EAI Endorsed Transactions
on Transportation Systems and Ocean Engineering Research Article EAI.EU

Legal Framework and Its Implications for Environmental Risk Management in Inland Waterway Transport of Dangerous Goods: The Case of Vietnam

Tien-Dat Tran[1], Žarko Koboević[2], Thi Duyen-Anh Pham[1,*]

[1]Artificial Intelligent in Transportation, University of Transport Ho Chi Minh City, Ho Chi Minh City 700000, Vietnam
[2]2nd Maritime Department, University of Dubrovnik, Dubrovnik 20000, Croatia

Abstract

Transporting dangerous goods (DG) on inland waterways (IWT) has caused significant environmental and safety failures, especially in Vietnam, where inland waterways play a vital role in the country's logistics network. This study analyzes Vietnam's current practices in managing environmental risks during the transport of DG, and compares these regulations with international standards such as the UN Model Regulations, ADR, and the IMDG Code. Although Vietnam has made significant improvements in the classification, labeling, and licensing structure of transport, there are still limitations in enforcement, digital monitoring, and professional training. The paper uses data collected from the Ministry of Transport's Survey and Price Assessment Study, and applies a qualitative analysis method to compare Vietnam's legal regulations with international standards. Finally, the paper proposes necessary steps to improve modern risk management capabilities through legal updates and enhanced operational rationalization, along with the application of modern technological tools such as AIS, GPS and IoT to enhance monitoring and management capabilities. These recommendations are expected to support future-oriented policies, contributing to the creation of a safer and more sustainable inland waterways operation system in Vietnam.

Keywords: Inland Waterway, National Legal Regulations, Dangerous Goods, IWT, Environmental Risk Management.

Received on 07 November 2025, accepted on 09 December 2025, published on 11 December 2025

doi: 10.4108/_____

1. Introduction

Transporting dangerous goods (DG) on inland waterways poses significant environmental and safety risks due to the ecological sensitivity of river systems and the high potential for chemical spills, infrastructure damage, and human error during cargo handling and navigation. Globally, strict regulatory frameworks such as the IMDG Code and the UN Model Regulations have been established to ensure proper classification, packaging, and handling of hazardous substances. However, ensuring consistent compliance remains a challenge worldwide. In Vietnam, these risks are amplified by the country's increasing reliance on inland waterways for logistics, while risk management mechanisms and law-enforcement capacity are still developing.

Hazardous chemicals are elements that have been proven on scientific evidence and with sufficient statistical confidence to pose a risk of harmful health consequences when exposed to such compounds [1]. Furthermore, the criteria for identifying the hazardous features of chemicals based on international guidelines or by a list of compounds and a predetermined volume threshold are used to assess whether an item is dangerous. When dangerous goods are moved on inland waterways, there are possible dangers and

*Corresponding author. Email: anh.pham@ut.edu.vn

substantial environmental concerns during loading and unloading as well as transit, such as:

- Displaced goods that are liquefied, eccentric, have chemical leaks, corrosion, or other infrastructure damage that endangers lives; human error; and a lack of a timely prevention and response strategy;
- The characteristics of each type of transported goods will also have potential risks and environmental issues. Extreme weather, floods, and droughts, for example, are all elements that contribute to environmental hazards and mishaps while carrying bulk products and hazardous materials.

Similarly, inland waterway operations are still in their infancy, even though there are currently various environmental protection laws governing the transfer of dangerous goods. Risk management and environmental incident responses are extremely crucial when carrying dangerous goods on inland waterways. Despite the existence of multiple environmental protection regulations related to the transport of dangerous goods, Vietnam still lacks a fully effective and standardized framework to manage environmental risks in inland waterway transport. Weak enforcement capacity, insufficient digital monitoring tools, and the absence of unified professional training remain major challenges that hinder the country's ability to ensure consistent safety standards. These gaps significantly limit Vietnam's capacity to prevent, detect, and respond to DG-related environmental incidents in a timely and coordinated manner. One of the most serious incidents that highlighted these risks was the 2003 Ganh Rai Bay oil spill, as illustrated in Figure 1. This incident exposed the limitations of emergency response capacity, weak law enforcement, and the lack of a standardized risk management framework for the transport of dangerous goods in Vietnam. This case highlights the urgent need to strengthen the legal regulations and operational safety procedures for inland transport of dangerous goods to prevent future environmental disasters.

Building on these concerns, the present study aims to provide a systematic assessment of Vietnam's legal framework for managing environmental risks associated with inland waterway transport of dangerous goods. Specifically, the research seeks to: (1) examine the degree of alignment between Vietnam's current DG regulations and international standards such as the UN Model Regulations, ADR, and the IMDG Code; (2) identify gaps in regulatory enforcement, monitoring capacity, and professional training; and (3) propose legal and technological reforms that can enhance Vietnam's ability to prevent and respond to DG-related environmental incidents. These research questions guide the analysis and support the development of evidence-based recommendations for improving DG management in Vietnam.

In addition to addressing these research questions, this study offers important contributions to both academic research and policy development. By examining Vietnam's DG transport regulations in comparison with international frameworks, the study provides a clearer understanding of the systemic gaps that hinder effective environmental risk management. The proposed integration of digital technologies—such as AIS, GPS, and IoT—along with the recommendation to establish standardized training and unified data systems, presents feasible pathways for improving regulatory enforcement and operational safety. These insights not only support Vietnam's ongoing regulatory modernization efforts but also provide valuable guidance for other Southeast Asian countries with similar inland waterway transport conditions.

The rest of this paper is organized as follows. In Section II, we overview the status and features of dangerous items transported on IWs in Vietnam. Section III examines and evaluates the existing situation of IWs carrying DGs in Vietnam's Northern and Southern. The findings are a component of the Ministry of Transport's environmental protection project [2]. Next section, we put up ideas to improve managerial effectiveness, mitigate risks, and decrease environmental harm in IWT. The discussion of challenging research directions and the conclusion is given in Section V.

Figure 1. Spill incident in Ganh Rai bay area in 2003

2. Laws related to the transport of dangerous goods

2.1. Dangerous Goods Definition

In consideration of international regulations, expressions like "dangerous cargoes and commodities" and "hazardous material" can be used in marine literature and regulation. The question "What are the distinctions between these words and terms?" is raised by the variety of terminology. "Dangerous goods" and "hazardous material" are largely interchangeable, according to Fox M.A. [3], a senior instructor and consultant on hazardous materials and dangerous goods. Dangerous goods should be referred to as "Dangerous Cargoes" to help in the transportation

process. According to Decree No. 34/2024/ND-CP4 [4], dangerous goods means goods containing dangerous substances that are a risk to human life or health, the environment or national security and safety when transported by land or inland waterways.

In particular, dangerous substance refers to a gas, liquid or solid substance or compound that may pose a threat to human life or health, the environment or national security and safety.

The term "dangerous goods/cargoes" is used by the International Maritime Organization (IMO) in a multitude of its documents, including the International Convention for the Safety of Life at Sea, 1974 (SOLAS), the International Maritime Dangerous Goods (IMDG) Code, as illustrated in Figure 2 and the "Recommendations on the Safe Transport of Dangerous Cargoes and Related Activities in Port Areas".

2.2. Literature review

The international literature reflects growing attention to the environmental and safety risks associated with the transport of dangerous goods (DG). Global regulatory frameworks such as the IMDG Code, ADR, and the Basel Convention provide the foundation for harmonized DG classification, packaging, and transport requirements. Regional studies, including the Mekong River Commission's assessment of DG transport along the Mekong River, highlight persistent challenges in Southeast Asia, particularly in monitoring capacity and cross-border coordination. Recent advancements in AIS-based traffic management, collision risk detection using deep-learning models, and data-cleaning techniques demonstrate an emerging global shift toward digitalized, data-driven approaches for improving safety in inland waterway transport.

Considering the modes of transportation and the technological process of loading and unloading at the terminal or port related to the transportation of dangerous products, the countries' priority ought to be to guarantee protection and safeguard the environment. The United Nations Environment Program (UNEP), founded in 1972, performs as the system's environmental voice. To encourage the responsible and sustainable use of global environmental development, UNEP serves as a catalyst, advocate, educator, and facilitator [5]. Moreover, global environmental assessments, regional and national environmental trends, international environmental development, institutional strengthening of environmental guardians, and national environmental instruments are all part of UNEP's activities. Then, UNEP placed strict limitations on the international transportation of unsafe waste and made the Basel Convention mandatory out of special concern for dangerous items. Inland transportation and the development of rivers for navigation can have significant negative environmental effects [2]. However, inland vessels always contribute to making transportation more sufferable, especially when it replaces road transportation. Waterway development projects can have significant effects on ecological relevance and water quality. Mitigation measures might also differ greatly, for example, between river lengths with solid banks and bottoms and spans with muddy or sandy floors in wetlands. In some circumstances, new navigational outcomes might be planned to enhance biodiversity, and the quality of the water, or to establish important habitats [6, 7].

Many studies, papers with survey results, and analyses of the current situation addressing risk management, control, and response to environmental accidents in dangerous goods transit on waterways inland have developed in the world. Europe, America, Asia, China, and the Mekong River basin are among these regions [8, 9]. The International Maritime Hazards Commodity Code (IMDG Code) has been approved as the international rule for dangerous maritime transport by sea, and there are also other applicable regional transport regulations for DGs in Europe that are limited and duty specific [10]. These regulations have also evolved the regional model of inland transportation regulations for dangerous goods in other sectors such as the countries of Southeast Asia (ASEAN) [11]}. More specifically, the survey and evaluation project on "Carriage, handling and storage of dangerous goods along the Mekong river" proposed ideas in 2012 [12] to assist governments of countries in the Mekong region in obtaining a better understanding of the situation regarding transportation on inland river routes. The reality of inland waterway transit in this region has drastically changed during the last ten years. Additionally, because Vietnam is situated where the Mekong River ends before flowing into the sea and because the terrain is suitable for development, both the amount produced and the number of transports have increased significantly, necessitating the need for the most recent assessments of this issue in Vietnam.

Hence, it is crucial to take into account and evaluate how current international legislation relating to this matter correspond to domestic regulations, which must be brought up to date current regulations and the current situation on safety assurance, risk control, incident response in the transportation of goods. In terms of modes of transport and risk management tools, these two factors will be intertwined by their practical relationship. Analysis and assessment of risks and impacts due to environmental risks and incidents when transporting dangerous goods by inland waterways to inland waterway infrastructure and safety in waterway transport operations inland and natural, social-economic environment along inland waterways. Traffic Management (TM), Collision Risk Detection (CRD), and Data Cleaning (DC) are the three essential aspects, and they may be outlined as follows:

- Traffic Management: This subdomain primarily focuses on route recognition, traffic, and arrival time estimation at the destination [13]. The AIS system is often the data source for this subdomain. Deep learning techniques, in particular those created using networks that allow real-time detection of vessel collisions, recognition of flow patterns in waterways,

etc., assist in identifying the vessel. However, the pre-processing for data cleaning and corrections is mentioned in every study concerning AIS.

- Collision Risk Detection: The complexity and strain of managing inland river traffic are rising, as are the hazards encountered by navigation vessels, which make up the majority of inland traffic operations [14]. In General, the Vessel Traffic Management (VTS) system is crucial for enhancing inland river traffic safety and reducing ship-related inland environmental pollution. Concerns with inland waterway navigation have drawn more attention from the global marine community in recent years. According to the survey, the European Maritime Safety Administration connects real-time traffic statistics with information on ship safety status to analyze ship traffic patterns while the US and Canadian Coast Guards also developed a similar method for dangerous ships in interior waterways.
- Data Cleaning: Studies on waterways and traffic surrounding ports are included in the search results since many of them are situated at the mouths of sizable rivers. These situations provide significant collision hazards, and many techniques are being investigated to quickly identify the threat. One of the issues dealt with in this subdomain is the lack of information on the rivers and canals that make up a territory [15].

It is crucial to analyze and evaluate the potential effects of environmental hazards and accidents on inland waterway infrastructure, safety in waterway transport operations, and the natural, socioeconomic environment around inland waterways. By the rules for inland waterway ports and commercial inland waterway terminals, the manager of the operation of the port, inland waterway terminal, and shipping unit is in charge of developing and carrying out the response plan DGs; setting up staff to oversee and complete the appointment of protecting the environment at ports and wharves. This demonstrates the state's strong interest in the existing form of inland waterway transportation.

Despite the existence of various regulatory documents governing the transport of dangerous goods in Vietnam, a significant research and regulatory gap remains. Vietnam still lacks a comprehensive and integrated risk-management framework specifically designed for inland waterway transport. Critical limitations include the absence of standardized digital monitoring tools, fragmented data systems that do not support real-time situational awareness, inconsistent enforcement practices across provinces, and the lack of unified training programs for personnel. These gaps prevent Vietnam from achieving regulatory effectiveness comparable to international best practices and highlight the urgent need for coordinated legal, technological, and institutional reforms.

2.3. Important considerations for dangerous goods laws

Complying with international guidelines and regulations, Vietnam basically also promulgates regulations on inland waterway transport of dangerous goods. Specifically, these products typically fall into one of the following categories:

(i) Compounds and groups that fall under levels 1 through 9 of the IMDG Code.
(ii) According to the IMSBC Code, dangerous products transported in bulk and solid form fall under Group B.
(iii) Materials that are either liquid cargo as specified in Annex I of the MARPOL Convention, defined as a "hazardous liquid" under section 1.3.23 Chapter 1 of the IBC Code, or listed in Chapter 19 of the IGC Code, but whose flash point does not exceed 60°C

List of dangerous goods

- The list of dangerous goods is classified by type, group, according to the United Nations Code and dangerous goods codes specified in Appendix I of Decree No. 34/2024/ND-CP [4] detailing the list of dangerous substances, means of transporting dangerous substances by road and inland waterways.
- Each substance in the list of dangerous substances has a dangerous code with a group of two to three numbers specified in Appendix II of Decree No. 34/2024/ND-CP [4].

Wrappings and containers of dangerous goods in Vietnam

Wrappings and containers of dangerous goods (hereinafter collectively referred to as "packaging"). The packaging, containers, and packing of dangerous goods on the territory must be in accordance with Vietnam national standards (TCVN) or Vietnam national technical rules (QCVN) based on the kind of goods. They are required to comply with regulations of specialized management ministries or use international standards and technical regulations established by law for types and groups of dangerous goods that do not yet have national standards or national technical regulations. The specialized management ministry made the announcement.

International standards and regulations on packaging, containers, and packaging of dangerous products applicable to dangerous goods categories and groups under their management must be announced by ministries of specialized management.

Hazard labels, logos and danger signs

The labeling, logos and label sizes of dangerous goods must comply with Government labeling regulations. Hazard symbols and warning signs are widely placed on the outside of each package or container containing dangerous goods.

3. Methodology

This study employed a qualitative research design combining legal analysis, comparative analysis, and document-based synthesis to evaluate Vietnam's legal framework for the transport of dangerous goods (DG) on inland waterways. The focus of the research was to identify gaps in existing regulations, assess the consistency of Vietnam's legal provisions with international standards, and analyze practical implementation challenges across inland waterway regions.

The data sources used in the study consist of: (i) Vietnamese legal documents related to DG transport, including national laws, decrees, and regulations governing classification, labeling, licensing, and safety management; (ii) international regulatory frameworks such as the UN Model Regulations, ADR, and the IMDG Code; and (iii) survey findings and assessment reports from the Ministry of Transport's environmental protection project, which provided practical insights into DG transport activities in both the Northern and Southern inland waterway systems.

Data were collected through systematic document review and extraction of regulatory provisions, operational practices, and environmental incident records. Reports from the Ministry of Transport were analyzed to identify enforcement challenges, institutional limitations, and technical gaps in monitoring and emergency response.

The study utilized legal text analysis tools to categorize regulatory components and identify differences in scope, definitions, responsibilities, and enforcement mechanisms between Vietnam's regulations and international standards. A comparative analysis matrix was applied to evaluate the degree of alignment between domestic and international requirements. Thematic qualitative analysis was then used to synthesize findings into major themes, including enforcement capacity, digital monitoring limitations, training requirements, and environmental risks associated with DG transport on inland waterways.

4. Results and Discussion

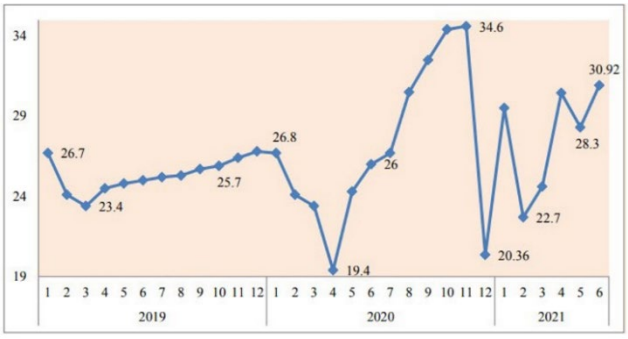

Figure 2. Volume of goods transported by inland waterways in Vietnam (2019–2021). Unit: million tons.

Figure [2] presents the volume of goods transported by inland waterways in Vietnam from 2019 to mid-2021. The data show significant fluctuations, particularly in 2020 due to the impacts of the COVID-19 pandemic, followed by a strong recovery in 2021. This illustrates the increasing importance of inland waterway transport in Vietnam's logistics system and highlights the need for consistent safety and environmental management of dangerous goods.

4.1. Results: Transport of dangerous goods in Vietnam

Vietnam's inland waterways play a crucial role in the transportation of both general and dangerous goods. Figure 4 shows typical inland waterway vessels operating on domestic river routes, which are the primary means of cargo movement and potential sources of environmental risk if not properly regulated.

Since its enforcement on March 31, 2024, Decree No. 34/2024/ND-CP [4] has served as the principal legal instrument regulating the transportation of dangerous goods (DGs) on Vietnam's inland waterways.

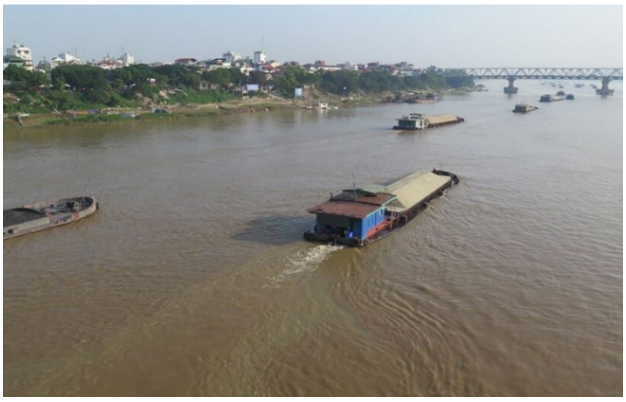

Figure 3. Typical inland waterway vessels operating on Vietnamese rivers — an essential mode for transporting goods, including dangerous goods, across the country.

The new Decree introduced a number of significant improvements:

- A clearer classification system consistent with the United Nations 18th Revision (2013) of the Dangerous Goods List.
- Mandatory labeling, packaging, and permitting procedures for carriers and consignees.
- Inclusion of English names and hazard symbols to facilitate international consistency.

Preliminary reports from the Ministry of Transport [2] indicate that the new regulatory framework has improved risk awareness and compliance among shipping

companies, leading to a reduction in minor DG-related incidents. However, implementation still varies by province, and local authorities face challenges in monitoring and enforcement due to limited human and technological resources.

These findings address the first and second research questions by highlighting the current DG transport conditions and the level of regulatory implementation in Vietnam.

4.2. Discussion: Environmental and Operational Risk Perspectives

Despite improvements in legal consistency, environmental risks associated with DG transportation remain a major concern. The Mekong Delta and Red River Delta systems face high vulnerability due to:

- Aging fleet structures and limited containment capacity;
- Extreme weather events (floods, storms, salinity intrusion);
- Human error during loading/unloading operations.

These factors contribute to accidental spills, leakage, and chemical exposure risks. Strengthening emergency response capacity and establishing standardized training programs are critical to mitigating such risks.

Future Directions:

To achieve international equivalence, Vietnam's inland waterway system needs to integrate digital risk monitoring platforms and data-driven management tools. The integration of AI-based vessel tracking, IoT sensor systems, and real-time environmental databases can significantly improve early warning, decision-making, and enforcement efficiency.

Ultimately, effective risk management will depend on the synergy between legal modernization and technological innovation, supported by stronger inter-agency cooperation among the Ministry of Transport, Ministry of Natural Resources and Environment, and local authorities.

These findings are consistent with previous international studies that highlight the vulnerability of inland waterway systems with aging fleets, limited monitoring capacity, and high dependence on weather conditions. The results reinforce the theoretical understanding that regulatory effectiveness depends not only on legal provisions but also on technological integration and institutional coordination. One notable observation is the regional disparity between the Red River and Mekong Delta systems, suggesting that uniform regulations may not address local risk factors adequately. This study is limited by its reliance on secondary data from MOT reports, which may not capture unreported incidents. Future research should develop quantitative risk models and evaluate the cost-effectiveness of digital monitoring technologies

5. Conclusion and Policy Recommendations

This paper examined the influence of Vietnam's national legal framework on the management and risk control of dangerous goods (DGs) in inland waterway transport (IWT), reaffirming the need to strengthen regulatory coherence and enhance environmental safety in this critical transport sector.

Through qualitative and comparative analysis, the study highlighted that Vietnam has made substantial progress in aligning its DG transport regulations with international standards such as ADR, AND, and the UN Dangerous Goods List. The unification of DG management across both road and waterway modes, as well as clearer requirements on labeling, packaging, and permits, mark important legal advancements.

However, despite these achievements, the research also identified key limitations. Implementation remains uneven across provinces, and the current framework lacks digital tracking, data integration, and standardized training systems. These weaknesses hinder effective monitoring and reduce the ability to respond swiftly to environmental incidents, especially in sensitive areas such as the Mekong Delta. These findings indicate that legal modernization alone is insufficient without adequate technological infrastructure and institutional capacity, highlighting the importance of coordinated multi-agency management.

The study contributes new insights by providing a systematic comparison of Vietnam's existing regulations with international frameworks and identifying concrete policy gaps. It also offers practical recommendations that can support future legislative reforms, institutional strengthening, and technological upgrading in DG transport. The proposed policy-oriented recommendations include:

(i) Develop a unified digital monitoring platform with AIS, GPS, and IoT.
(ii) Standardize training and certification based on IMO and UN standards.
(iii) Establish a centralized DG database for permits, incidents, and environmental data.
(iv) Promote regional cooperation in the Mekong subregion.
(v) Regularly update new UN revisions and sustainability measures.

Despite these contributions, the study has limitations. It relies primarily on secondary data from the Ministry of Transport, which may not fully capture unreported incidents or local enforcement challenges. Additionally, the absence of quantitative risk modeling limits the ability to estimate accident probabilities or simulate environmental impacts.

Future research should explore the development of quantitative DG risk-assessment models tailored to Vietnam's inland waterways, evaluate the cost-effectiveness of digital monitoring technologies, and

examine region-specific regulatory needs—particularly the differences between the Red River and Mekong Delta systems.

In summary, strengthening Vietnam's DG transport management requires legal modernization, technological innovation, and regional collaboration to achieve a safer, greener, and more sustainable transport system. Continued research and policy commitment will be essential to supporting this long-term transformation.

References

[1] A. Oggero, et al., "A survey of accidents occurring during the transport of hazardous substances by road and rail," Journal of Hazardous Materials, vol. 133, pp. 1-7, 2018, doi: 10.1080/17445302.2020.1827632.

[2] Ministry of Transport of Vietnam, "Survey to assess the current status and develop technical guidelines for risk control and response to environmental incidents in the transportation of dangerous goods on inland waterways," 2021.

[3] M. A. Fox, "Dangerous Goods and Hazardous Materials," Glossary for the Worldwide Transportation of Dangerous Goods and Hazardous Materials. Berlin, Heidelberg: Springer, pp. 54–57, 1999, doi: 10.1007/978-3-662-11890-0_21.

[4] Government of Vietnam, Decree No. 34/2024/ND-CP on the List of Dangerous Goods and the Transport of Dangerous Goods by Road and Inland Waterways, March 2024.

[5] A. Kumar, "United Nations Environment Programme (UNEP) as a specialized agency for environmental protection and sustainable development," Yearbook of International Environmental Law, vol. 34(1), 2023, doi:10.1093/yiel/yvae022.

[6] A. N. Sexton, J. N. Beisel, C. Staentzel, et al., "Inland navigation and land use interact to impact European freshwater biodiversity," Nature Ecology & Evolution, vol. 8, pp. 1098–1108, 2024, doi:10.1038/s41559-024- 02414-8.

[7] P. Wang, H. Zhang, J. Li, and Y. Tian, "Numerical simulation of habitat restoration for floating fish eggs in the upper Yangtze River tributaries," Sustainability, vol. 16, no. 5, pp. 1799, 2024, doi:10.3390/su16051799.

[8] A. L. Marcu Turcanu, L. M. Moga, and E. V. C. Rusu, "Analysis of some essential aspects related to the navigation conditions on the Danube River," Inventions, vol. 6, no. 4, pp. 97, 2021, doi:10.3390/inventions6040097.

[9] V. Pencheva, A. Asenov, I. Georgiev, B. Ivanov, and I. Zanev, "Study of inland waterway transport routing options under conditions of uncertainty in navigational restrictions," Transport Problems, vol. 18, no. 3, pp. 89–99, 2023, doi:10.20858/tp.2023.18.3.08.

[10] International Maritime Organization, IMDG Code: International Maritime Dangerous Goods Code, Amendment 40-20, London, UK: IMO Publishing, 2020.

[11] United Nations Economic Commission for Europe (UNECE), European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), 2023, Edition. Available: https://unece.org.

[12] Mekong River Commission (MRC) Navigation Programme, Carriage, Handling and Storage of Dangerous Goods along the Mekong River — Volume I: Risk Analysis, April 2012, doi:10.52107/mrc.ajgt3g.

[13] M. Zhang, D. Zhang, S. Fu, P. Kujala and S. Hirdaris, "A predictive analytics method for maritime traffic flow complexity estimation in inland waterways," Reliability Engineering & System Safety, vol. 220, pp. 108317, 2022, doi:10.1016/j.ress.2021.1083174.

[14] H. Ding and J. Weng, "A robust assessment of inland waterway collision risk based on AIS and visual data fusion," Ocean Engineering, vol. 307, pp. 118242, 2024, doi:10.1016/j.oceaneng.2024.118242.

[15] M. Liang, J. Su, R. W. Liu and J. S. L. Lam, "AISClean: AIS data-driven vessel trajectory reconstruction under uncertain conditions," Ocean Engineering, vol. 306, pp. 117987, 2024, doi:10.1016/j.oceaneng.2024.117987.