The Improvement Model of Navigational Safety for Inland Waterway Transport

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This paper aims at evaluating navigational safety for inland waterway transport (IWT). In doing so, the literature and operational features of IWT were initially reviewed to figure out risk elements (REs) influencing the navigational safety for IWT. After that, a fuzzy Analytic Hierarchical Process (AHP) approach was adopted to estimate the weight for the likelihood and consequence measures of REs. Then, continuous risk matrix (RM) was introduced to identify REs' risk level. Lastly, to test the proposed research model's applicability, IWT operators across Vietnam were empirically surveyed. The empirical findings could be useful for IWT operators in launching managerial policies to boost their navigational safety. Furthermore, the proposed risk evaluation framework may serve as a methodological reference in relevant literature.

KEY WORDS

~ Improvement model
~ Navigational safety
~ Inland waterway transport
~ Risk elements.

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doi: 10.7225/toms.v12.n01.003

Received: Jul 1, 2022 / Revised: Jan 30, 2023 / Accepted: Apr 18, 2023 / Published: Apr 20, 2023

1. INTRODUCTION

Inland waterway transport (IWT) is an essential component of integrated transportation systems in a number of nations. Inland waterway shipping has a large transport volume (Solomon et al., 2021) and low energy consumption (Ibrahim et al., 2022) when compared to other means of transport systems. As a result, it helps alleviate the dual constraints of resources and the environment, while boosting economic and social progress. As inland waterway transportation has grown in recent years, the increasing volume of freight and passenger transported has put more strain on the safety management of inland waterway transportation.

Unlike ocean liners, which are designed to operate long-distance international routes, IWT vessels, also known as traffic ships, often refer to types of multi-functional ships that may carry both passengers, vehicles, and freight for relatively short distances, especially in rivers (Bu & Nachtmann, 2021) and among inland islands (Caris et al., 2014). Moreover, IWT is sometimes regarded as a mass transit method for islands and coastal communities (Wiegmans & Konings, 2016, p.115). It is posited that the cost of IWT trips is much cheaper than the expense of building a bridge or a tunnel to convey people between two locations. However, a drawback of IWT is that it can be interrupted due to bad weather. According to Solomon et al. (2021), IWT's top priority is getting passengers and freight to their destinations as quickly as possible. As a result, in terms of ship design, the ship's tonnage is rather small in comparison to other means of sea-borne container transport. Additionally, sea-borne vessels have more stringent criteria for marine navigation facilities and amenities than IWT ones. As a rule, sea-borne vessels not only have a wide range of qualified crew members and lifesaving equipment, but they also have strict guidelines for preventing maritime mishaps and providing ongoing education for their crew members. IWT safety management, on the other hand, is far less comprehensive than that of sea-borne ships, with the exception of basic rescue and evacuation equipment. IWT operators may also overlook to follow standard operational procedures (SOPs) of safety navigation because of the short-distance traffic (Hekkenberg, 2015). Even though governments have implemented more stringent restrictions to improve the safety navigation of IWT, many accidents that result in death have recently become more common.

Waterway safety is affected by a wide range of issues, which makes it difficult to trust on the dependability and efficiency of inland waterway shipping. Collisions between ships, which can result in fatalities (Nam & Win, 2014), economic losses (Mia et al., 2021), and environmental contamination (Sys et al., 2020) are among the most prevalent waterway transportation mishaps. For instance, there was a collision between two cruise ships in Budapest's Danube River on May 29, 2019, in which the "Hableany," a tiny tourist ship, collided with "Viking Sigyn" (Hungary). In April 2021, a serious incident happened in Bangladesh when an overcrowded ferry crashed into a cargo ship head-on, killing a total of 34 people. Also, the number of waterway accidents that have been reported makes people worry about how navigational safety is managed for ferry transportation. For example, at least 110 domestic ferry mishaps were reported in South Korea between 2015 and 2019, despite the government's efforts to prevent waterborne disasters. Vietnam Inland Waterways Administration (VIWA) officially reported that 679 navigational accidents in terms of IWT happened between 2014 and 2020 by some main causes, for example, leaking and foundering (12.41 %), human negligence (45.58 %), ship equipment, and working condition, (22.03 %), fire and explosion (3.89 %), ship collision and grounding (31.3 %).

In addition, numerous countries are currently seeing an increase in the percentage of navigational mishaps. It is witnessed that 37.5 % of accidents involving IWT, including ferry vessels, occurred in low-income nations (i.e., Bangladesh, Ghana, and Myanmar) between 2007 and 2019 (Mia et al., 2021; Nam & Win, 2014; Solomon et al., 2021). Besides, the development of waterborne traffic, the growth of the aquaculture industry in rivers (Kulkarni et al., 2020), and the construction of civilian houses along river banks (Platz & Klatt, 2016, p.103-113) all seem to be giving rise to the danger of IWT accidents. A single mishap involving IWT is argued to result in mass deaths and property damage because IWT ships normally carry a large number of people and cargo onboard. The majority of relevant studies have solely looked at identifying seaborne ship navigational safety factors. In comparison, factors impacting safety navigation for IWT have rarely been examined in more depth in major articles. As a practical matter, different risk levels of safety elements necessitate varied safety management systems for ship navigation.

In addition, evaluating navigational safety for IWT can be seen as the problem of multiple-criteria decision analysis (MCDA). In practice, to solve the numerous MCDA problems, among the many popular approaches to MCDM problem-solving, Analytic Hierarchy Process (AHP) developed by Saaty (1980) has become popular because of its simple and straightforward mathematical operations. However, the primary shortcoming of AHP applications in assessing navigational safety for transport systems is the basis of the crisp number. According to Nguyen et al. (2022), human judgements are often subjective, vague, and uncertain; as a result, judged results can be biased and unreliable in some empirical cases. To overcome this challenge, the theory of fuzzy mathematics is a good way to solve this kind of problem in an uncertain environment. It is safe to argue that combining fuzzy mathematics and AHP is really necessary to assess navigational safety for transport systems. Hsu et al. (2021) also argued that the fuzzy AHP method is mostly used for multi-attribute analysis and structured hierarchy decision making; thus, it is better than the traditional AHP method at getting priority weight vectors for multi-attribute decision making. Besides, fuzzy AHP is an enhanced method based on conventional AHP that makes use of fuzzy numbers to ascertain doubts in translating individual preferences into a numerical value over a range of selection criteria (Hsu et al., 2022).

In an effort to fill the above-mentioned research gap, this article analyses navigational safety for IWT. To do so, risk elements (REs) affecting navigational safety for IWT are first examined in this study. Next, a fuzzy AHP approach is utilised to weight the likelihood and consequence for REs, whose results are used for the construction of the continuous risk matrix to rank REs' risk levels. As a final step, IWT operators in Vietnam (the Vietnam-IWT case) are empirically surveyed to validate the proposed research model.

The remainder of the article is structured as follows: Section 2 presents an overview of IWT in Vietnam, and reviews REs for navigational safety in inland waterway transport; Section 3 presents research methodology used in this study; Section 4 discusses the main research findings. Finally, some conclusions, limitations, and suggestions for further research are presented in Section 5.

2. LITERATURE REVIEW

2.1. The Overview of the IWT in Vietnam

It is argued that IWT plays a crucial role in the transport of cargoes and passengers in Vietnam. According to the 2021 official report from VIWA, IWT accounts for around 18.2 % of the overall domestic cargo volume in Vietnam. Besides, there are an estimated 212.5 million tons of material transported by IWT each year with the average distance of approximately 212 kilometers. By comparison, road transportation makes up 76.97 % of overall transport volume, but with short distances of about 60 km. Meanwhile, coastal shipping transports a lower volume (roughly 6.03 %) over a significantly greater distance (almost 2,000 km on average). By contrast, freight transport by rail constitutes only 0.5 % of total transport volume, with a transport distance of around 620 km.

There are now more than 169,100 inland watercraft in Vietnam, with an increasing number of larger, specialised vessels. However, the vast majority of vessels, particularly dry bulk carriers, are medium-sized, with a tonnage ranging from 7 to 31 DWT. Many inland ports and wharves are located across the country's interior to serve IWT ships, but they are plagued by poor infrastructure and outdated equipment, making it difficult for ships to dock. With a total of 8,098 inland ports and wharves, 5,102 of them are located in the national waterway network as of the beginning of 2019. More specifically, VIWA licensed 4,134 inland ports and wharves, while 1,026 are unlicensed.

2.2. The Risk Elements of Navigational Safety

Vassalos and Konovessis (2008) divided safety assessment requirements for ferry Ro-Ro (Safer EURORO) navigation into four categories: humanware, hardware, software, and environment, as shown in Figure 1. Much navigation-related research has been done using that paradigm (Arof & Nair, 2017; Jovanović et al., 2022; Zis & Psaraftis, 2017). It is demonstrated that REs for waterway transportation may encompass many issues, such as the organisation (Arof & Nair, 2017), the working environment (Bu & Nachtmann, 2021), human errors (Caris et al., 2014), machinery failure (Yuan et al., 2021), bad weather and climate (Chang et al., 2015). In particular, human mistakes and the machinery failure frequently result in disastrous consequence for IWT. Therefore, IWT operators and researchers should pay special attention to how to deal with potential risks to ensure navigational safety.

In terms of waterway navigational safety, this article heavily depends on previous research and International Maritime Organisation (IMO) standards. With regard to the navigational safety, there are five key dimensions for evaluating the navigational safety for IWT, including safety equipment, crew

Figure 1.
Dimensions for navigational safety.

members' ability, safety instruction, ship structure, and ship documentation, which are in agreement with the Safer EURORO Report framework.

2.2.1. Safety Equipment

Unsafe conditions include a lack of adequate fire protection and instability in a vessel. A study by Akyuz (2017) indicated that fire, collision, and grounding are major criteria in the evaluation of cruise ship safety. Fan et al. (2019) used a systematic safety assessment method to examine containerships and fishing vessels. In offshore installations, this paper has identified fires and explosions to be substantial hazards that could result in catastrophic results. Bye and Almklov (2019) pointed out that fire-fighting protocols are a critical requirement for ship navigation. They also stressed that fatal accidents can be avoided if proper fire and explosion procedures are followed and emergency response standards and equipment are used. Accordingly, passenger ship operations necessitate the use of fire extinguishing equipment.

Besides, rescue equipment is argued to be one of the most critical factors for ship navigation. For instance, when the Titanic sank back in 1912, a lack of rescue equipment became a major problem for the death of 1,517 passengers onboard. The International Convention for the Safety of Life at Sea (SOLAS) mandates that all life-saving equipment must be operational before a vessel departs the terminal and during the trip (Hathaway et al., 2020). It is suggested that IWT operators provide enough life rafts and personal flotation devices (i.e. lifejackets) for passengers in the event of a shipwreck to ensure that passengers can be rescued. This is why Wang et al. (2019) advised that the examination of life-saving devices should be used in evaluating the safety for passenger transport service.

2.2.2. Crew Members' Ability

It is posited that both awareness and personal experience play a role in waterborne transportation safety and security. Over 80 % of cargo transportation accidents are caused by human factors (Ozturk & Cicek, 2019). Human error is also shown to be the main cause of 78.5 % of European maritime disasters between 1990 and 2016 (Abbassi et al., 2017). In East Asia, it has been proved that human error is the root cause of about 79.7 % of towing vessel groundings (Ung, 2021), nearly 27.9 % of fire and explosion incidents (Kim & Moon, 2018), and roughly 32.6 % of fire/explosion onboard (Chen et al., 2015). Internal and external errors of the crew's operation might be categorised. Psychological and/or physical health issues may be blamed for an employee's mistakes within an organisation, for instance, anxiety disorders (Baldauf & Hong, 2016), and depression (Graziano et al., 2016). An alternative explanation for external human error is a poor working environment (i.e., filthy workplace, excessive noise) and the surrounding natural environment, which can lead crew members to lose focus on their tasks. Misjudgment and misunderstanding, inadequate technical expertise, the lack of knowledge about the ship's own system, exhaustion, poor rescue communication, and a lack of safety awareness on survival procedures are all examples of crew members' onboard blunders that impair navigational safety. A crew member's capacity to respond effectively to shipping mishaps is argued to limit the loss of property and human life (Uğurlu et al., 2015). It is safe to say that passenger boat operations can be greatly improved by increasing safety behaviour, including compliance and involvement (Ung, 2018), which has been shown to have a significant impact on accident reduction. To conclude, navigational safety assessments must take the importance of the crew into account.

2.2.3. Safety Instruction

Hystad et al. (2016) illustrated that passengers' knowledge of their own safety and the safety of others could both be improved through safety education. After passengers have checked in, onboard workers should provide them with safety instructions and a life jacket exercise before the ship sets sail. Passenger ship evacuations are also extremely complicated since they include a huge number of people on a complex moving platform. When a ship is involved in a collision, sinks, or has a fire, passengers typically have very little information and very little time to respond. Therefore, Trincas et al. (2017) postulated that passenger safety education might enhance the likelihood of their survival in an emergency. A study by Wang et al. (2021) found that passengers who were educated about evacuations may be more likely to respond in the event of an watercraft crash. In summary, navigation safety assessments should include safety instruction, including providing a proof of rescue devices and equipment, and demonstrating emergency exits.

2.2.4. Ship Structure

There are several reasons why a ship's construction can go wrong, and this can result in both the loss of vessels and their cargoes and passengers. Many prior research have examined some criteria for safety assessment of container vessels, for example, the general engineering and mechanical system (Nikcevic Grdinic, 2015), the overall personnel evaluation system (Iperen, 2015), the composite operational process (Chang et al., 2015), and the management system for superstructure and infrastructure (Graziano et al., 2017), and the overall operational environment (Hiremath et al., 2016). Such criteria may be outlined as: (1) the main structure of a ship, (2) strength and stability, (3) cargo-related issues, (4) ballast operations, (4) maneuverability, (5) navigational equipment, (6) forecastle and foredeck, (7) power and propulsion. Furthermore, relevant literature has assessed the accident-prevention ability of a ship based on its structural safety and reliability, fuel leakage capacity, and energy absorption. They reached a consensus on energy dissipation (Mohammed et al., 2016), fuel leakage quantity (Sys et al., 2020), and the residual strength of hull girder (Yuan et al., 2021) being crucial evaluation parameters. In order to avoid crashes when fishing, Vettor et al. (2016, p.73-80) investigated the design of vessels and the use of light-based safety features. In conclusion, the structure of a ship should be considered while evaluating the navigation safety for IWT services.

2.2.5. Ship Documentation

Uğurlu et al. (2015) and Iperen (2015) agreed that an important component in increasing the safety of ships' operations is the use of standard operating procedures (SOPs) and IMO regulations. Meanwhile, Heikkilä et al. (2017) advised that all necessary documents and database pertinent to the safety management system should be controlled according to the International Safety Management (ISM) Code, which is followed by shipping companies worldwide. There should be protocols in place to guarantee that all relevant locations have access to valid documents, and that any modifications to documents are reviewed and approved by the appropriate persons (Heikkilä et al., 2017). All required documents for a given ship must be retained on board (Graziano et al., 2017), stored in a format that the shipping corporation deems most efficient (Hiremath et al., 2016). On top of that, the vessel's certificate, operating guidelines and instructions, the list of crew members, the qualification certificate of crews, and repair and maintenance record should all be included in the ship documentation. It is concluded that the navigation safety assessment should involve the careful examination of these papers.

2.3. Risk Matrix

An increasing amount of attention is being paid to ship safety by governments and international organisations alike. Thus, the International Maritime Organization (IMO) has been addressing these issues head-on for decades. Accordingly, the framework of Formal Safety Assessment (FSA) is introduced to improve waterborne navigational safety, including the protection of life, health, the water environment, and property (Seeing Figure 2). Theoretically speaking, there are five key stages to a formal safety assessment: (1) identification of hazards, (2) assessment of risks, (3) risk control options, (4) cost benefit assessment, and (5) recommendations for decision-making.

Following the FSA framework, the concept of a risk matrix (RM) has been used since 1998 to assess the risk level for REs (Garvey & Lansdowne, 1998, p.78-89). Since then, RM has been recognised as one of the most often used qualitative risk evaluation methodologies due to its simple implementation. This quasi-qualitative tool has been termed by several academics as the risk matrix (Blokus & Dziula, 2019; Hasanspahić et al., 2018; Yoon & Kim, 2022). However, when the likelihood and the severity of its consequences are qualitatively portrayed, RM becomes a qualitative approach of risk evaluation and prevention. For instance, Figure 3 expresses a traditional RM with the probability of failure on the vertical axis and its severity on the horizontal axis. Here, we can easily visualise qualitative outcomes when they are distinguished by distinct hues. There are, however, many primary disadvantages in terms of RM. The panel is transformed into a discrete risk matrix as a result of the discontinuity degrees of both probability and severity.

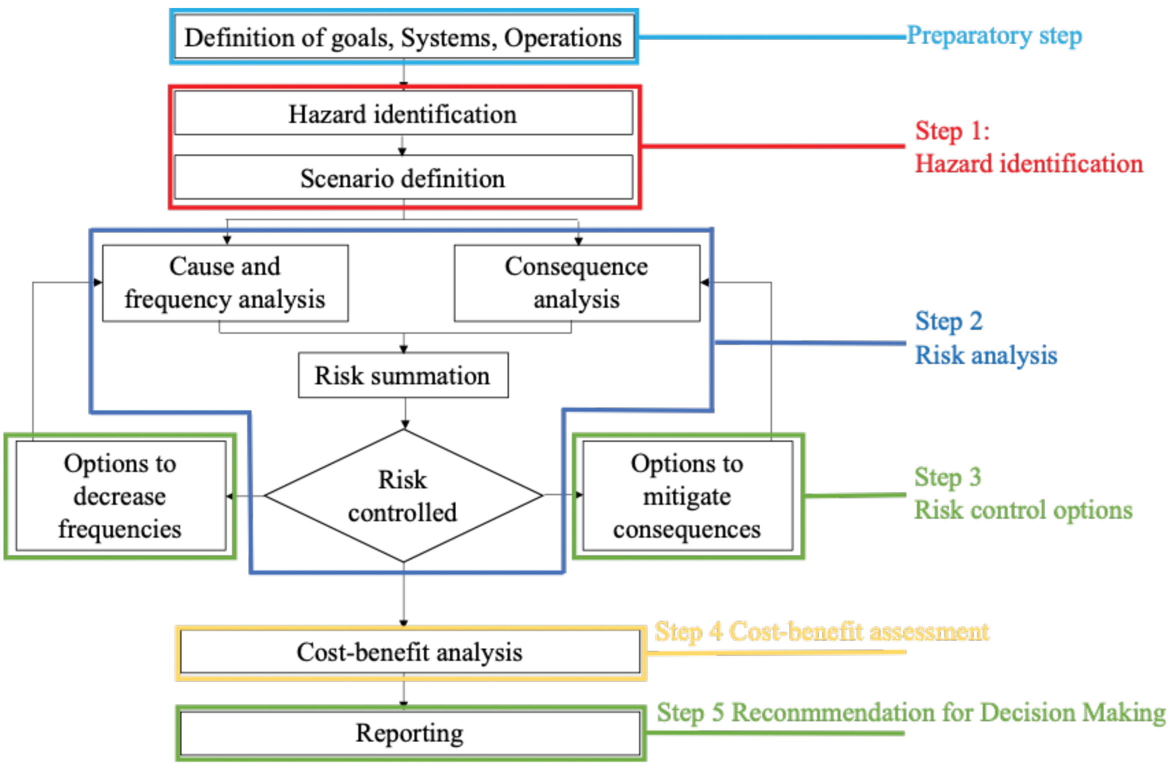

Figure 2.
The Formal Safety Assesment (FSA) procedure.

Severity of consequences

Probability of failures		Negligible	Minor	Morderate	Severe
	Highly frequent	Low	Medium	Medium High	High
	Moderately frequent	Low	Low Medium	Medium	High
	Less frequent	Low	Low Medium	Medium	Medium High
	Rarely frequent	Low	Low	Low Medium	Medium

Figure 3.
The traditional risk matrix.

To improve the drawbacks of the traditional RM, which may limit its usefulness in terms of accuracy, the continuous RM is suggested by Duijm (2015), as displayed in Figure 4. The continuous RM also has the advantage of improving resolution, making it feasible to distinguish between risks that would be assigned to the same cell in a RM.

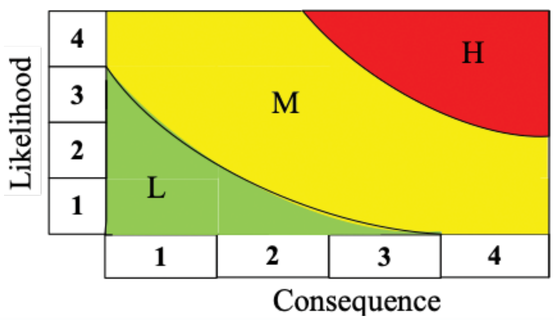

Figure 4.
The continuous risk matrix.

3. RESEARCH METHOD

3.1. The Hierarchical Structure of Risk Elements

This article uses the fuzzy AHP approach to estimate the likelihood and consequences of REs for IWT. Accordingly, the first thing has been to establish the hierarchical structure of REs. Based on the literature review and operational features of IWT, the initial hierarchical structure of REs included five dimensions and twenty-three criteria. To ensure the validity and verification of such an initial hierarchical structure, seven crew members from four major IWT operators of Vietnam (i.e., SOWATCO, PVT, VTO, and SOTRANS) were asked to revise the REs to make sure they are understandable. Consequently, after four rounds of modification, the hierarchical two-layer structure of REs, including five dimensions with twenty REs, have been completed for further analysis, as seen in Table 1.

Table 1.
The hierarchical structure of risk elements.

Layer 1: Dimensions	Code	Layer 2: Risk elements	References
Equipment-related issues (SE)	SE1	Inadequate maintenance	Uğurlu et al. (2015), Hasanspahić et al. (2018), Iperen (2015)
	SE2	Mechanical equipment failure	Xue et al. (2021), Fan et al. (2019), Ozturk and Cicek (2019), Yuan et al. (2021)
	SE3	Equipment not operational	Nikcevic Grdinic (2015), (Akyuz, 2017)
	SE4	Inadequate removal and replacement of unsuitable tools/equipment	Ung (2021), Bye and Almklov (2019)
Crew member's ability (CA)	CA1	Physical/physiological capacity-stress	Graziano et al. (2016), Ung (2018), Abbassi et al. (2017)
	CA2	Lack of emergency training program	Kum and Sahin (2015), Hystad et al. (2016)
	CA3	Crew's negligence on duty	Blokus and Dziula (2019), Heikkilä et al. (2017)
	CA4	Lack of self-discipline for work	Wang et al. (2019), Mia et al. (2021)
System related issues (SI)	SI1	Inadequate procedures	Fan et al. (2019), Ozturk and Cicek (2019)
	SI2	Providing inadequate reference documents, directives and guidance publications	Yuan et al. (2021), Akyuz (2017)
	SI3	Absence of process to record and analyze accidents	Cui (2019), Wang et al. (2021)
	SI4	Misapplication of regulations, policies, standards	Blokus and Dziula (2019), Kum and Sahin (2015)
Ship structure (SS)	SS1	Ship design inadequate	Kececi and Arslan (2017), Kurt et al. (2015)
	SS2	Inadequate assessment of operational readiness	Puisa et al. (2018), Kim and Moon (2018)
	SS3	Construction material select defect	Yuan et al. (2021), Kececi and Arslan (2017), Akyuz (2017)
	SS4	Lack of Environmental sanitation	Cui (2019), Graziano et al. (2016), Wang et al. (2021)
Ship documentation inspection (SD)	SD1	Certification fraud	Nikcevic Grdinic (2015), Ozturk and Cicek (2019), Akyuz (2017)
	SD2	Inadequate inspection	Ung (2021), Kurt et al. (2015), Bye and Almklov (2019)
	SD3	Lack of navigation record	Ozturk and Cicek (2019), Ung (2021), Yuan et al. (2021)
	SD4	Inadequate warning system	Nikcevic Grdinic (2015), Hystad et al. (2016), Akyuz (2017)

3.2. Sample Size, Questionnaire Design, and Data Collection

The goal of this research is to assess safety navigation for IWT in Vietnam. Thereby the respondents must be working in the IWT industry at the time of surveying. As of 2021, according to Vietnam Inland Waterways Administration (VIWA), approximately eighty-one enterprises were doing business in the IWT industry across Vietnam. Among them, we have selected twenty-five target companies for data collection, whose shares had been listed in the stock exchanges, viz., HoSE, HNX, OTC, UPCoM. Then we asked each enterprise to provide two-four experts to answer the survey questions. Finally, we had a list of seventy-three respondents who were willing to survey. Note that due to the professional nature of the questions in the questionnaire, all of the participants being surveyed were required to have adequate professional expertise in shipping navigation.

To adopt the fuzzy AHP for data analysis, a nine-point expert questionnaire was designed to measure the weight for likelihood and consequence of five dimension and twenty REs. After that, seventy-three questionnaires were delivered to the equal number of experts experts from January 2022 to May 2022. However, only fifty-seven questionnaires were returned at the end of May 2022. In total, we had 114 samples because each expert was asked to respond both their perceived consequences and the likelihood on REs. Keeping in mind each expert's judgment, we have established twelve individual pairwise comparison matrixes (IPCMs), which were then tested for consistency by and , where CI and CR represent the consistent index and consistent ratio, respectively. While is the biggest eigenvalue of IPCM, n is the number of criteria in IPCMs. In the meantime, RI stands for random indexes, whose estimated values are shown in Table 2. It is suggested that the will be a valid range (Saaty, 2001, p.65-77).

Table 2.
Random index.

n	3	4	5	6	7	8	9	10	11	12
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535

In this article, we have adopted the package 'rARPACK' in RStudio to estimate for IPCMs. Then CI and CR values have been computed by two above formulas. Results have pointed out that fourteen responses did not satisfy the consistency test; therefore the corresponding questionnaires have been removed. At last, only forty-three questionnaires have been used for official analysis. The respondents' background is also shown in Table 3.

Table 3.
Respondents profile.

Features	Range	Frequency	%
Age level	<30	2	4.65
	30~40	3	6.98
	41~50	5	11.63
	51~60	9	20.93
	>61	24	55.81
Educational level	Undergraduate	27	62.79
	Postgraduate	16	37.21
Seniority (years)	5~10	3	6.98
	11~15	9	20.93
	16-20	13	30.23
	>20	18	41.86

Number of employees	<40	4	9.30
	20~80	7	16.28
	61~120	18	41.86
	120~160	5	11.63
	>160	9	20.93
Job title	Captain	11	25.58
	Senior engineering officer	6	13.95
	Chief officier	5	11.63
	Chief engine	7	16.28
	Main mechanic	5	11.63
	Deputy sailor	9	20.93
Gender	Male	37	86.05
	Female	6	13.95
Total		43	100.00

3.3. The Weights of the REs

As has been already mentioned, for the Vietnam IWT case, each response resulted in six IPCMs for the likelihood measure and six IPCMs for the consequence one. The fuzzy AHP technique was then utilised to compute the weight for the consequence and the likelihood of REs in order to reflect the linguistic fuzziness and vagueness of respondents as they were filling in the questionnaire. To explain how to use the fuzzy AHP, this paper takes the SE dimension with likelihood measures as a typical example. As seen in Table 1, the SE dimension includes four REs, viz., SE1, SE 2, SE 3, and SE 4. The application of fuzzy AHP goes through four key steps, as follows:

Step 1: The combination of respondents' multi-judgements.

Call $L = (1,2,...,l,...,43)$ be the number of respondents taking part in the survey. As such, each respondent's evaluation will form one IPCM, donoted as $X = [x_{ij}]_{n \cdot n}$.

Sypolically:

$$X = \begin{cases} x_{ij} & , \text{if } i > j \\ 1 & , \text{if } i = j \\ 1/x_{ij} & , \text{if } i < j \end{cases} \qquad (1)$$

For the case of the SE dimension, there are forty-three IPCMs in total. Then a fuzzy pairwise comparison matrix (FPCM) is formed by using the formula:

$$X_{ij} = [l_{ij}, m_{ij}, u_{ij}] = [\min_{1 \le l \le 43} \{X^{(l)}_{ij}\}, (\prod_{l=1}^{43} X^{(l)}_{ij})^{1/43}, \max_{1 \le l \le 43} \{X^{(l)}_{ij}\}] \qquad (2)$$

For the SE dimension, by means of Equation (1), forty-three IPCMs are combined into the FPCM (X_1).

$$X_1 = \begin{bmatrix} (1.00,1.00,1.00) & (0.25,1.77,5.00) & (0.27,2.78,3.00) & (0.20,3.94,4.00) \\ (0.20,0.56,4.08) & (1.00,1.00,1.00) & (0.85,2.14,5.00) & (0.81,4.52,7.00) \\ (0.33,0.36,3.69) & (0.20,0.47,1.17) & (1.00,1.00,1.00) & (0.10,2.65,4.00) \\ (0.25,0.25,5.04) & (0.14,0.22,1.24) & (0.25,0.38,10.43) & (1.00,1.00,1.00) \end{bmatrix} \qquad (3)$$

Step 2: A consistent test for FPCMs

This paper has tested the consistency for FPCMs using the formula developed by Wang and Lin (2017). Let $X = x_{ij} = (x^L_{ij}, x^M_{ij}, x^U_{ij})_{n \cdot n}$ be FPCM, then its geometric consistency index (GCI), defined as:

$$GCI(X) = \max\left\{ \frac{2}{(n-1)(n-2)} \sum_{i<j} (\log x^M_{ij} - \frac{1}{n}\sum_{k=1}^{n} \log x^M_{ik} + \log x^M_{kj})^2; \right.$$

$$\frac{2}{(n-1)(n-2)} \sum_{i<j} [\log x^L_{ij} + \log x^U_{ij} - \frac{1}{n} \sum_{k=1}^{n} \qquad (4)$$

$$\left. (\log x^L_{ik} + \log x^U_{ik} + \log x^L_{kj} + \log x^U_{kj})]^2 \right\}$$

The value for the GCI threshold depends on the number of criteria in FPCMs, particularly as shown below:

$$GCI = \begin{cases} 0.3147 & , \text{if } n = 3 \\ 0.3562 & , \text{if } n = 4 \\ 0.3700 & , \text{if } n > 5 \end{cases} \quad (5)$$

Turn to the SE dimension, by equation (2), we have: GCI (X_1) = max { 0.2737; 0.1374 } = 0.2737. Obviously, GCI (X_1) < 0.3562 implies the consistency of the fuzzy matrix X_1. The remaining FPCMs can be estimated in the same way. The results for the consistent test are shown in Table 4.

Table 4.
Consistent test for fuzzy matrixes.

	Layer	GCI	Thresholds
Likelihood	Layer 1	0.3195	0.3562
	Layer2: SE	0.2737	0.3562
	Layer2: CA	0.2184	0.3562
	Layer2: SE	0.2908	0.3562
	Layer2: SS	0.1911	0.3562
	Layer2: SD	0.1442	0.3562
Consequence	Layer 1	0.1831	0.3562
	Layer2: SE	0.2632	0.3562
	Layer2: CA	0.3404	0.3562
	Layer2: SE	0.1330	0.3562
	Layer2: SS	0.1026	0.3562
	Layer2: SD	0.2671	0.3562

Step 3: The computation of the REs' local priority weights

Because FPCMs are positively reciprocal, this paper uses the simplified method (NGMR) to find the priority vector for FPCMs.

For the R_i (i = 1, 2,..., n) in the matrix X, its geometric means t_i is defined by:

$$t_i = (\prod_{j=1}^{n} x_{ij})^{1/n} = [(\prod_{j=1}^{n} x^l_{ij})^{1/n}, (\prod_{j=1}^{n} x^m_{ij})^{1/n}, (\prod_{j=1}^{n} x^u_{ij})^{1/n}], i=1,2,...n \quad (6)$$

$$\sum_{i=1}^{n}(t_i) = [\sum_{i=1}^{n}(\prod_{j=1}^{n} x^l_{ij})^{1/n}, \sum_{i=1}^{n}(\prod_{j=1}^{n} x^m_{ij})^{1/n}, \sum_{i=1}^{n}(\prod_{j=1}^{n} x^u_{ij})^{1/n}] \quad (7)$$

Then, the fuzzy weight $w_i = (w^l_i , w^m_i , w^u_i)$ for R_i (i = 1, 2,..., n) is obtained by:

$$w_i = t_i / \sum_{i=1}^{n} t_i \left[\frac{(\prod_{j=1}^{n} x^l_{ij})^{1/n}}{\sum_{i=1}^{n}(\prod_{j=1}^{n} x^m_{ij})^{1/n}}, \frac{(\prod_{j=1}^{n} x^m_{ij})^{1/n}}{\sum_{i=1}^{n}(\prod_{j=1}^{n} x^m_{ij})^{1/n}}, \frac{(\prod_{j=1}^{n} x^u_{ij})^{1/n}}{\sum_{i=1}^{n}(\prod_{j=1}^{n} x^l_{ij})^{1/n}} \right], i=1,2,...,n \quad (8)$$

In this step, the Buckley's index (1981) is adopted to convert w_i (i = 1, 2,..., n) into the crisp matrix, as follows:

$$w_i = \sqrt[4]{w^l_i \cdot (w^l_i)^2 \cdot w^u_i}, i = 1,2,...,n \quad (9)$$

Finally, through the normalisation process, the crisp local weight (v_i) for RE_i is obtained:

$$v_i = \frac{w_i}{\sum_{i=1}^{n} w_i} ; i = 1,2,...,n \quad (10)$$

Returning to the matrix x_i, and following the Equations (3) to (7), the local weight for the SE dimension is attained as: v = (0.3319, 0.3462, 0.1831, 0.1388). Local weights for Res, in terms of likelihood and consequence measures, have been estimated in the same way and shown in Table 5.

Step 4: The computation of the REs' global priority weights

The REs' global weights are computed by timing REs' local weights by their corresponding dimensions' global weights. Consequently, for Vietnam-IWT case, the REs' global weights for likelihood and consequence measures are displayed in the two last column of Table 5, respectively.

Table 5.
Likelihood and consequence weight for risk elements.

Layer 1: Constructs	The global weights of Layer 1 (%)		Layer 2: Res	The local weights of Layer 2 (%)		The global weights of Layer 2 (%)	
	Likelihood	Consequence		Likelihood	Consequence	Likelihood	Consequence
SE	27.95	21.53	SE1	33.19	18.57	9.46	4.00
			SE2	34.62	32.88	9.70	7.08
			SE3	18.31	30.08	5.04	6.48
			SE4	13.88	18.46	3.75	3.98
CA	24.07	22.19	CA1	21.38	15.44	5.15	3.43
			CA2	26.07	19.47	6.27	4.32
			CA3	16.00	28.98	3.85	6.43
			CA4	36.55	36.12	8.80	8.02
SI	27.30	23.04	SI1	29.45	38.56	8.04	8.88
			SI2	19.29	14.50	5.26	3.34
			SI3	25.03	29.43	6.83	6.78
			SI4	26.23	17.50	7.16	4.03
SS	12.85	17.09	SS1	18.96	33.20	2.44	5.67
			SS2	28.95	23.68	3.72	4.05
			SS3	13.20	14.60	1.70	2.49
			SS4	38.89	28.53	5.00	4.88
SD	7.84	16.15	SD1	21.06	29.22	1.65	4.72
			SD2	16.34	34.96	1.28	5.64
			SD3	29.74	15.86	2.33	2.56
			SD4	32.86	19.97	2.58	3.22

3.4. The Continuous Risk-matrix

is based on the likelihood and consequence of REs, as calculated in the previous section. To classify the risk level for REs, this paper uses the risk value (RV), which can be estimated by Formula (11):

$$RV_i = \frac{a_i \cdot b_i}{\sum_{i=1}^{n} (a_i \cdot b_i)} \cdot 100\%, i = 1,2,...,n \quad (11)$$

In which, a_i and b_i are the likelihood and consequence of RE_i, respectively.

By virtue of Equation (8), the risk value for REs is found and exhibited in the second-to-last column of Table 6.

Table 6.
Risk values for risk elements.

SEs	Likelihood (%)	Consequence (%)	Risk value (%)	Risk level
SI1	8.04	8.88	13.10	E
CA4	8.80	8.02	12.93	
SE2	9.67	7.08	12.56	
SI3	6.83	6.78	8.50	H
SE1	9.28	4.00	6.80	
SE3	5.12	6.48	6.08	
SI4	7.16	4.03	5.30	
CA2	6.27	4.32	4.97	M
CA3	3.85	6.43	4.54	
SS4	5.00	4.88	4.47	
CA1	5.15	3.43	3.23	
SI2	5.26	3.34	3.23	
SS2	3.72	4.05	2.76	
SE4	3.88	3.98	2.83	
SS1	2.44	5.67	2.54	L
SD4	2.58	3.22	1.52	
SD1	1.65	4.72	1.43	
SD2	1.28	5.64	1.33	
SD3	2.33	2.56	1.09	
SS3	1.70	2.49	0.78	

Furthermore, this paper adopts the package "ggRepel" in Rstudio to visualise the continuous matrix, which includes the horizontal axis (i.e., likelihood weights) and the vertical axis (i.e., consequence weights). As shown in Figure 5, the continuous risk matrix is segmented into four risk regions, including extreme (E), high (H), moderate (M), low (L) risk levels, by three convexities towards the origins of the coordinate axis. To begin, the middle convexity with the risk value of 5 % is formed by the average of twenty REs' risk value, as displayed in the second-to-last column of Table 6. As such, this convexity separates twenty REs into two distinct groups based on their risk value. Group 1 consists of seven REs (i.e., SI1, CA4, SE2, SI3, SE1, SE3, and SI4), and Group 2 contains the remaining thirteen REs. The average of the seven REs's risk value in Group 1 results in the second convexity with the risk value of 9.34 %. The third convexity with the risk value of 2.82 % has been obtained in the same manner.

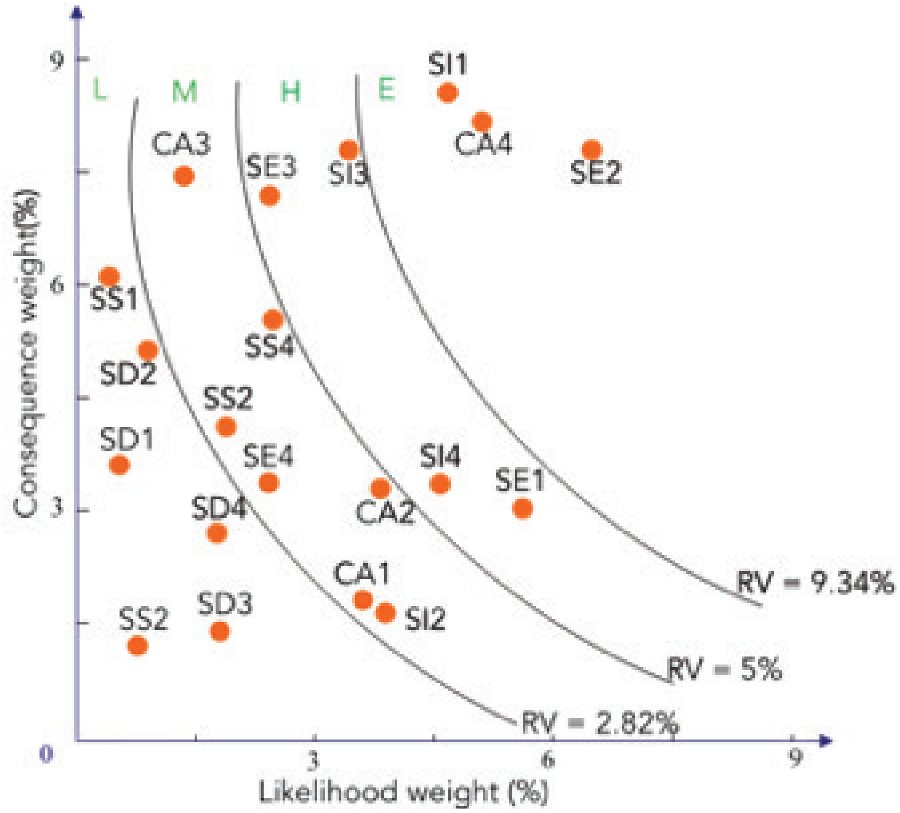

Figure 5.
Continous risk matrix for REs.

4. DISCUSSIONS

Three REs are rated as the extreme risk level, including SI1 (inadequate procedures), CA4 (lack of self-discipline for work), and SE2 (mechanical equipment failure) by the continuous RM for the Vietnam IWT case. According to the theory of the risk matrix, decision-makers should pay more attention to extreme-risk REs in the context of limited resources. In the light of these findings, along with extensive literature review, the authors have performed follow-up interviews with some of the survey's professional specialists and have come up with the managerial recommendations for DIWT operators, as shown below:

Inadequate procedures

One can see that among the twenty REs, which are ranked by their risk values, inadequate procedures should receive most attention from IWT operators. This risk element is typically linked to insufficient processes (Kececi & Arslan, 2017) or deviations from SOPs (Coraddu et al., 2020). Nautical accidents have frequently been linked to inadequate procedures in the last research. As an example, a SEAHORSE project sponsored by the EU found that up to a third of SOPs are unworkable and inefficient (Kurt et al., 2016), and thus are not being properly followed (Kurt et al., 2015). In their research, they found that inadequate processes and/or insufficient resources are the primary causes of accident risks and fire hazard incidents.

As has been previously stated, the vast majority of incidents that occur on the sea are caused by human error. It is suggested that IWT firms implement SOPs for crew members to abide by, so that instances like these can be avoided. Our research shows that SOPs are widely used but not always strictly adhered to. Overcrowding and overloading are also major problems in Vietnam's IWT and pose a danger to IWT. Crew members could be motivated to ignore SOPs as a result of these issues. Operators of IWTs should be held legally and financially responsible for overcrowding and overloading before setting sail on any voyage. Furthermore, our post-interview feedback suggests that commercial goods should not be allowed to travel on passenger ships. Furthermore, this paper suggests that IWT management continually enhances current SOPs and mandates that crew members keep hardcopies of the SOPs for reference once ad hoc events occur, as safety management standards are typically developed over time.

Lack of training programs

According to the past research, a lack of training programs has also been found to be a major contributor to catastrophic accidents in waterway transport. As an example, a review of marine accident records found inadequate training to be a common element in all of the incidents examined (Puisa et al., 2018). Moreover, using the TRACEr taxonomy, Graziano et al. (2016) discovered that insufficient training and inadequate education were responsible for the majority of the grounding accidents. Besides, Kum and Sahin (2015) pointed out the collision accidents in harsh conditions could be linked to poor training quality and lack of extension.

The crisis management capabilities of the crew members might be improved in practice by providing them with adequate safety information and training courses. According to the findings of the post-interview, this risk element may be abated by considering the following recommendations:

First of all, occasional training exercises, such as the usage of fire-fighting devices, emergency rescue, and alert systems, should be conducted to improve the crew's capacity to adapt to in the event of an emergency. According to Kececi and Arslan (2017), staff onboard can be prepared for a disaster by conducting training drills that educate them with the equipment and procedures. Secondly, in order to maintain or renew a working certification, crew members should be required to finish functional recurring education, either via practical activities at their workplace or a web-based learning system (E-Learning). Coraddu et al. (2020) also have a similar suggestion. Finally, IWT operators should motivate and finance their crew members to attend scholarly lectures and courses on adaptation and mitigation measures. This recommendation is in line with that of Kurt et al. (2016) and Puisa et al. (2018).

Mechanical equipment failure

The basic literature has argued mechanical equipment failure as one of the most common risks for marine accidents, such as collisions (Hasanspahić et al., 2018), grounding (Bu & Nachtmann, 2021), explosions/fire (Cui, 2019). Akyuz (2017) adding that the vessel's inspection and maintenance operations sometimes fail to address mechanical equipment failures in a timely manner. The lack of preventive measures to keep ships in good condition are likely to lead to a disaster. Cabin damage during grounding or accidents is more likely if the ship is not adequately maintained and corrosion soon sets in. As evidenced by Xue et al. (2021), inadequate maintenance or bad ship conditions may be to blame for the sinking of the fishing ships in China from 2010-2017.

Through the post-interview, practical experts have recommended a variety of tactics to minimise equipment failure, but which one is the most appropriate chiefly depends upon the machine's criticality, the predictability of its failures, and the available money and monitoring infrastructure. This paper summarises the least to most complicated ways to deal with machine failures in IWT, including reactive maintenance, diagnostic analytics, preventive and predictive maintenance.

5. CONCLUSION

IWT is argued to be the most preferred method for carrying cargoes and passengers in developing nations. Because IWT operations often focus on the decrease in operational costs by applying low freight rates, it is easy to overlook some operational safety regulations during transportation, which puts passengers at risk for disaster. Accordingly, researchers, legislators, and practitioners are paying close attention to how to ensure navigational safety for this kind of transport. Yet, this topic is seldom discussed in relevant literature. To fill the literature gap, this paper aims at assessing navigational safety for IWT. A total of twenty potential hazards (i.e., REs) in connection to IWT were examined in the study's initial stages. Next, using the Fuzzy AHP technique, a continuous RM to evaluate the risk level for REs was built. It is demonstrated that the proposed framework to evaluate risks in this research may supply a methodological reference for related research in the risk management approach, not just for IWT, but also for coastal shipping and interocean transport.

For the empirical study, the leading IWT operators in Vietnam have been surveyed in order to verify the proposed research model's practical implementation. Empirical results have identified three REs for the Vietnam IWT case that should be paid more attentions to, namely: SI1 (inadequate procedures), CA4 (lack of self-discipline for work), and SE2 (mechanical equipment failure). Managerial recommendations have then been proposed for improving the navigation safety for IWT.

A few limitations should be addressed in this paper. To begin with, the likelihood and consequence of REs is assessed using Fuzzy AHP, which assumes the independency of criteria (in this case, REs) in the hierarchical structure. Yet, in this research, the independence of REs has only been confirmed by the respondents during the process of the questionnaire draft. Theoretically, it might not suffice. It is suggested that ANP (Analytic Network Process) should be used to examine REs instead in future research. Finally, twenty-two practical experts from the leading IWT operator in Vietnam have been surveyed as a part of this study. Nevertheless, more representative samples may be required in further studies to adequately verify the empirical result.

CONFLICT OF INTEREST STATEMENT

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Abbassi, R. et al., 2017. "Risk analysis of offshore transportation accident in arctic waters." International Journal of Maritime Engineering, 159(A3). Available at: https://doi.org/10.5750/ijme.v159iA3.1025.

Akyuz, E., 2017. "A marine accident analysing model to evaluate potential operational causes in cargo ships." Safety Science, 92, pp. 17-25. Available at: https://doi.org/10.1016/j.ssci.2016.09.010.

Arof, A. M., & Nair, R., 2017. "The identification of key success factors for interstate Ro-Ro short sea shipping in Brunei-Indonesia-Malaysia-Philippines: a Delphi approach." International Journal of Shipping and Transport Logistics, 9(3), pp. 261-279. Available at: https://doi.org/10.1504/IJSTL.2017.10002950.

Baldauf, M., & Hong, S.-B., 2016. "Improving and Assessing the Impact of e-Navigation applications." International Journal of e-Navigation and Maritime Economy, 4, pp. 1-12. Available at: Available at: https://doi.org/10.1016/j.enavi.2016.06.001.

Blokus, A., & Dziula, P., 2019. "Safety analysis of interdependent critical infrastructure networks." TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 13. Available at: https://doi.org/10.12716/1001.13.04.10.

Bu, F., & Nachtmann, H., 2021. "Literature review and comparative analysis of inland waterways transport: 'Container on Barge'." Maritime Economics & Logistics, pp. 1-34. Available at: https://doi.org/10.1057/s41278-021-00195-6.

Bye, R. J., & Almklov, P. G., 2019. "Normalization of maritime accident data using AIS." Marine Policy, 109, p. 103675. Available at: https://doi.org/10.1016/j.marpol.2019.103675.

Caris, A. et al., 2014. "Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges." Journal of Transport Geography, 41, pp. 126-136. Available at: https://doi.org/10.1016/j.jtrangeo.2014.08.022.

Chang, C.-H., Xu, J., & Song, D.-P., 2015. "Risk analysis for container shipping: from a logistics perspective." The International Journal of Logistics Management.

Chen, C., Shigeaki, S., & Kenji, S., 2015. "Study on a numerical navigation system in the East China Sea." Applied Ocean Research, 53, pp. 257-266. Available at: https://doi.org/10.1016/j.apor.2015.09.006.

Coraddu, A., et al., 2020. "Determining the most influential human factors in maritime accidents: A data-driven approach." Ocean Engineering, 211, p. 107588. Available at: https://doi.org/10.1016/j.oceaneng.2020.107588.

Cui, H., 2019. "Optimization of Preventive Maintenance Cycle of Ship Mechanical and Electrical Equipment Based on MRO System." Journal of Coastal Research, 93(SI), pp. 953-959. Available at: https://doi.org/10.2112/SI93-138.1.

Duijm, N. J., 2015. "Recommendations on the use and design of risk matrices." Safety Science, 76, pp. 21-31.

Fan, L., Wang, M., & Yin, J., 2019. "The impacts of risk level based on PSC inspection deficiencies on ship accident consequences." Research in Transportation Business & Management, 33, p. 100464. Available at: https://doi.org/10.1016/j.rtbm.2020.100464.

Garvey, P. R., & Lansdowne, Z. F., 1998. "Risk matrix: an approach for identifying, assessing, and ranking program risks." Air Force Journal of Logistics, 22(1), pp. 18-21.

Graziano, A., Schröder-Hinrichs, J.-U., & Ölcer, A. I., 2017. "After 40 years of regional and coordinated ship safety inspections: Destination reached or new point of departure?" Ocean Engineering, 143, pp. 217-226. Available at: https://doi.org/10.1016/j.oceaneng.2017.06.050.

Graziano, A., Teixeira, A., & Soares, C. G., 2016. "Classification of human errors in grounding and collision accidents using the TRACEr taxonomy." Safety Science, 86, pp. 245-257. Available at: https://doi.org/10.1016/j.ssci.2016.02.026.

Hasanspahić, N. et al., 2018. "Analysis of Navigation Safety Regarding Tankers in Narrow Waterways." Pomorski zbornik, 55(1), pp. 201-217. Available at: https://doi.org/10.18048/2018.00.13.

Hathaway, O. A., Bradley, C. A., & Goldsmith, J. L., 2020. "Background Statement Concerning the Amendments To Chapter II-2 of the International Convention For The Safety Of Life At Sea, 1974 Adopted At London April 10, 1992 Entered Into Force October 1, 1994." Harvard.

Heikkilä, E. et al., 2017. "Safety qualification process for an autonomous ship prototype–a goal-based safety case approach." In Marine Navigation, pp. 365-370. CRC Press.

Hekkenberg, R., 2015. "Technological challenges and developments in European inland waterway transport." In Transport of water versus transport over water, pp. 297-313. Springer.

Hiremath, A. M., Pandey, S. K., & Asolekar, S. R., 2016. "Development of ship-specific recycling plan to improve health safety and environment in ship recycling yards." Journal of Cleaner Production, 116, pp. 279-298.

Hsu, W.-K. K. et al., 2022. "Assessing the investment environment in container terminals: A knowledge gap model." Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 236(3), pp. 585-599.

Hsu, W.-K., Huang, S.-H., & Huynh, T. N., 2021. "An Evaluation Model for Foreign Direct Investment Performance of Free Trade Port Zones." Promet-Traffic&Transportation, 33(6), pp. 859-870.

Hystad, S. W., Olaniyan, O. S., & Eid, J., 2016. "Safe travel: Passenger assessment of trust and safety during seafaring." Transportation Research Part F: Traffic Psychology and Behaviour, 38, pp. 29-36. Available at: https://doi.org/10.1016/j.trf.2016.01.004.

Ibrahim, M. et al., 2022. "Power to gas technology: Application and optimization for inland transportation through Nile River." International Journal of Hydrogen Energy. Available at: https://doi.org/10.1016/j.ijhydene.2021.12.143.

Iperen, W., 2015. "Classifying ship encounters to monitor traffic safety on the North Sea from AIS data." TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 9(1). Available at: https://doi.org/10.12716/1001.09.01.06.

Jovanović, I. et al., 2022. "The feasibility of autonomous low-emission ro-ro passenger shipping in the Adriatic Sea." Ocean Engineering, 247, p. 110712. Available at: https://doi.org/10.1016/j.oceaneng.2022.110712.

Kececi, T., & Arslan, O., 2017. "SHARE technique: A novel approach to root cause analysis of ship accidents." Safety Science, 96, pp. 1-21. Available at: https://doi.org/10.1016/j.ssci.2017.03.002.

Kim, T.-G., & Moon, B.-S., 2018. "Study on Estimating Economic Risk Cost of Aids to Navigation Accident in Busan Port, Korea using Contingent Valuation Method." Journal of Navigation and Port Research, 42(6), pp. 478-485. Available at: https://doi.org/10.5394/KINPR.2018.42.6.478.

Kulkarni, K. et al., 2020. "Preventing shipping accidents: Past, present, and future of waterway risk management with Baltic Sea focus." Safety Science, 129, p. 104798. Available at: https://doi.org/10.1016/j.ssci.2020.104798.

Kum, S., & Sahin, B., 2015. "A root cause analysis for Arctic Marine accidents from 1993 to 2011." Safety Science, 74, pp. 206-220. Available at: https://doi.org/10.1016/j.ssci.2014.12.010.

Kurt, R. et al., 2015. "SEAHORSE project: Dealing with maritime workarounds and developing smarter procedures." The 25th European Safety and Reliability Conference, Switzerland.

Kurt, R. et al., 2016. "SEAHORSE procedure improvement system: development of instrument." International SEAHORSE Conference on Maritime Safety and Human Factors.

Mia, M. J. et al., 2021. "An era of inland water transport accidents and casualties: the case of a low-income country." Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5(2), pp. 32-39. Available at: https://doi.org/10.1080/25725084.2021.1919432.

Mohammed, E. A. et al., 2016. "Design safety margin of a 10,000 TEU container ship through ultimate hull girder load combination analysis." Marine Structures, 46, pp. 78-101.

Nam, K., & Win, E., 2014. "Competitiveness between road and inland water transport: the case of Myanmar." Transport problems, 9. Available at: https://www.infona.pl/resource/bwmeta1.element.baztech-e64bf8b8-1daf-4f37-9f05-16b391c430f6/tab/summary.

Nguyen, T. Q. et al., 2022. "Assessing port service quality: An application of the extension fuzzy AHP and importance-performance analysis." PloS one, 17(2), e0264590.

Nikcevic Grdinic, J., 2015. "Legal regulations in the function of ensuring ship safety." Pomorstvo, 29(1), pp. 30-39. Available at: https://hrcak.srce.hr/140204.

Ozturk, U., & Cicek, K., 2019. "Individual collision risk assessment in ship navigation: A systematic literature review." Ocean Engineering, 180, pp. 130-143. Available at: https://doi.org/10.1016/j.oceaneng.2019.03.042.

Platz, T., & Klatt, G., 2016. The role of inland waterway transport in the changing logistics environment (1st ed.). Routledge, pp. 103-113.

Puisa, R. et al., 2018. "Unraveling causal factors of maritime incidents and accidents." Safety Science, 110, pp. 124-141. Available at: https://doi.org/10.1016/j.ssci.2018.08.001.

Saaty, T., 1980. "The analytic hierarchy process (AHP) for decision making." Kobe, Japan.

Saaty, T. L., 2001. Decision making for leaders: the analytic hierarchy process for decisions in a complex world. RWS publications, pp. 65-77.

Solomon, B. et al., 2021. "Inland waterway transportation (IWT) in Ghana: A case study of Volta Lake transport." International Journal of Transportation Science and Technology, 10(1), pp. 20-33. Available at: https://doi.org/10.1016/j.ijtst.2020.05.002.

Sys, C. et al., 2020. "Pathways for a sustainable future inland water transport: A case study for the European inland navigation sector." Case Studies on Transport Policy, 8(3), pp. 686-699. Available at: https://doi.org/10.1016/j.cstp.2020.07.013.

Trincas, G., Braidotti, L., & De Francesco, L., 2017. "Risk-based system to control safety level of flooded passenger ships." Brodogradnja: Teorija i praksa brodogradnje i pomorske tehnike, 68(1), pp. 31-60. Available at: https://doi.org/10.21278/brod68103.

Uğurlu, Ö., Yıldırım, U., & Başar, E., 2015. "Analysis of grounding accidents caused by human error." Journal of Marine Science and Technology, 23(5), p. 19. Available at: https://doi.org/10.6119/JMST-015-0615-1.

Ung, S.-T., 2018. "Human error assessment of oil tanker grounding." Safety Science, 104, pp. 16-28. Available at: https://doi.org/10.1016/j.ssci.2017.12.035.

Ung, S.-T., 2021. "Navigation Risk estimation using a modified Bayesian Network modeling-a case study in Taiwan." Reliability Engineering & System Safety, 213, p.107777. Available at: https://doi.org/10.1016/j.ress.2021.107777.

Vassalos, D., & Konovessis, D., 2008. "The thematic network SAFER EURORO: An integrated approach to safe European RoRo ferry design." Marine Technology and SNAME News, 45(01), pp. 1-8.

Vettor, R. et al., 2016. "Route planning of a fishing vessel in coastal waters with fuel consumption restraint." Maritime Technology and Engineering, 3, pp. 167-173.

Wang, L. et al., 2019. "Effectiveness assessment of ship navigation safety countermeasures using fuzzy cognitive maps." Safety Science, 117(3), pp. 352-364. Available at: https://doi.org/10.1016/j.ssci.2019.04.027.

Wang, X. et al., 2021. "Passengers' safety awareness and perception of wayfinding tools in a Ro-Ro passenger ship during an emergency evacuation." Safety Science, 137, p. 105189. Available at: https://doi.org/10.1016/j.ssci.2021.105189.

Wang, Z.-J., & Lin, J., 2017. "Acceptability measurement and priority weight elicitation of triangular fuzzy multiplicative preference relations based on geometric consistency and uncertainty indices." Information Sciences, 402, pp. 105-123. Available at: https://doi.org/10.1016/j.ins.2017.03.028.

Wiegmans, B., & Konings, R., 2016. Inland Waterway Transport: Challenges and Prospects, 115. Routledge.

Xue, J. et al., 2021. "A comprehensive statistical investigation framework for characteristics and causes analysis of ship accidents: A case study in the fluctuating backwater area of Three Gorges Reservoir region." Ocean Engineering, 229, p. 108981. Available at: https://doi.org/10.1016/j.oceaneng.2021.108981.

Yoon, M. G., & Kim, J. K., 2022. "Evaluation methodology for safety maturity in air navigation safety." Journal of Air Transport Management, 98, p. 102159. Available at: https://doi.org/10.1016/j.jairtraman.2021.102159.

Yuan, P., Wang, P., & Zhao, Y., 2021. "Innovative method for ship navigation safety risk response in landslide-induced wave." Advances in civil engineering, 2021. Available at: https://doi.org/10.1155/2021/6640548.

Zis, T., & Psaraftis, H. N., 2017. "The implications of the new sulfur limits on the European Ro-Ro sector." Transportation Research Part D: Transport and Environment, 52, pp. 185-201. Available at: https://doi.org/10.1016/j.trd.2017.03.010.