

Original article

RESEARCH ON INLAND WATERWAY TRAFFIC ACCIDENT TRENDS IN VIETNAM THROUGH MAPS DURING THE PERIOD 2017 – 2024

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Abstract

The primary objective of the study is to analyze and evaluate the situation and trends of inland waterway traffic accidents in Vietnam from 2017 to 2024. The study employs reliable secondary data sources, which are analyzed using statistical methods and heatmap applications to examine and assess trends in inland waterway traffic accidents in Vietnam. The results indicate a steady increase in both the number and scale of inland waterway accidents nationwide over the years. Additionally, the accident-prone areas in key inland waterways will be identified. Based on these findings, the research team has proposed recommendations and solutions aimed at improving traffic safety on Vietnam's inland waterways.

Keywords: Traffic accident, inland waterways, heatmap, accident prone areas

1. Introduction

In recent years, inland waterway traffic accidents have emerged as a pressing concern in Vietnam. From 2017 to 2024, the rapid expansion of inland waterway transport plays a crucial role in freight and passenger transportation. However, as traffic volume has increased, the frequency of accidents has also risen, posing significant challenges for management, monitoring, and traffic safety enforcement. This study is conducted within the context of Vietnam's ongoing efforts to improve inland waterway infrastructure, implement safety policies, and raise public awareness to mitigate accident risks. The research focuses on Vietnam's inland waterways from 2017 to 2024, analyzing the current situation and trends in traffic accidents during this period.

According to data from the Vietnam Maritime Safety Corporation, the overall trend indicates a decline in the number of accidents from 2017 to 2021. However, a noticeable increase began in 2023. Specifically, in 2017, there were 99 accidents nationwide, resulting in 45 fatalities and 16 injuries. Over the next five years, the number of accidents steadily decreased, reaching just 32 cases in 2021. Despite this reduction, the severity and complexity of these incidents remained a significant concern. By the 2022–2024 period, the number of accidents surged, with 50 cases recorded by September 2024 alone. While the number of fatalities has fluctuated over the years, it continues to be a critical issue (National Traffic Safety Committee, 2024).

Meanwhile, the number of injuries has consistently remained low, likely reflecting the nature of inland waterway accidents, where survival rates tend to be higher compared to other types of traffic incidents. Given the unpredictable and escalating nature of these accidents, urgent and effective measures from regulatory agencies are essential to address the situation.

To establish a scientific foundation for setting objectives and targeted solutions, it is crucial to systematically collect and analyze detailed accident data. This approach aims to identify key causes and distribution patterns of inland waterway traffic accidents. However, to date, no comprehensive studies have been conducted on this issue. Therefore, this research will focus on analyzing accident causes, trends, and spatial distribution based on secondary data sources. The findings will contribute to the development of

recommendations and solutions to enhance the safety of Vietnam's inland waterway transport system.

2. Literature review

To date, a significant body of domestic and international research has been conducted on inland waterway traffic accidents. Many studies, both domestic and international, have examined inland waterway traffic accidents. Igor Bačkalov et al (2023) analyzed 700 European accidents, identifying key causes such as human error and environmental conditions, but did not propose measures to reduce accidents. A study in Bangladesh (1995-2005) by Awal (2006) revealed a rising trend in accidents, mainly due to overloading, whirlpools, and collisions, and suggested improvements to the transportation system. In Vietnam, a study of Ha et al(2023) used the integrated Fuzzy – AHP – Topsis model, identified 20 major causes of accidents and proposed corrective measures. Luu (2019) pointed out that, besides weather factors, accidents were mainly caused by low awareness of traffic laws, but did not provide specific solutions for inland waterway accidents. While previous studies have analyzed the causes and influencing factors of accidents, no research has been conducted on the current situation of inland waterway traffic accidents in Vietnam. This study builds upon prior work by focusing on the causes, trends, and distribution areas of these accidents and proposing solutions to mitigate inland waterway traffic accidents in Vietnam.

3. Research framework

To achieve the research objectives, this study applies a traffic accident analysis framework, as illustrated in Figure 1. The research utilizes reliable secondary data sources on inland waterway traffic accident (IWTA) over an 8-year period (2017-2024), divided into two main phases for focused analysis. In the first phase (2017-2021), the data was sourced from comprehensive, up-to-date reports, providing thorough support for the research. However, during the second phase (2022-2024), the study employed secondary data collection methods to aggregate information from government sources such as the Southern and Northern Maritime Safety Corporation, the Vietnam Register, the Traffic

Police Department, and electronic portals from various provinces such as Quang Ninh, Hai Phong, etc. Using descriptive statistical methods, the study analyzes the trends and characteristics of traffic accidents to assist in the compilation of statistics and the creation of a heatmap. Based on the heatmap, the study identifies the distribution of severe traffic accident points for each year, presented on the heatmap with varying color gradients. From the analysis results and drawing on both domestic and international experiences, the study proposes specific measures to enhance traffic safety for the inland waterway channels and infrastructure system in Vietnam.

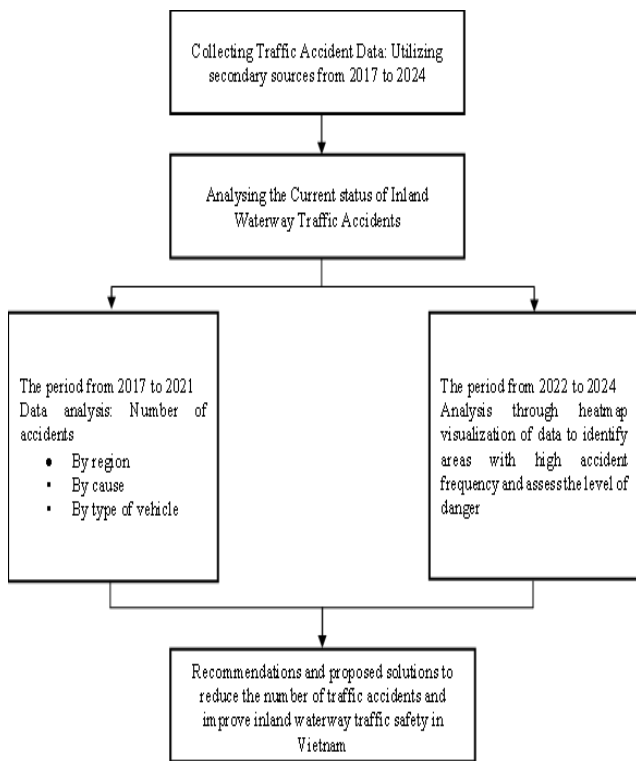


Figure 1. Research Framework

4. Research results

During the period from 2017 to 2021, the country recorded 364 inland waterway traffic accidents, resulting in 199 fatalities and 39 injuries. The number of accidents, fatalities, and injuries gradually decreased over the five years, thanks to the government’s policies on control and attention starting in 2019 (Figure 2). However, the severity of accidents slightly increased, with the number of fatalities remaining high. The first two years of the period, a higher number of accidents were recorded, as inland waterway traffic control had not yet been prioritized.

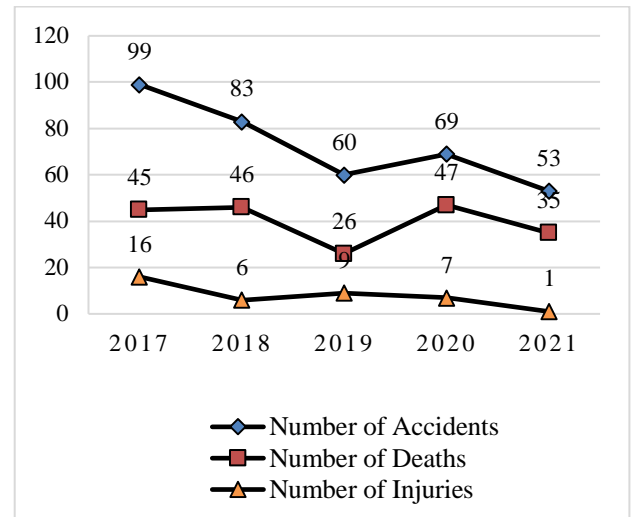


Figure 2. Analysis of accident cases during 2017-2021

Based on an analysis of Figure 3, the Southern region recorded the highest number of inland waterway traffic accidents in Vietnam from 2017 to 2021. This trend can be attributed to the region’s dense river network and well-developed infrastructure, which result in a high volume of vessel traffic. The fatality rate in the South was significantly higher than in the North, accounting for 66.88% of total deaths—103 more fatalities than in the North. Additionally, the number of injuries in both regions remained relatively low compared to the number of fatalities. Given the severe human toll of inland waterway accidents, it is crucial to implement appropriate measures and policies to effectively mitigate risks.

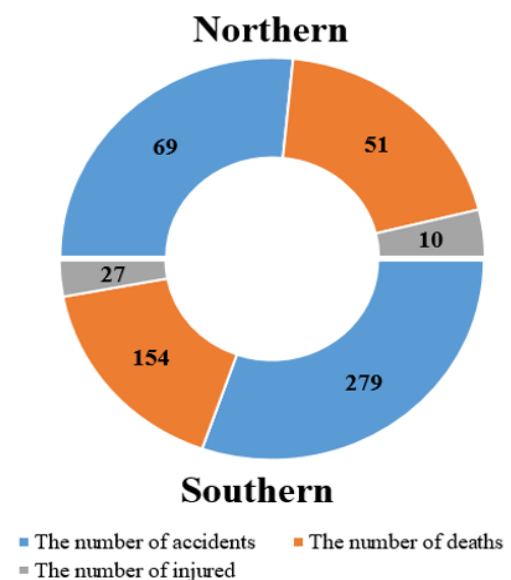


Figure 3. The number of accidents by region during 2017–2021

According to Figure 4, during 5 years (2017 – 2021), human-related factors accounted for 42.18% of inland waterway accidents, primarily due to negligence. These factors included a lack of

professional certification, violations of safety regulations, substance use (specifically alcohol consumption), and non-compliance with mooring rules. In contrast, external factors such as adverse weather conditions and signaling system deficiencies contributed to only 8.84% of total incidents. Enhancing inland waterway signaling systems is essential to improving safety. However, accidents with unidentified causes represented the largest proportion, reaching 48.34%. This highlights the need for thorough investigations into the root causes of waterway accidents. Most incidents were linked to human awareness during navigation and the use of rudimentary, technically unprepared vessels. Addressing these issues requires raising awareness, improving signaling infrastructure, and strengthening safety regulations.

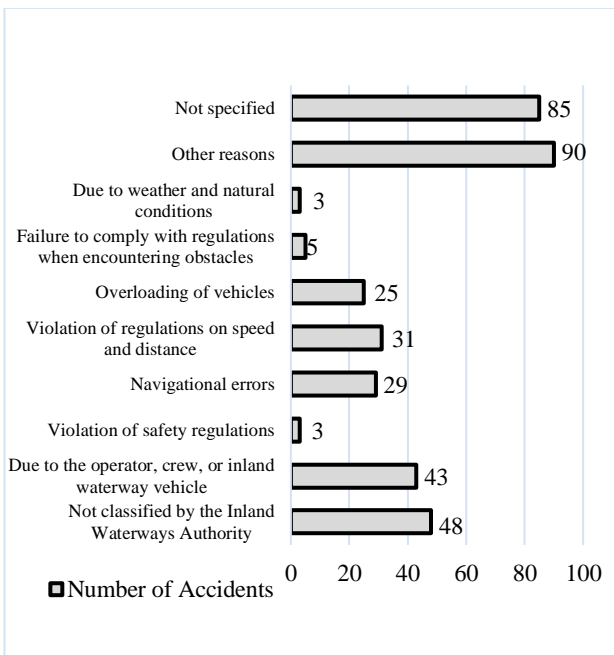


Figure 4. The number of accidents by cause 2017-2021

According to statistical data from Figure 5, the number of inland waterway incidents showed a decreasing trend from 2017 to 2021. However, the severity of these accidents increased, with a rising number of fatalities. The primary cause of these accidents was often human error, particularly among operators of informal and unregulated watercraft such as small motorized boats, sampans, and local vessels. Additionally, a significant number of accidents remained unexplained or were attributed to underlying factors. This lack of comprehensive and clear accident reporting presents challenges for both

the public and vessel operators, making inland waterway navigation more hazardous.

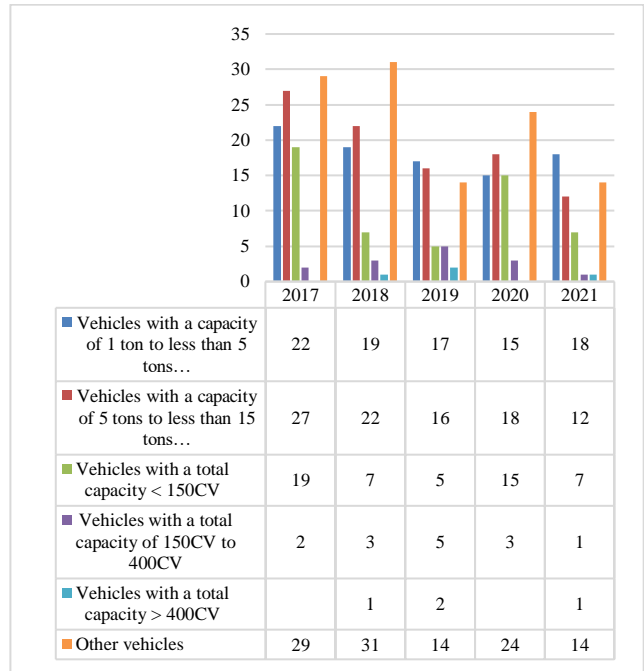


Figure 5. The number of traffic accidents by vehicle type in the period 2017 - 2021

From 2022 to 2024, the research team utilized heatmaps—a visualization technique that employs distinct colors to represent data density across various coordinate points on a predefined map. Areas with a high concentration of data points are highlighted in warm colors (typically red or orange), while regions with fewer data points are represented in cooler tones (such as blue or green). This method provides a comprehensive and objective overview of inland waterway traffic accidents.

To construct the heatmap, the research team collected accident data and compiled a database containing the geographical coordinates of accident locations. The development of this database presented a significant challenge, as data had to be gathered from multiple sources and manually processed, making it a time-consuming task. This phase was one of the most critical aspects of the study, as the geospatial accident dataset served as the foundation for analyzing and visualizing high-risk accident zones, which were ultimately presented through heatmaps.

| No | Name of vehicle | Month | Time | Coordinates | | Type of accident | Type of vehicle | Reason | Location |
|----|---------------------|-------|----------|-------------|----------|------------------|-----------------|-------------------------------|------------|
| | | | | Longitude | Latitude | | | | |
| 1 | Sa lan HN - 1891 | 7 | 5:00 am | 104.735 | 10.041 | Adrift | Cargo | Flooded | Khanh Hoa |
| 2 | Tau ca HT 20390 TS | 10 | 4:30 pm | 107.776 | 10.646 | Sunk | Fishing | Aground and sunk by the waves | Binh Thuan |
| 3 | Sa lan Hoa Lu 02 | 12 | 10:30 pm | 109.252 | 14.136 | Sunk | Cargo | Sunk by big waves | Binh Dinh |
| 4 | Rowboat | 9 | | 107.416 | 11.513 | Sunk | Commuting | Capsized | Lam Dong |
| 5 | Sa lan Phu Quang 09 | 12 | 8:00 am | 109.208 | 14.285 | Sunk | Cargo | Aground and sunk by the waves | Tra Vinh |
| 6 | Sa lan HY-0681 | 7 | 4:20 pm | 109.151 | 11.892 | Sunk | Cargo | Sunk by big waves | Tra Vinh |
| 7 | Tau SG 7838 | 3 | 6:00 am | 106.758 | 10.582 | Sunk | Cargo | Capsized | Tra Vinh |
| 8 | Sa lan TV-6769 | 11 | 5:20 pm | 106.213 | 9.658 | Sunk | Cargo | Sunk by waves | Kien Giang |
| 9 | Sa lan Thanh Binh 6 | 9 | 11:50 am | 106.780 | 10.432 | Sunk | Cargo | Sunk by waves | Kien Giang |
| 10 | 4 rowboats | 6 | 5:00 pm | 104.833226 | 9.971937 | Sunk | Commuting | Sunk by hard rain and tornado | Kien Giang |

Figure 6. The results of data collected in the document 'Accident Coordinates.'

By following the steps outlined above, geographic coordinate data were collected on inland waterway traffic accidents and compiled into the file "Accident Coordinates.xls." The collected data were then processed and transformed for visualization on a heatmap. The final outcome was a heatmap image that visually illustrates inland waterway accident locations, enabling the identification of high-incident areas and supporting efforts to prevent and mitigate traffic accidents.

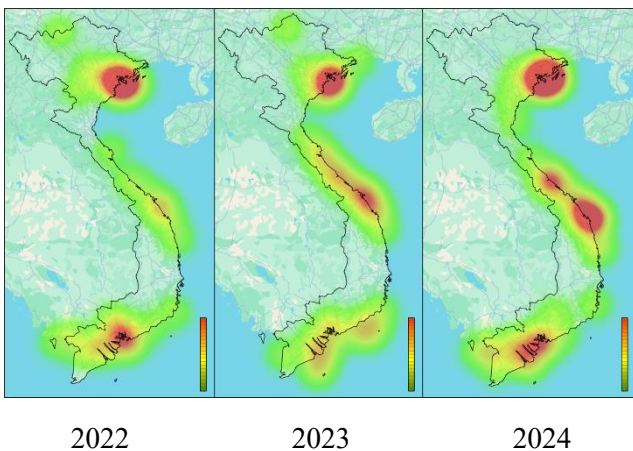


Figure 7. Heat map of inland waterway accidents for the period 2022-2024

From 2022 to 2024, heatmaps, a visualization technique that uses distinct colors to represent data density, was used. To generate the heatmap, data were collected based on key criteria, including accident coordinates, latitude and longitude, time, location, and the type of vessel involved. The findings revealed several challenges in data collection, including limitations in information sources and inconsistencies in reporting. Furthermore, inland waterway traffic accidents demonstrated a consistent upward trend over the years, varying in scale and severity. The incidents exhibited increasing

geographical concentration, primarily occurring in high-traffic areas such as ports, docking zones, and river mouth channels.

In the Northern region, the majority of accidents were recorded in the Red River Delta, particularly in Hai Phong and Quang Ninh. The Central region experienced frequent incidents along the Quang Ninh – Kien Giang inland waterway corridor, while the Southern region, especially the Mekong Delta, emerged as an accident prone-area with the highest accident density. Additionally, the scope of accidents showed a tendency to expand toward nearshore waters, though still within Vietnam's baseline maritime boundary.

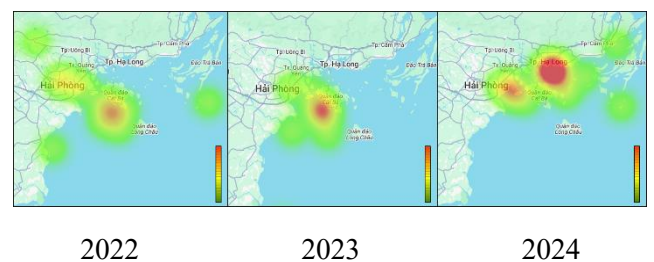


Figure 8. Heatmap of Inland Waterway Traffic Accidents in Northern Vietnam

In recent years, inland waterway transportation in Northern Vietnam has experienced significant growth, particularly in the Red River Delta, traffic density and cargo volumes are notably high. However, this growth has been accompanied by an increase in accident frequency, attributed to various risk factors.

In 2022, Hai Phong – Quang Ninh region recorded 18 accidents, predominantly caused by external factors such as engine failures or adverse natural conditions. By 2023, the number of incidents had decreased to 14, with the majority occurring in Hai Phong, which remained a high-risk accident prone

area. The primary cause shifted to human error, particularly negligence in vessel operation. In 2024, the number of accidents rose to 24, with a concentration in Quang Ninh, largely due to the impact of Typhoon Yagi.

Capsizing and grounding continued to be the leading causes of accidents, particularly affecting boats, ships, and barges. These trends underscore the urgent need for strengthened regulatory measures and implementation of risk mitigation strategies in critical areas.

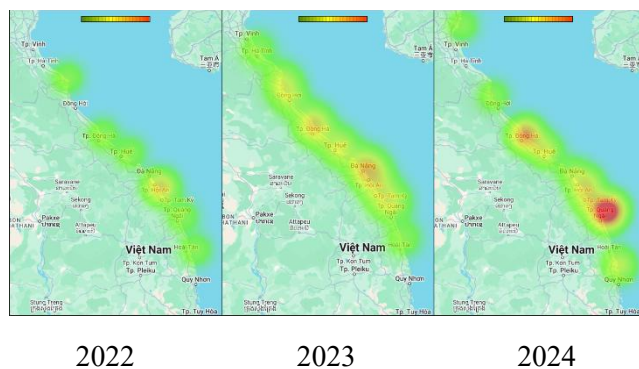


Figure 9. Heatmap of Inland Waterway Traffic Accidents in Central Vietnam

The Central region of Vietnam, characterized by its narrow, steep terrain and frequent flooding, has historically received limited investment in inland waterway infrastructure. However, during the 2022–2024 period, the number of waterway traffic incidents in the region increased significantly.

In 2022, a total of nine accidents were recorded, with 50% involving fishing vessels, primarily due to capsizing, sinking, or overturning. These incidents were attributed to both human-related factors such as loss of control and lack of vigilance, as well as environmental conditions, including hydrological phenomena. Quang Nam reported the highest accident rate (37.5%).

By 2023, the number of incidents rose to 17, predominantly occurring along the coastline and river mouths. Fishing vessels accounted for 58.82% of total accidents, particularly in the latter months of the year. The primary causes included adverse weather conditions (52.9%), vessel technical issues, and navigational hazards such as submerged reefs.

In 2024, the number of accidents further increased to 21, with incidents concentrated in Quang Nam, Quang Tri, and Quang Ngai, which together accounted for 71.43% of cases, making this a high-risk area. While the proportion of fishing vessel accidents declined to 28.57%, incidents involving civilian watercraft rose to 14.29%. The leading

causes remained severe weather, navigational obstacles, and vessel collisions. These findings emphasize the urgent need for improved maritime safety measures in the region.

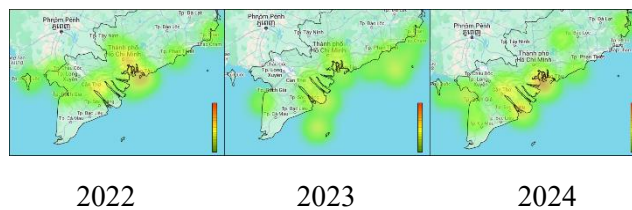


Figure 10. Heatmap of Inland Waterway Traffic Accidents in Southern Vietnam

The Southern region of Vietnam, with its extensive river network—including the Tiền and Hậu Rivers—has fostered a highly active inland waterway transportation system. However, this has also led to a high accident density, particularly in river mouths and estuaries. From 2022 to 2024, the region accounted for over one-third of the country's total inland waterway accidents, with the Soai Rap – Vung Tau – Đĩnh An area alone contributing more than 50%. The primary causes included collisions in narrow, unregulated waterways and adverse weather conditions, such as strong winds and high waves.

In 2022, 18 accidents were recorded (40.9% of the national total), with sinking and capsizing incidents being the most prevalent (11 cases). These incidents were concentrated during the Mekong River flood season (July to November). By 2023, the number of accidents slightly declined to 17 cases (35.4%), but the accident locations shifted toward the East Sea and coastal areas near Phan Rang – Phan Thiet, primarily due to severe weather conditions. In 2024, the number of accidents further decreased to 16 cases (25.4%), with incidents clustering in Vung Tau, Soai Rap River, and Đĩnh An – Can Tho, areas with a high concentration of cargo transport activities. Sinking and capsizing incidents remained dominant, accounting for 14 out of 16 accidents that year. These trends highlight the urgent need for enhanced management and waterway traffic safety measures in the region.

The frequency and severity of inland waterway traffic accidents in Vietnam have been increasing, particularly in high-traffic areas such as inland waterway routes and ports. High-risk “black spots” at ports, docking zones, and river mouth channels are notably prevalent in Northern Vietnam, Central Vietnam, and the Mekong Delta. Identifying and improving safety conditions in these areas—especially through strengthened monitoring and early warning systems—will be crucial in reducing accidents and ensuring the safety of both waterway

users and vessels.

5. Conclusions and recommendations

The study emphasizes that inland waterway transport plays a crucial role in Vietnam's logistics, particularly in densely riverine regions such as the Mekong Delta and the Red River Delta. However, the increasing number of accidents highlights the urgent need to improve safety measures. Based on the analysis of accident data from 2017 to 2024, the trend indicates that accidents are becoming increasingly concentrated in specific "black spots," particularly in areas with high traffic density, such as inland waterways, ports, and inland waterway terminals across the country. The study proposes several recommendations to reduce inland waterway traffic accidents in Vietnam, including tightening vehicle management, improving infrastructure, enhancing weather forecasting, and leveraging technology, alongside developing a comprehensive information and accident warning system. Many vehicles do not meet technical standards but are still permitted to operate. Operators often show negligence, lacking awareness, and frequently overload their vessels, fail to equip lifesaving devices, or operate outside regulations. Furthermore, inspection and enforcement measures lack sufficient deterrence, allowing violations to persist. Therefore, it is essential to rigorously monitor vehicle quality, enforce violations strictly, and raise operators' sense of responsibility. In parallel, addressing accident 'black spots' should be prioritized by establishing signaling systems, maintaining, and upgrading key waterway routes through close collaboration between regulatory authorities and transport companies.

The increasing complexity and unpredictability of weather patterns have direct implications for inland waterway transportation. Accidents during adverse weather conditions account for a significant proportion of incidents, particularly in areas frequently affected by natural disasters, such as Central and Northern Vietnam. Consequently, the government must upgrade the weather forecasting system to minimize risks from adverse weather conditions. More effective application of technologies such as GPS and AIS is needed to track vehicle routes in real time, facilitating transportation control, detecting violations, and issuing early warnings for hazardous situations, such as inclement weather,

restricted zones, or collision risks. Software to support the retrieval of information in the event of accidents would promote transparency and accountability. Additionally, establishing a synchronized database and a user-friendly accident warning website would allow timely updates on hazardous areas, enhance public awareness, and ensure the safety of inland waterway transportation.

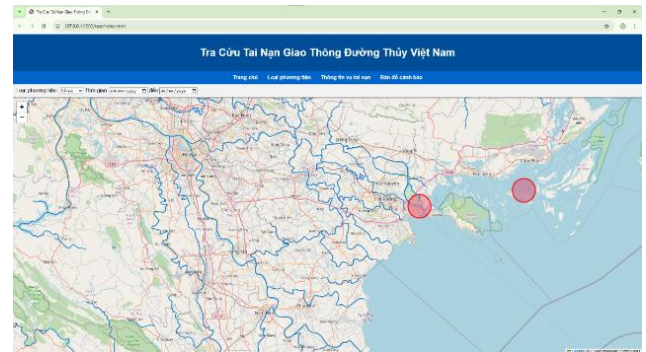


Figure 11. Website demo

Furthermore, the study suggests the development of a website dedicated to inland waterway traffic accident data. This website aims to address difficulties in accessing official accident data from government portals, as many current websites are hard to navigate, fail to update accident information comprehensively, or lack statistical data on accidents. The following is a demo of the website that the study developed, based on the identified limitations.

This website will provide forecasts related to hazardous areas, such as regions with unfavorable weather conditions or areas where vessels have run aground or sunk and have not yet been salvaged. With the application of digital technology and OpenStreetMap, the website will display inland waterway routes in Vietnam based on the map, along with updated and statistical data on traffic accidents. Machine learning technologies will be applied to analyze this data, enabling the website to generate a warning map highlighting frequently occurring accident 'black spots.' Additionally, the website will provide detailed information on traffic accidents, including time, location, causes, and consequences, facilitating easy access to specific accident-related data.

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