of the factors constructed from the responses are shown in Table V.

Table V: Values of Vessel Traffic

Dimen-sions	VT1	VT2	VT3	VT4
VT1	1.00	0.32	0.39	0.79
VT2	3.14	1.00	1.20	2.61
VT3	2.58	0.83	1.00	2.07
VT4	1.27	0.38	0.48	1.00
SUM	8.00	2.54	3.07	6.47

From Table V the criteria weight (CW) and weighted sum vector (WSV) are calculated, where they are used to calculate the consistency of the numbers that are checked by calculating the ʎmax Random Consistency value (RC), Consistency Index (CI), and Consistency Ratio (CR). However, Table VI shows CW and WSV Values of Vessel Traffic.

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Table VI: CW and WSV Values of Vessel Traffic

CW	WSV
0.62	2.50
1.99	7.94
1.62	6.51
0.78	3.12

λmax= ((2.50/0.62) + (7.94/1.99) + (6.51/1.62) + (3.12/0.78)) /4 = 4.0004574
CI= (4.0004574 - 4)/3 = 0.0001525
CR= 0.0001525 / 0.9 = 0.0001694
It is concluded that CR value is < 0.1. Thus, the values are acceptably consistent.

After that the pairwise comparison is done as shown in Table VII. From the table of pairwise comparison, the decision matrix is obtained. VT2 is the first in ranking followed by VT3. The third rank is VT4, while the fourth is VT1.

Table VII: A Pairwise Comparison Matrix of Vessel Traffic

	GM	W
VT1	0.56	12.46%
VT2	1.77	39.55%
VT3	1.45	32.44%
VT4	0.70	15.55%
Sum	4.48	100.00%

Ranking the Preference of Marine Pilot

The ranking is identified through making a pairwise comparison, decision matrix and the Marine Pilot weight. The values of the factors constructed from the responses are shown in Table VIII.

Table VIII: Values of Marine Pilot

Dimensions	MP1	MP2	MP3	MP4
MP1	1.00	0.24	0.29	0.45
MP2	4.17	1.00	1.15	1.84
MP3	3.47	0.87	1.00	1.41
MP4	2.22	0.54	0.71	1.00
SUM	10.85	2.66	3.14	4.70

From Table VIII the criteria weight (CW) and weighted sum vector (WSV) are calculated and they are used to calculate the consistency of the numbers, as it is shown in Table IX.

Table IX: CW and WSV Values of Marine Pilot

CW	WSV
0.49	1.97
2.04	8.09
1.69	6.76
1.12	4.52

λmax= ((1.97/0.49) + (8.09/2.04) + (6.76/1.69) + (4.52/1.12)) /4 = 4.001986392
CI= (4.001986392 - 4)/3 = 0.0006621
CR= 0.000662131 / 0.9 = 0.0007357
It is concluded that CR value is < 0.1. Thus, the values are acceptably consistent. After that the pairwise comparison is done as shown in Table X. From the table of pairwise comparison, the decision matrix is obtained. MP2 is the first in ranking followed by MP3. The third rank is MP4, while the fourth is MP1.

Table X: A Pairwise Comparison Matrix of Marine Pilot

	GM	W
MP1	0.42	9.26%
MP2	1.72	37.90%
MP3	1.44	31.67%
MP4	0.96	21.18%
Sum	4.54	100.00%

Ranking the Preference of Fairway Traffic

The ranking is identified through making a pairwise comparison, decision matrix and the Fairway Traffic weight. The values of the factors constructed from the responses are shown in Table XI.

Table XI: Values of Fairway Traffic

Dimensions	FT1	FT2	FT3	FT4
FT1	1.00	0.40	0.48	0.87
FT2	2.50	1.00	1.24	2.23
FT3	2.07	0.81	1.00	1.59
FT4	1.16	0.45	0.63	1.00
SUM	6.73	2.66	3.35	5.69

From Table XI CW and WSV are calculated, where they are used to calculate the consistency of the numbers in Table XII.

Table XII: CW and WSV Values of Fairway Traffic

CW	WSV
0.69	2.75
1.74	6.96
1.37	5.48
0.81	3.25

λ_{max}= ((2.75/0.69) + (6.96/1.74) + (5.48/1.37) + (3.25/0.81)) /4 = 4.0039573
CI= (4.003957267 - 4)/3 = 0.001319089
CR= 0.001319089 / 0.9 = 0.001465655
It is concluded that CR value is < 0.1. Thus, the values are acceptably consistent. After that the pairwise comparison is done as shown in Table XIII. From the table of pairwise comparison, the decision matrix is obtained. FT2 is the first in ranking followed by FT3. The third rank is FT4, while the fourth is FT1.

Table XIII: A Pairwise Comparison Matrix of Fairway Traffic

	GM	W
FT1	0.64	14.91%
FT2	1.62	37.74%
FT3	1.28	29.74%
FT4	0.76	17.61%
Sum	4.29	100.00%

Ranking the Preference of Navigation Aids

The ranking is identified through making a pairwise comparison, decision matrix and the Navigation Aids' weight. Values of the factors constructed from the responses are shown in Table XIV.

Table XIV: Values of Navigation Aids

Dimen-sions	NA1	NA2	NA3
NA1	1.00	1.09	2.17
NA2	0.91	1.00	1.92
NA3	0.46	0.52	1.00
SUM	2.38	2.61	5.09

From Table XIV the criteria weight (CW) and weighted sum vector (WSV) are calculated and are used to calculate the consistency of the numbers which is obvious in Table XV.

Table XV: CW and WSV Values of Navigation Aids

CW	WSV
1.42	4.25
1.28	3.85
0.66	1.98

λ_{max}= ((4.25/1.42) + (3.85/1.28) + (1.98/0.66)) /3 = 3.0001415
CI= (3.0001415 - 3)/2 = 0.0000708
CR= 0.0000708 / 0.58 = 0.000122014
It is concluded that CR value is < 0.1. Thus, the values are acceptably consistent. After that the pairwise comparison is done as shown in Table XVI. From the table of pairwise comparison, the decision matrix is obtained. NA1 is the first in ranking followed by NA2, while the third is NA3.

Table XVI: A Pairwise Comparison Matrix of Navigation Aids

	GM	W
NA1	1.33	42.18%
NA2	1.21	38.17%
NA3	0.62	19.65%
Sum	3.16	100.00%

Ranking the Preference of Ship Berthing

The ranking is identified through making a pairwise matrix, decision matrix and the Ship Berthing's weight. The values of the factors constructed from the responses are shown in Table XVII.

Table XVII: Values of Ship Berthing

Dimen-sions	SB1	SB2	SB3	SB4
SB1	1.00	0.31	0.43	0.89
SB2	3.24	1.00	1.41	3.17
SB3	2.31	0.71	1.00	2.24
SB4	1.13	0.32	0.45	1.00
SUM	7.68	2.33	3.29	7.29

From Table XVII the criteria weight (CW) and weighted sum vector (WSV) are calculated, where they are used to calculate the consistency of the numbers as represented in Table XVIII.

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Table XVIII: CW and WSV Values of Ship Berthing

CW	WSV
0.66	2.65
2.20	8.83
1.56	6.26
0.72	2.86

λmax= ((2.65/0.66) + (8.83/2.20) + (6.26/1.56) + (2.86/0.72)) /4 = 4.0011487
CI= (4.001148686 - 4)/3 = 0.000382895
CR= 0.000382895 / 0.9 = 0.0004254
It is concluded that CR value is < 0.1. Thus, the values are acceptably consistent. After that the pairwise comparison is done as shown in Table XIX. From the table of pairwise comparison, the decision matrix is obtained. SB2 is the first in ranking followed by SB3. The third rank is SB4, while the fourth is SB1.

Table XIX: A Pairwise Comparison Matrix of Ship Berthing

	GM	W
SB1	0.59	12.88%
SB2	1.95	42.87%
SB3	1.38	30.38%
SB4	0.63	13.88%
Sum	4.55	100.00%

Ranking of Preferences Graphically

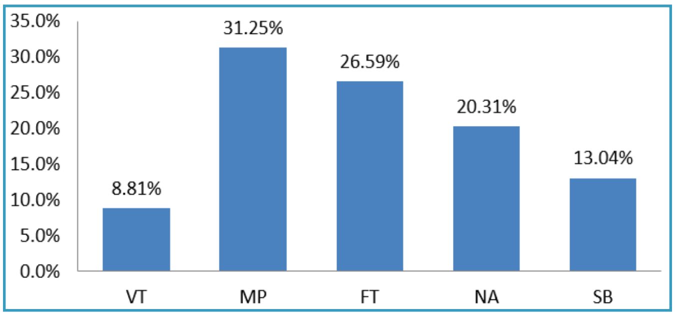

Fig. 1. Weight of the port's service attribute for ship navigation safety

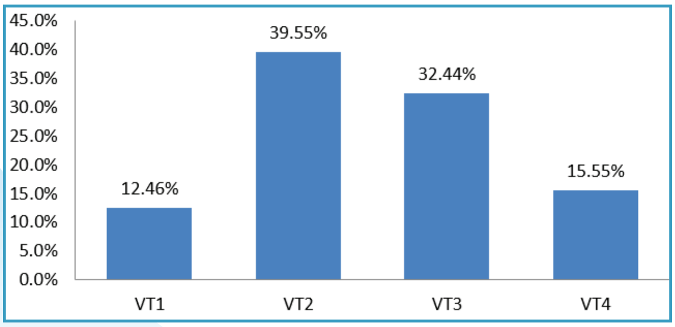

Fig. 2. Weight of Vessel Traffic

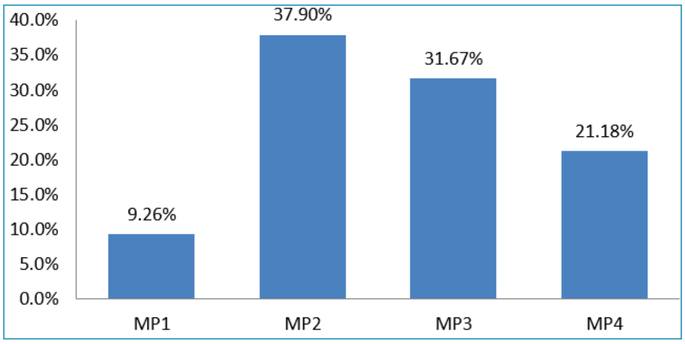

Fig. 3. Weight of Marine Pilot

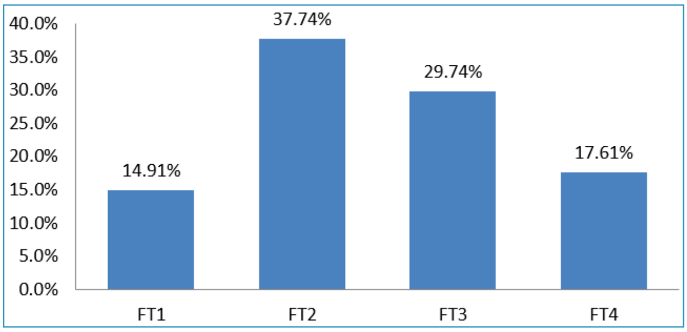

Fig. 4. Weight of Fairway Traffic

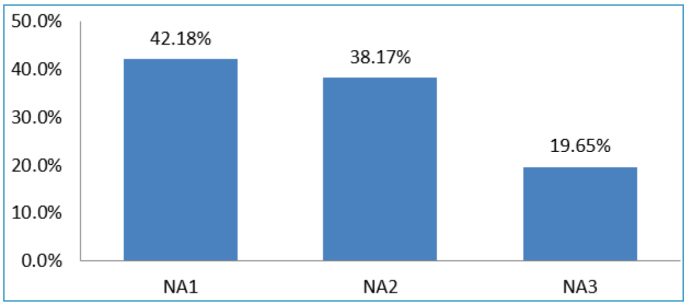

Fig. 5. Weight of Fairway Traffic

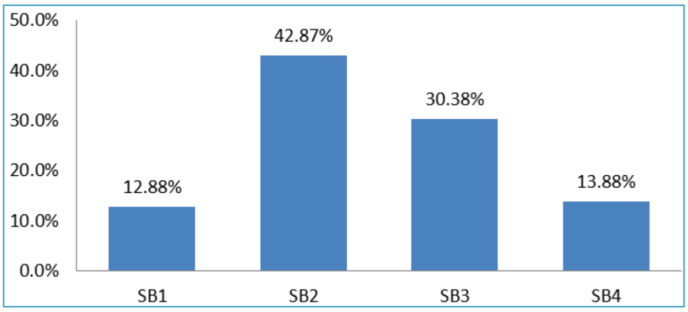

Fig. 6. Weight of Ship Berthing

DISCUSSION

The initial goal of the study is to prioritize the factors that affected ship's safety and relieve collisions by asking many experts and decision-makers to know the factors arranged from the highest to the least one. In this research there are 5 factors that affected ship's safety and asking whether these can be manipulated, will either reduce ship collisions or not. These elements were vessel traffic, marine pilot, fairway traffic, navigation aids and ship berthing, respectively.

By ranking the preferences of vessel traffic, vessel traffic is the first item affected ships' safety. Vessel container and supplemental navigation system did not deal well with measuring the distance to the port, gauging the speed and vessels' size, but for doing these measures one has to modify the vessel traffic service (VTS) to reduce the difficulty in the system and to be more simplified (Dahlman et al., 2015; Goh et al., 2019; Hoogendoorn et al., 2019; Qiu et al., 2020; Ye et al., 2019; Srše et al., 2021). These aforementioned studies were consistent with the researcher's view about maintaining vessel traffic, while there are some authors who showed that to maintain vessel traffic by vessel traffic service is to combine with other systems like the system for marine geographic or an ex-change data according to the situation as stated by Park and Bang (2016) and Jin et al. (2017)

Marine pilots came in the second level of preferences as no doubt the humans' element in every sector is important as man is the one who manages the system. In maritime industry, pilots are a very important element since if they make any mistake, this will threat the ship's safety. Marine pilots were attributed by many factors which were: simulation training as if the simulation training is simple and understandable it will be more effective; instructors' way in giving the training; how the instructor delivers the information and how the pilots can use the navigation system; also the relationship between the instructor and pilot; the mental and psychological interaction and how the pilots deal with the stress and load in work and how they are trained to maintain the stress in work during the simulation training. This in addition to behavior attributes by dealing with the risk level and trying to be safe from collisions by every possible means onboard the ship. Finally, technology training is the best way to enhance the pilots' level to professional ability to deal with every situation (Sellberg 2017; Orlandi and Brooks, 2018; Sellberg 2018; Kalulu 2018; Mateichuk et al., 2020; Fu et al., 2021) and these studies are consistent with the researcher's variables.

The third one is fairway traffic and how fairway is crucial in maritime industry. After the ship arriving at to the port, the most important step is how the ship will pass from the waterway until berthing. There are factors that impacted the fairway and caused ships' collisions which were: the width of the crossing waterway related to the ship's width, the relation between fairway size and safety level as the higher fairway level, the lower security level, the safety level between ship's structure and ships' route depends on whether the fairway is one-way or two-ways, and the schedule time for arriving and departure and how the port will manage it (Ai and Ding, 2014; Weng and Xue 2015; Zhou et al., 2015; Cho et al., 2020a; Cho et al., 2020b; Liu et al., 2022). These mentioned studies were consistent with the researcher's variables, while Hirdaris et al. (2020) and Park et al. (2022) showed that maintaining fairway should be by applying technology models as sensor to the ship and the control room to indicate that there is threat in a very simple way.

Navigation aids have some difficulties to help marine pilots in visualizing scenarios and in choosing the best one. The implementation of more lighthouses and buoys in the vessel traffic service, the calculation of the distance of port and vessel speed in each step from departure and berthing to the new port, and the sending of a simple notification with the problem were among these challenges (Wilhoit et al., 2014; Soares et al., 2014; Perera and Soares, 2017; Kwon et al., 2016; Dahlman et al., 2022). These mentioned studies were consistent with the researcher's variables.

The last preference is ship berthing. One of the critical elements in marine industry is how to maintain the berth and unberth to the ships. The berth was assigned by motions and maximum mooring line loads, the location of ship if it is close to yard or not, the speed of ships during berthing, and berth lengths are the primary safety variables influencing ship berthing at harbor piers, all these factors affected berthing and reducing safety level. (Hsu 2015; Kang and Park 2016; Nguyen and Im 2019; Cho et al., 2020a; Anning et al., 2021; Cho et al., 2022). These mentioned studies were consistent with the researcher's variables.

By reviewing all the variables that lead to maritime safety, the research's goals and purpose have been reviewed and the findings have been confirmed. Based on these results, conclusions have been reached. The recommendations made in the next section are based on the findings.

CONCLUSION

The current study concentrates on how to reduce ships' collisions by prioritize the factors that caused threat to maritime navigation safety. First, it might be helpful to think about how to reinforce the simulation maritime training to reduce risks and hazards. Future studies should focus more on improving simulation training rather than other factors including marine behaves and instructors' way with students, and the technology used to advance the education process to prepare professional pilots and relieve ships' collisions as much as one can for helping marine environment.

LIMITATIONS

The study focuses on a very limited number of experts and decision-makers, while the next research should focus on a bigger number and include in the survey pilots, software-engineers and workers as it will help in the analysis and knowing the threats from other perspectives and it will also be beneficial in the prioritization of the factors which lead to decrease the safety level.

By ranking vessel traffic as the first item that leads to ships' collisions, future studies should reinforce and confirm this study's conclusion. There is lack of research in how language enhance communication between the control room and pilots, especially the English language as it is the very common language worldwide. Also, in vessel traffic factors there is lack of research about how to advance technology to warn the ship if there is a threat. In the maritime pilots' element, the research that deals with service attitude and language is limited, while there are numerous studies that tackle the psychological behavior. In the same time, simulation training should cover service attitude also as the pilots have to be calm so as not to get into crashes. In addition, there are pilots from all over the world so we have to concentrate on which level of English they have and standardize an English accent for decreasing the misunderstanding between the control room and pilots.

In the aids to navigation (ATN), there is a gap in the research about the importance of the lighthouse, landmarks in port, and buoys to indicate the inbound and outbound lanes and how they decrease ships' crashes. The research concentrates on building more simple models to the pilots who neglect the signals and that can help and be cheap. There are also gaps in managing tugboats to help the big ships not to crowd in port. The third limitation is the qualification in general and the drivers' qualification specifically and how they will help in berthing and departing more precisely without collisions.

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