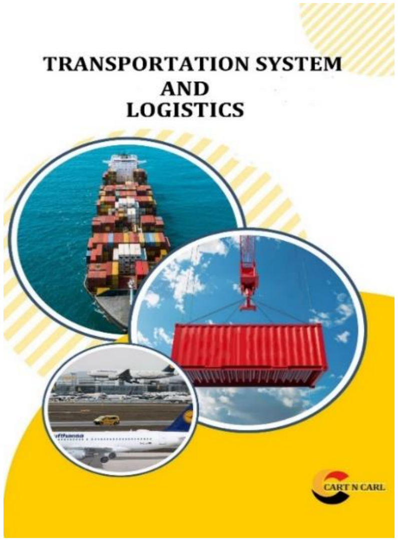
Original Research

Transportation System and Logistics
https://cartcarl.com/journal/transportation-system-and-logistics

E-ISSN: 0331-846X



Spatial Patterns of Marine Vessel Accidents Determinants and Forecast Future Casualties Along Inland Waterways in Rivers State, Nigeria

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Received: 01 September 2026
Accepted: 10 September 2026
Published: 12 September 2026

Citation
Ehibor, S. E., Wizor, C. H. and Kpang, M.B.T. (2026). Spatial Patterns of Marine Vessel Accidents Determinants and Forecast Future Casualties Along Inland Waterways in Rivers State, Nigeria. *Transportation System and Logistics, 3* (1), 17 - 31. https://doi.org/10.70726/tsl.2026.846X003

Abstract

This study analyzes the spatial patterns of marine vessel accidents, examines their determinants, and forecasts future casualties along inland waterways in Rivers State, Nigeria. The study adopts a retrospective longitudinal research design integrating Geographic Information Systems (GIS), statistical techniques, and time-series forecasting. Data on recorded marine vessel accidents, fatalities, injuries, accident locations, vessel types, causes, environmental conditions, and operational characteristics will be obtained from relevant maritime regulatory, safety, emergency-response, and security agencies. Primary data will also be collected from vessel operators, passengers, boat owners, waterfront residents, and other relevant stakeholders through structured questionnaires and interviews. Descriptive statistical techniques will be used to establish accident frequencies, casualty levels, temporal trends, and major accident characteristics. GIS-based spatial techniques, including Kernel Density Estimation, Average Nearest Neighbour, Global Moran's I, and Getis-Ord Gi* statistics, will be employed to identify accident concentrations, spatial clustering, and high-risk locations. Regression analysis will be used to examine the effects of human, technical, environmental, infrastructural, and institutional factors on accident occurrence and severity. Furthermore, time-series forecasting, particularly the Autoregressive Integrated Moving Average (ARIMA) model, will be applied to historical casualty data to estimate future trends in fatalities and injuries. Forecasting accuracy will be evaluated using Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE). The study is expected to identify significant spatial and temporal variations in marine vessel accidents, with accident hotspots potentially concentrated around heavily trafficked waterways, major jetties, navigationally difficult channels, and areas characterized by intensive commercial activities. Human-related factors, including overloading, overspeeding, inadequate safety compliance, operator error, and poor navigation practices, are expected to be important determinants, alongside mechanical failures and adverse environmental conditions.

Keywords : Accident Determinants, Casualties, Forecasting, Inland Waterways, Marine Vessel Accidents, Maritime Safety, Spatial Analysis

Introduction

Inland waterways constitute an important component of Nigeria's transportation system, particularly in riverine and coastal areas where rivers, creeks, estuaries and lagoons provide essential links between communities, markets, ports and economic centres. In Rivers State, the extensive network of waterways supports passenger transportation, fishing, movement of agricultural and commercial goods, petroleum-related activities and access to communities that may have limited road connectivity. The increasing dependence on inland waterways has consequently made navigational safety an important environmental, transportation and public-health concern, particularly because accidents involving passenger and commercial vessels can result in fatalities, injuries, economic losses and environmental damage (Nze & Nze, 2023; Zakari et al., 2025).

Marine vessel accidents along inland waterways are increasingly recognized as a significant transportation safety challenge in Nigeria. Such accidents may involve passenger boats, cargo vessels, fishing vessels, tugboats, barges and other types of watercraft operating within rivers, creeks and coastal channels. The consequences can be severe because accidents may lead to loss of human lives, injuries, destruction of vessels and cargo, disruption of economic activities and, in some circumstances, pollution of aquatic ecosystems. The occurrence of these accidents is generally influenced by an interaction of human, mechanical, environmental and infrastructural factors rather than by a single cause (Idiapho & Awwal, 2020; Akpudo, 2021).

Human factors constitute some of the most important determinants of vessel accidents on Nigerian inland waterways. These factors include overloading, excessive speed, inadequate experience, operator negligence, fatigue, poor knowledge of navigation rules, failure to use personal flotation devices and non-compliance with established safety regulations. Akpudo (2021) found that human factors accounted for the largest proportion of identified causes of boat accidents in Nigeria, demonstrating that unsafe operational practices remain a major contributor to casualties. Similarly, Zakari et al. (2025) identified over-speeding and overloading among the prominent human-related factors associated with passenger-vessel accidents in the South-South region of Nigeria.

Mechanical and technical conditions of vessels also contribute significantly to inland-waterway accidents. Engine failure, steering-system malfunction, poor vessel maintenance, structural defects and other equipment failures can compromise the ability of operators to control vessels, particularly during adverse navigation conditions. Research on marine tugboat accidents in Rivers, Bayelsa and Delta States indicates that technical and mechanical failures interact with human and environmental factors to increase accident risks (Idiapho & Awwal, 2020). Consequently, effective accident prevention requires not only responsible behaviour by vessel operators but also regular inspection, maintenance and certification of vessels and their equipment.

Environmental and physical characteristics of waterways can further influence the occurrence and severity of marine vessel accidents. Weather conditions such as heavy rainfall, strong winds, storms, poor visibility and turbulent water can reduce navigational safety, while narrow channels, sharp bends, irregular river morphology, strong currents, sedimentation and inadequate channel maintenance can create additional hazards. Studies of Nigerian waterways have shown that natural factors constitute an important component of accident causation, particularly when environmental conditions interact with inappropriate vessel speed, inadequate navigation skills or poor route knowledge (Akpudo, 2021; Ogboeli et al., 2023). These conditions make the geographical characteristics of waterways important variables in understanding accident occurrence.

The spatial distribution of vessel accidents is particularly important because accidents are not necessarily distributed uniformly across the inland waterways of a state. Certain locations may experience higher accident frequencies because of greater vessel traffic, concentration of landing sites, navigational constraints, population density, commercial activities, poor infrastructure or environmental hazards. Ogboeli et al. (2023) observed variations in marine accident fatalities across different Nigerian river routes and emphasized the importance of route characteristics and vessel-use intensity in explaining accident patterns. Spatial analysis can therefore reveal accident clusters and hotspots that may remain hidden when accident data are examined only through overall frequencies or annual totals.

Rivers State provides an important geographical setting for investigating these spatial patterns because of its extensive network of rivers, creeks, estuaries and other navigable waterways. The state's waterways support substantial passenger and commercial transportation and are closely connected with fishing, petroleum exploration, port activities, trade and settlement development. These multiple uses increase the volume and diversity of vessel movements and may create competition for navigational space. Studies focusing on the South-South region have identified Rivers State as part of a geographical area where passenger-vessel accidents are influenced by human, mechanical and environmental factors, including overloading, excessive speed, adverse weather and navigator-related failures (Zakari et al., 2025).

The Niger Delta environment, within which Rivers State is located, also presents distinctive challenges for inland-waterway transportation. The extensive network of interconnected rivers and creeks can make navigation difficult, particularly where channels are narrow, poorly maintained or affected by sediment deposition and changing hydrological conditions. Nze and Nze (2023) identified several risk factors associated with inland-waterway transportation in the Niger Delta Basin and emphasized the importance of waterway maintenance, safety management and regulatory enforcement in reducing transportation risks. These challenges suggest that understanding the geographical distribution of accidents in Rivers State requires consideration of both the physical characteristics of waterways and the intensity of human activities occurring along them.

Another important dimension of the problem is the relationship between accident occurrence and casualties. An accident involving a small vessel carrying only a few people may produce relatively limited casualties, whereas an accident involving an overloaded passenger vessel can result in substantial loss of life. Therefore, the analysis of inland-waterway safety should not be restricted to the number of accidents but should also examine the number of fatalities and injuries associated with individual incidents. Akpudo (2021) demonstrated the substantial human cost of boat accidents in Nigeria, while Zakari et al. (2025) showed that operational factors such as overloading and speeding can increase the potential severity of passenger-vessel accidents.

The temporal dimension of vessel accidents is equally important for understanding future safety conditions. Historical accident records can be examined to determine whether accident frequencies and casualties are increasing, decreasing or fluctuating over time. Trend analysis can provide useful evidence about the evolution of waterway safety and can establish a statistical basis for forecasting future casualties. According to Akpudo (2021), analysis of historical boat-accident records provides important evidence for identifying trends and major causal factors in Nigeria. Similarly, Ogboeli et al. (2023) demonstrated the usefulness of analysing accident and fatality trends across Nigerian waterways for understanding changing patterns of maritime safety.

Forecasting future casualties is particularly important because preventive policies should be based not only on past accident experiences but also on likely future conditions. Statistical forecasting can enable researchers to estimate the number of fatalities or injuries that may occur in subsequent years if existing patterns continue. Such forecasts can provide policymakers and safety agencies with early information for planning emergency response, strengthening vessel inspection, improving navigational infrastructure and targeting high-risk locations. The application of predictive and analytical approaches to marine safety has increasingly become important because data-driven assessment can help identify accident risks and support more proactive rather than reactive safety management (Zakari et al., 2025).

The need for improved accident prevention is also reflected in current institutional efforts in Nigeria. The National Inland Waterways Authority (NIWA) and the Nigerian Safety Investigation Bureau (NSIB) have emphasized the need for stronger collaboration, accident investigation, safety enforcement and information sharing to reduce recurring accidents on inland waterways. Such institutional efforts indicate that improving waterway safety requires reliable information about where accidents occur, the factors responsible for them and the populations most vulnerable to casualties (National Inland Waterways Authority [NIWA], 2026). Spatial and temporal analysis can therefore complement regulatory interventions by providing empirical evidence for prioritizing high-risk locations and activities.

Despite existing studies on inland-waterway accidents in Nigeria, there remains a need for a more integrated geographical analysis of marine vessel accidents specifically within Rivers State. Existing research has provided valuable information on accident causes, trends and risk factors at national, regional and Niger Delta levels, but fewer studies have simultaneously examined the spatial distribution of accidents, their determinants and the future trajectory of casualties at the state level. A location-specific study is necessary because the physical characteristics, vessel-use patterns, population distribution, economic activities and navigational conditions of Rivers State may produce accident patterns that differ from those observed elsewhere in Nigeria (Nze & Nze, 2023; Ogboeli et al., 2023).

Therefore, the study titled "Analyze the Spatial Patterns of Marine Vessel Accidents, Determinants and Forecast Future Casualties along Inland Waterways in Rivers State" seeks to provide an integrated assessment of inland-waterway safety in the state. The study will examine the geographical distribution and concentration of vessel accidents, identify the major human, mechanical, environmental and infrastructural determinants of accidents, and analyse temporal patterns in fatalities and injuries. It will further employ appropriate statistical forecasting techniques to estimate future casualty levels. The findings are expected to provide useful evidence for accident-risk mapping, safety planning, regulatory enforcement, emergency preparedness, vessel management and sustainable transportation along the inland waterways of Rivers State (NIWA, 2026; Zakari et al., 2025).

Literature Review

Concept of Marine Vessel Accidents

Marine vessel accidents refer to unintended events involving vessels that result in fatalities, injuries, damage to vessels or cargo, environmental pollution, or disruption of navigation. Although the term "marine accident" is commonly associated with offshore and ocean-going vessels, it is also applicable to vessels operating on inland waterways, including passenger boats, ferries, barges, tugboats and fishing vessels. In Nigeria, inland-waterway accidents have become an important transportation-safety concern because of the increasing use of rivers, creeks and coastal channels for passenger and commercial transportation (Idiapho & Awwal, 2020; Akpudo, 2021).

Marine vessel accidents can take different forms, including collisions between vessels, capsizing, grounding, sinking, fire or explosion, engine failure, contact with submerged objects and accidents resulting from adverse weather conditions. The nature of an accident often determines the number of casualties and the extent of property or environmental damage. For example, capsizing of an overloaded passenger boat may result in substantial loss of life, particularly where passengers are not wearing life jackets or where rescue facilities are unavailable. Idiapho and Awwal (2020) identified collision, grounding, overloading, overcrowding, engine failure and steering failure among important accident mechanisms affecting vessels operating in Nigerian waters.

The occurrence of marine vessel accidents is rarely attributable to a single factor. Rather, accidents commonly emerge from interactions among human behaviour, vessel conditions, environmental conditions, navigational characteristics and institutional weaknesses. This systems perspective is important for inland-waterway accident research because an apparently simple event, such as capsizing, may result from a combination of overloading, excessive speed, poor vessel maintenance, adverse weather and inadequate emergency preparedness. Recent research in the South-South region similarly demonstrates that passenger-vessel accidents are influenced by multiple human, natural and mechanical factors (Zakari et al., 2025).

Inland Waterways Transportation

Inland waterways are navigable rivers, creeks, lakes, canals, estuaries and other water channels used for transportation and other socioeconomic activities. Inland-waterway transportation is particularly important in areas where water bodies constitute natural transportation corridors and where road infrastructure is inadequate or expensive to develop. In Nigeria, the extensive network of rivers and coastal waterways provides opportunities for passenger transportation, movement of agricultural products, fishing, commerce and industrial activities, particularly within the Niger Delta (Nze & Nze, 2023).

Rivers State represents an important inland-waterway transportation environment because of its extensive network of rivers, creeks and estuarine channels. Water transportation connects several riverine settlements with Port Harcourt and other commercial centres and provides access to communities that are difficult to reach by road. The waterways also support fishing, oil and gas activities, maritime commerce and other economic activities. Consequently, the intensity of vessel movement within Rivers State creates a need for systematic assessment of transportation risks and accident patterns (Ogboeli et al., 2023; Zakari et al., 2025).

The importance of inland waterways to the Nigerian economy also makes their safety an important component of national transportation policy. The Federal Government has recognized recurring boat mishaps as a major challenge and established a Special Committee on the Prevention of Boat Mishaps to review commercial boat operations, identify causes of accidents and recommend measures for improving safety. This demonstrates the increasing policy attention being given to the safety of inland-waterway transportation in Nigeria (National Inland Waterways Authority [NIWA], 2025).

Spatial Patterns of Marine Vessel Accidents

Spatial patterns refer to the geographical distribution, concentration, clustering and variation of phenomena across space. In the context of marine vessel accidents, spatial analysis involves examining where accidents occur, the frequency of accidents at different locations, the characteristics of accident hotspots and the geographical factors associated with accident occurrence. Such analysis is important because accident risk may vary substantially between different waterways, river routes, jetties and landing points (Ogboeli et al., 2023).

Marine vessel accidents are not necessarily randomly distributed across geographical space. Accident concentrations may occur around locations characterized by high vessel traffic, busy jetties, narrow channels, sharp bends, strong currents, poor visibility, inadequate navigation aids or intense commercial activities. Ogboeli et al. (2023), in examining marine accident fatalities along river routes connecting major Nigerian seaports, demonstrated the importance of examining accident occurrence across specific routes rather than relying exclusively on aggregate national accident statistics.

Geographic Information Systems (GIS) provide useful tools for analysing spatial accident patterns. GIS can be used to geocode accident locations, identify clusters, determine distances from accidents to waterways and settlements, and overlay accident locations with environmental and infrastructural variables. Spatial techniques such as kernel density estimation, nearest-neighbour analysis, hotspot analysis and spatial autocorrelation can help identify areas with unusually high concentrations of accidents. Such approaches can provide a stronger basis for targeted safety intervention than generalized state-level accident statistics.

The spatial analysis of inland waterways is especially relevant to Rivers State because of the complexity of its riverine environment. Different waterways within the state vary in channel width, depth, traffic intensity, settlement density, navigational conditions and economic activity. Recent GIS-based research in Rivers State has demonstrated substantial spatial variation in vulnerability along major inland-waterway corridors, illustrating the usefulness of spatial approaches for understanding risks within the state's waterway network (Obadina et al., 2025).

Determinants of Marine Vessel Accidents

Determinants of marine vessel accidents are the conditions or factors that increase the probability of an accident occurring or influence its severity. These determinants can broadly be classified into human, mechanical/technical, environmental, infrastructural and institutional factors. The classification is useful because accident prevention requires interventions that address the different dimensions of risk rather than focusing on only vessel operators (Idiapho & Awwal, 2020; Zakari et al., 2025).

Human Determinants

Human factors refer to behaviours, decisions, skills and operational practices of vessel operators and passengers that can influence accident occurrence. Important human determinants include over-speeding, overloading, overcrowding, fatigue, alcohol or substance use, inadequate navigation skills, poor knowledge of waterways, night sailing without adequate lighting and failure to comply with safety regulations. Idiapho and Awwal (2020) identified human factors as central causes of boat and ferry accidents in Nigerian waterways, while Zakari et al. (2025) found over-speeding and overloading to be leading human-related factors in passenger-vessel accidents in the South-South region.

Overloading is particularly dangerous because it reduces vessel stability and increases the consequences of sudden movements, strong currents or adverse weather. When a vessel carries passengers or cargo beyond its safe capacity, its freeboard is reduced and its ability to withstand waves and sudden shifts in weight may be compromised. Zakari et al. (2025) reported overloading as one of the leading human factors associated with passenger-vessel accidents in the South-South region, demonstrating the importance of passenger capacity management in accident prevention.

Over-speeding is another major human determinant because excessive speed reduces the time available for operators to identify and respond to obstacles, other vessels, sudden changes in channel conditions or adverse weather. High speed may also increase the severity of collisions and make vessel control more difficult. In their South-South study, Zakari et al. (2025) identified over-speeding as one of the leading reported human factors associated with passenger-vessel mishaps.

Technical and Mechanical Determinants

Technical determinants involve the condition, design, maintenance and operational reliability of vessels and their equipment. Engine failure, steering failure, hull defects, corrosion, electrical failure and poor vessel construction can compromise navigation safety. Idiapho and Awwal (2020) identified steering failure, engine failure, corrosion and hull-related defects among the technical factors associated with marine vessel accidents in Nigeria.

Poor maintenance can increase the likelihood of mechanical breakdown during navigation, particularly when vessels are operated frequently under demanding conditions. Inadequate inspection and certification may also allow defective vessels to remain in commercial service. Consequently, vessel inspection, preventive maintenance and compliance with technical standards are important components of inland-waterway accident prevention. The Federal Government's 2025 Special Committee on Boat Mishaps specifically included reviewing existing boat specifications and their relationship with acceptable safety standards among its terms of reference (NIWA, 2025).

Environmental Determinants

Environmental determinants include weather, hydrological and physical conditions that influence navigation. These include storms, strong winds, heavy rainfall, waves, currents, tides, poor visibility, darkness, flooding and changing water levels. Environmental hazards become particularly dangerous when vessel operators lack adequate information about changing conditions or when vessels are poorly equipped to operate under adverse circumstances (Idiapho & Awwal, 2020).

The importance of environmental factors is demonstrated by recent evidence from the South-South region. Zakari et al. (2025) identified storm and wind conditions as leading natural factors associated with passenger-vessel accidents. Such findings are particularly relevant to Rivers State because its waterways are influenced by rainfall, tidal processes, river currents and the wider hydrological characteristics of the Niger Delta.

Infrastructural Determinants

Waterway infrastructure plays an important role in navigation safety. Relevant infrastructure includes navigational aids, properly maintained channels, jetties, lighting systems, communication facilities, rescue equipment and emergency response facilities. Inadequate infrastructure can increase accident risks by making it difficult for vessel operators to identify navigational hazards or obtain timely assistance during emergencies. Research on inland-waterway transportation in the Niger Delta has emphasized infrastructure and maintenance deficiencies as important components of waterway risk (Nze & Nze, 2023).

Marine Accident Casualties

Marine accident casualties refer primarily to deaths and injuries resulting from vessel accidents, although the broader concept may also include damage to vessels, cargo and infrastructure. Casualties are an important measure of accident severity because two locations may record similar numbers of accidents but substantially different levels of human loss. Consequently, an analysis of accident frequency should ideally be accompanied by an assessment of fatalities and injuries associated with each accident (Ogboeli et al., 2023). The severity of casualties can be influenced by passenger numbers, vessel type, accident type, availability of life jackets, operator response, rescue capacity and the time required to reach survivors. Accidents involving overloaded passenger vessels may produce disproportionately high casualties because a large number of people are exposed to the same accident event. Zakari et al. (2025) reported that passenger-vessel accidents in the South-South region were frequently associated with fatal consequences, emphasizing the importance of examining casualties alongside accident frequency.

Temporal Trends in Marine Vessel Accidents

Temporal analysis examines how accident frequency and casualties change over time. Analysing accident trends is important because it allows researchers to determine whether safety conditions are improving, deteriorating or fluctuating. Trend analysis can also identify years or periods characterized by unusually high accident frequencies and provide information for assessing the effectiveness of safety interventions (Akpudo, 2021).

Akpudo (2021) conducted a statistical analysis of boat accidents in Nigeria between 2010 and 2021 and demonstrated substantial variation in accident occurrence across the study period. The study illustrates the usefulness of historical accident records for understanding the temporal dynamics of inland-waterway safety. Such an approach can be extended to Rivers State by examining annual accident frequencies, fatalities and injuries and determining whether significant temporal trends exist.

Forecasting Future Marine Accident Casualties

Forecasting involves using historical data and statistical models to estimate future outcomes. In the context of inland-waterway transportation, casualty forecasting can provide estimates of future fatalities and injuries based on observed historical trends. Forecasting is valuable because it enables authorities to adopt preventive measures before future accidents occur rather than responding only after casualties have occurred. Several statistical approaches can be used for casualty forecasting, including time-series analysis, moving averages, exponential smoothing, autoregressive integrated moving average (ARIMA), regression analysis and other predictive models. The choice of method depends on the nature, length and quality of the available accident dataset. Contemporary research on inland-waterway safety has demonstrated the usefulness of data-driven models for identifying accident risk factors and predicting navigation safety outcomes. For example, a data-driven Bayesian network study of inland shipping in the Pearl River Basin demonstrated that vessel type, accident timing and other variables could contribute significantly to navigation-safety prediction (Wang et al., 2024).

For Rivers State, casualty forecasting can provide information on the likely future burden of fatalities and injuries if existing patterns continue. The results could assist government agencies in determining the locations requiring stronger enforcement, emergency response facilities, operator training, navigational infrastructure and public safety campaigns. Forecasting can therefore complement spatial hotspot analysis by indicating not only where accidents are concentrated but also how the casualty situation may develop in the future.

Theoretical Review

Systems Theory of Accident Causation

Systems Theory provides a useful theoretical foundation for understanding marine vessel accidents because accidents generally arise from interactions among several components of a transportation system. The system may include the vessel, operator, passengers, waterway environment, regulatory agencies, infrastructure and emergency-response institutions. From this perspective, an accident is not necessarily the result of one individual's error but may emerge from interactions or failures within several interconnected components of the system (Idiapho & Awwal, 2020).

The application of Systems Theory to inland-waterway accidents suggests that accident prevention requires simultaneous attention to operators, vessel conditions, environmental conditions and institutional arrangements. For example, an accident may occur when an inexperienced operator navigates an overloaded vessel with inadequate safety equipment through a poorly marked channel during adverse weather. The accident therefore results from the interaction of multiple system components rather than a single isolated cause.

This theory is particularly relevant to the present study because the proposed research seeks to examine multiple determinants of marine vessel accidents rather than attributing accidents exclusively to human error. It provides a framework for examining how human, technical, environmental, infrastructural and institutional variables interact to produce different spatial and temporal accident outcomes.

Swiss Cheese Model of Accident Causation

The Swiss Cheese Model, associated with Reason's theory of accident causation, explains accidents as the result of weaknesses or “holes” occurring across multiple layers of defence. In transportation systems, these layers may include operator training, vessel inspection, safety regulations, navigation procedures, life-jacket requirements, monitoring systems and emergency response. An accident occurs when weaknesses across these layers align and allow a hazard to pass through the system.

The model is useful for understanding inland-waterway accidents because safety failures may exist simultaneously at different levels. For example, inadequate operator training may combine with weak enforcement, poor vessel maintenance and adverse weather to produce an accident. Strengthening only one layer may therefore be insufficient if other weaknesses remain. The model supports a comprehensive approach to accident prevention involving operator behaviour, vessel standards, infrastructure and regulatory enforcement.

Recent Safety and Institutional Evidence

Recent institutional developments indicate that inland-waterway accident prevention remains a major policy concern in Nigeria. In 2025, the Federal Government inaugurated a Special Committee on the Prevention of Boat Mishaps to review commercial boat operations, examine accident causes and recommend measures for improving safety standards. The initiative demonstrates the continuing national concern regarding recurring boat mishaps and the need for evidence-based safety interventions (NIWA, 2025).

More recently, NIWA reported strengthened collaboration with the Nigerian Safety Investigation Bureau in areas including accident investigation, information sharing and safety promotion. Such collaboration is important because reliable accident data are essential for spatial analysis, identification of risk factors and forecasting future casualties. Improved institutional data-sharing could therefore strengthen research and policy responses to inland-waterway accidents in Rivers State (NIWA, 2026)

Method and Materials

Research Design

The study will adopt a retrospective longitudinal research design incorporating spatial analysis, descriptive statistics, inferential statistics and time-series forecasting. The retrospective component will involve the collection and analysis of historical records of marine vessel accidents and associated casualties along inland waterways in Rivers State over a defined study period. The longitudinal approach is appropriate because the study seeks to examine changes in accident occurrence and casualties through time, identify trends and forecast future casualty levels. Similar approaches have been applied in Nigerian studies investigating the temporal trends and causes of boat accidents and marine fatalities (Akpudo, 2021; Ogboeli et al., 2023).

The study will also employ a Geographic Information System (GIS) approach to determine the spatial distribution and concentration of marine vessel accidents within Rivers State. Accident locations will be georeferenced and represented spatially using appropriate GIS techniques. Spatial analysis will allow the study to identify accident hotspots and examine variations in accident occurrence among waterways, Local Government Areas (LGAs), landing points and other relevant geographical units. GIS-based analysis is particularly suitable because spatial location is a fundamental component of accident-risk assessment (Ogboeli et al., 2023; Obadina et al., 2025).

In addition, a cross-sectional survey will be used to obtain primary information from vessel operators, passengers, waterfront residents and relevant maritime stakeholders concerning perceived determinants of vessel accidents. The combination of accident records and primary survey information will provide both objective and contextual evidence concerning accident causation. The mixed approach is considered appropriate because accident databases can reveal where and when accidents occur, whereas stakeholder responses can provide information about operational practices, safety compliance and environmental conditions that may not be adequately captured in official records (Idiapho & Awwal, 2020; Zakari et al., 2025).

Study Area

The study will be conducted in Rivers State, Nigeria, which is located in the eastern part of the Niger Delta region. The state lies within the tropical rainforest and freshwater/marine ecological transition of the Niger Delta and is characterized by an extensive network of rivers, creeks, estuaries, tidal channels and coastal waterways. The abundance of navigable waterways makes water transportation an important means of movement for people and goods, particularly among riverine communities. Rivers State has 23 Local Government Areas, with several communities relying substantially on waterways for transportation, fishing, commerce and access to social and economic services. The state is also a major centre of petroleum exploration, maritime commerce, port activities, fishing and industrial development. These activities generate substantial vessel movement and interaction among passenger boats, fishing boats, barges, tugboats, service vessels and other watercraft, creating a complex environment for navigation and safety assessment.

Population of the Study

The population of the study will consist of two major groups. The first population will comprise all documented marine vessel accidents and associated casualties recorded along inland waterways in Rivers State during the selected study period. Accident records will constitute the principal unit of analysis for determining spatial and temporal patterns.

The second population will consist of vessel operators, passengers, waterfront residents, boat owners, jetty managers and relevant maritime officials operating or residing within selected inland-waterway communities in Rivers State. These respondents will provide primary information concerning accident determinants, safety practices, navigational conditions and regulatory compliance.

The use of both accident records and human respondents is appropriate because official accident records provide measurable evidence of accident occurrence and casualties, while stakeholders can provide information concerning behavioural, operational and environmental conditions associated with accidents (Idiapho & Awwal, 2020; Zakari et al., 2025).

Study Period

The study may cover a 10-year period, for example 2016–2025, depending on the availability and completeness of accident records. A ten-year period is considered adequate for identifying temporal trends and developing a forecasting model because it provides a relatively long sequence of annual observations.

Where monthly accident data are available, monthly observations will be preferred because they provide a larger number of observations for time-series modelling. Annual data will be used where monthly records are unavailable or inconsistent. The final study period will therefore be determined by the quality and completeness of records obtained from relevant agencies.

Sources of Data

The study will use both primary and secondary data.

Primary Data

Primary data will be obtained through structured questionnaires administered to selected vessel operators, passengers, waterfront residents, boat owners and other relevant stakeholders. The questionnaire will obtain information on:

1. Vessel operating practices;
2. Overloading;
3. Over-speeding;
4. Operator experience;
5. Navigation skills;
6. Use of life jackets;
7. Night navigation;
8. Vessel maintenance;
9. Engine and steering conditions;
10. Weather conditions;
11. Waterway characteristics;
12. Availability of navigation aids;
13. Safety regulations;
14. Emergency-response facilities; and
15. Perceived causes of accidents.

The questionnaire will use a five-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree, to measure respondents' perceptions of accident determinants.

Secondary Data

Secondary data will constitute a major component of the research. Accident records will be obtained, where accessible, from relevant institutions such as the National Inland Waterways Authority (NIWA), Nigerian Safety Investigation Bureau (NSIB), Nigerian Maritime Administration and Safety Agency (NIMASA), Rivers State Government agencies, marine police, hospitals, emergency-response agencies and other credible sources. The secondary dataset will contain, as far as available:

1. Date of accident;
2. Time of accident;
3. Accident location;
4. LGA;
5. Waterway/river;
6. Vessel type;
7. Vessel activity;
8. Accident type;
9. Number of passengers;
10. Number of fatalities;
11. Number injured;
12. Number rescued;
13. Vessel damage;
14. Suspected cause;
15. Weather condition;
16. Water condition;
17. Operator-related factors; and
18. Other relevant observations.

Recent collaboration between NIWA and NSIB has emphasized improved accident investigation and information sharing, which is important for developing more reliable inland-waterway accident databases (NIWA, 2026).

Materials and Instruments

The major materials and instruments required for the study will include:

1. Structured questionnaire;
2. Interview guide;
3. Accident-record extraction sheet;
4. Global positioning system (GPS) device or GPS-enabled smartphone;

5. Geographic information system (GIS) software;
6. Satellite imagery;
7. Digital administrative maps of rivers state;
8. Statistical software such as SPSS, r, python or STATA;
9. Spreadsheet software such as Microsoft excel;
10. Computer system;
11. Portable storage devices; and
12. Relevant topographic, hydrological and navigational maps.

GIS will be particularly important for converting accident coordinates into spatial points and analysing their geographical distribution.

Sampling Technique

A multistage sampling technique will be adopted for the primary survey.

First, major inland-waterway corridors and waterfront communities in Rivers State will be identified based on waterway use, vessel traffic, recorded accident incidence and accessibility. Second, selected jetties, landing points and waterfront communities will be purposively selected to represent areas with different levels of accident risk.

Third, respondents will be selected using stratified and simple random sampling techniques. Respondents may be stratified into vessel operators, passengers, boat owners, waterfront residents and relevant officials. This approach will ensure that different categories of stakeholders involved in inland-waterway transportation are adequately represented.

For the accident-record component, a census approach will be adopted where complete accident records are available. In other words, all documented accidents meeting the study criteria during the selected study period will be included rather than selecting a sample of accidents.

Determination of Sample Size

The sample size for the questionnaire survey may be determined using Taro Yamane's formula:

n=N1+N(e)2n = \frac{N}{1+N(e)^2}

Where:

nn = required sample size; N = estimated population of the study; e = acceptable margin of error, commonly 0.05.

For example, if the accessible population is known, the value will be substituted into the formula to determine the minimum number of respondents required.

Where the population of vessel operators and other stakeholders cannot be reliably established, Cochran's formula may alternatively be used:

n0=Z2pqe2n_0=\frac{Z^2pq}{e^2}

where ZZ is the standard normal deviation, pp is the estimated population proportion, q=1−pq=1-p, and ee is the acceptable level of precision.

Data Collection Procedure

Before data collection, permission will be obtained from relevant institutions and community authorities. Research assistants, where required, will be trained on the objectives of the study, questionnaire administration, ethical considerations and procedures for recording geographical coordinates.

Historical accident data will first be collected and entered into a standardized database. Each accident will be assigned a unique identification number. Information obtained from different sources will be compared to identify duplicate records and resolve inconsistencies.

For accidents with identifiable locations, geographical coordinates will be obtained using GPS, existing coordinates, digital maps or geocoding procedures. Where exact coordinates are unavailable, the accident will be referenced to the nearest identifiable river, creek, jetty, community or landing point, with the level of positional accuracy clearly documented.

Questionnaires will subsequently be administered to selected respondents at identified jetties, waterfront communities and other relevant locations. Completed questionnaires will be checked daily for completeness before data entry.

Data Processing and Analysis

Data will be entered into Microsoft Excel and subsequently imported into appropriate statistical and GIS software for analysis. Descriptive statistics such as frequencies, percentages, means, standard deviations and rates will be used to summarize accident characteristics and respondent information. The analysis will be organized around the three major objectives of the research:

1. Spatial analysis of accident patterns;
2. Determination of accident determinants; and
3. Forecasting future casualties.

Analysis of Spatial Patterns

GIS will be used to map the geographical distribution of marine vessel accidents in Rivers State. Accident coordinates will be imported into a GIS environment and represented as point features.

The spatial distribution will first be examined using point-density analysis to identify areas with high concentrations of accidents. Kernel Density Estimation (KDE) may be employed to produce a continuous accident-density surface:

f^(x,y)=1nh2∑i=1nK(dih)\hat{f}(x,y)=\frac{1}{nh^2}\sum_{i=1}^{n}K\left(\frac{d_i}{h}\right)

Where:

n = number of accident observations; h = bandwidth; K = kernel function; and did_i = distance between location ii and the estimation point.

The resulting density map will identify accident hotspots and areas of relatively low accident concentration.

The Average Nearest Neighbour (ANN) technique may also be used to determine whether accident locations exhibit clustered, random or dispersed patterns. The nearest-neighbour ratio will be calculated as:

R=DoDeR=\frac{D_o}{D_e}

Where DoD_o represents the observed mean nearest-neighbour distance and DeD_e represents the expected mean distance under a random spatial distribution. A value of R<1R<1 indicates clustering, R=1R=1 indicates approximately random distribution, while R>1R>1 indicates dispersion.

Where adequate data are available, Global Moran's I and Local Indicators of Spatial Association (LISA) will also be employed to determine spatial autocorrelation and identify statistically significant high-high and low-low accident clusters.

Accident Hotspot Analysis

Hotspot analysis will be conducted to identify locations where accident frequencies or casualties are significantly higher than expected.

The Getis-Ord Gi* statistic may be used to identify statistically significant hotspots:

Gi∗=∑jwijxj−X¯∑jwijSn∑jwij2−(∑jwij)2n−1G_i^*= \frac{ \sum_j w_{ij}x_j-\bar{X}\sum_jw_{ij} }{ S\sqrt{ \frac{n\sum_jw_{ij}^2-(\sum_jw_{ij})^2}{n-1} } }

A statistically significant positive zz-score indicates a hotspot, while a statistically significant negative zz-score indicates a cold spot. The resulting hotspot map will enable the study to identify waterways, landing points and communities requiring priority safety interventions.

Analysis of Determinants of Marine Vessel Accidents

Descriptive statistics will initially be used to rank the perceived importance of accident determinants. Human, technical, environmental, infrastructural and institutional variables will be summarized using means, standard deviations and percentages. A multiple regression model may subsequently be employed to examine the relationship between accident occurrence/casualty severity and the identified determinants.

A general model may be specified as:

Y=β0+β1X1+β2X2+β3X3+β4X4+β5X5+ϵY=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\epsilon

Where: YY = accident frequency or casualty level; X1X_1 = human factors; X2X_2 = vessel/technical factors; X3X_3 = environmental factors; X4X_4 = infrastructural factors; X5X_5 = regulatory/institutional factors; β0\beta_0 = intercept; β1−β5\beta_1-\beta_5 = regression coefficients; and ϵ\epsilon = error term.

Where the dependent variable is a count of accidents or fatalities, Poisson regression or negative binomial regression would be preferable to ordinary least squares regression if the data demonstrate count-data characteristics and overdispersion.

Analysis of Accident Severity

Accident severity may be classified into categories such as:

1. no fatality;
2. minor injury;
3. serious injury;
4. one or more fatalities; and
5. multiple fatalities.

Where appropriate, ordinal logistic regression or binary logistic regression may be used to determine the factors associated with higher accident severity.

The general logistic model can be expressed as:

ln(p1−p)=β0+β1X1+β2X2+⋯+βkXk\ln\left(\frac{p}{1-p}\right)
=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_kX_k

where pp represents the probability of a specified accident-severity outcome.

This analysis will help establish whether factors such as overloading, over-speeding, poor weather, vessel type, operator experience and lack of safety equipment significantly influence the likelihood of severe casualties.

Forecasting Future Casualties

Historical annual or monthly casualty data will be subjected to time-series analysis. Before forecasting, the dataset will be examined for trends, seasonality, stationarity and structural changes. Where appropriate, an ARIMA (Autoregressive Integrated Moving Average) model will be employed. The general ARIMA model can be represented as:

ϕ(B)(1−B)dYt=θ(B)ϵt\phi(B)(1-B)^dY_t=\theta(B)\epsilon_t

Where:

1. YtY_t = number of casualties at time tt;
2. BB = backshift operator;
3. dd = order of differencing;
4. ϕ(B)\phi(B) = autoregressive component;
5. θ(B)\theta(B) = moving-average component; and
6. ϵt\epsilon_t = random error term.

The appropriate ARIMA model will be selected using the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), autocorrelation function (ACF), partial autocorrelation function (PACF) and diagnostic tests. Forecast accuracy will be assessed using measures such as:

1. Mean Absolute Error (MAE);
2. Root Mean Square Error (RMSE); and
3. Mean Absolute Percentage Error (MAPE).

The selected model will then be used to forecast the expected number of marine-vessel casualties for future years.

Seasonal Analysis

If monthly accident records are available, seasonal patterns will be examined to determine whether accident frequency or casualties vary according to seasons or months. The analysis may compare accident occurrence during:

1. Rainy season;
2. Dry season;
3. High-water periods;
4. Low-water periods; and
5. Periods of high or low vessel activity.

This is particularly relevant because weather, rainfall, water level, visibility and currents may influence navigational safety in Rivers State (Idiapho & Awwal, 2020; Zakari et al., 2025).

Result and Discussion

Pattern of Marine Vessel Accident Arising from Different Causes

Table 1 presents casualty figures arising from different causes of marine accidents over a nine-year period (2017–2025) with a total of 786 recorded casualties. The data show that accident-related casualties fluctuate over the years, with the highest annual total recorded in 2021 (119 casualties), followed by 2017 (114) and 2019 (103). The lowest number occurred in 2020 (48 casualties), indicating a sharp decline that year before rising again in 2021. In terms of causes, sea piracy is the most significant contributor, accounting for 149 casualties, making it the leading cause throughout the period despite fluctuations. This is followed by over boarding (89 casualties) and reckless navigation (65 casualties), both of which consistently contributed to accident rates across the years. Other notable causes include robbery (62 casualties), abduction (60 casualties), and collision with another boat (59 casualties).

Moderate contributors include violent waves (49 casualties), militancy (47 casualties), and engine fire (45 casualties), indicating a mix of environmental, mechanical, and human-related factors. Less frequent causes include over-speeding (35 casualties), engine failure the least (28 casualties), and vandalization of oil pipelines (19 casualties), significant causes are boat snatching (16 casualties), heart failure of rider (10 casualties), abandonment of boat laden with arms (10 casualties), and hijack (3 casualties), which occurred very rarely over the study period. The table reveals that human-related factors (such as piracy, over boarding, reckless navigation, and robbery) are the dominant causes of marine accident casualties, while mechanical and natural factors contribute moderately Marine accidents in the area are influenced by varying operational, security, and environmental conditions over time.

Table 4.1: Causes of accident showing number of Casualties per year

S/N	Causes of Accident	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
1	Sea piracy	42	19	17	3	22	13	8	18	7	149
2	Abduction	4	0	1	4	17	18	8	6	2	60
3	Over boarding	18	4	17	1	13	8	7	14	7	89
4	Collision with another boat	7	3	0	2	12	9	4	2	20	59
5	Reckless navigation	5	16	8	7	4	8	5	12	0	65
6	Overspeeding	4	3	7	2	5	3	2	6	3	35
7	Robbery	8	26	8	5	3	0	6	2	4	62
8	Collision with submerged wreck	2	4	17	6	4	2	0	0	5	40
9	Violent wave	4	3	5	7	5	4	2	17	2	49
10	Heart failure of rider	1	0	3	0	3	0	1	2	0	10
11	Abandonment of boat laden with arms	2	1	2	1	4	0	0	0	0	10
12	Vandalization of oil pipelines	2	3	2	1	8	2	1	0	0	19
13	Militancy	6	8	5	2	11	6	4	5	0	47
14	Engine failure	3	5	2	2	2	4	3	3	4	28
15	Engine fire	2	4	6	3	5	16	3	3	3	45
16	Hijack	0	0	0	0	0	0	0	3	0	3
17	Boat snatching	4	2	3	2	1	0	1	2	1	16
	Grand total	**114**	**101**	**103**	**48**	**119**	**93**	**55**	**95**	**58**	**786**

Source: *Department of Marine Operation, Nigeria Police Force (2025)*

Conclusion

Marine vessel accidents along inland waterways constitute a significant transportation-safety challenge in Rivers State because of the extensive dependence of riverine communities on waterways for passenger transportation, fishing, commercial activities and access to settlements. The review of existing literature indicates that accidents result from the interaction of human, technical, environmental, infrastructural and institutional factors rather than from a single cause (Idiapho & Awwal, 2020; Nze & Nze, 2023).

The study concludes that human factors constitute some of the most important determinants of marine vessel accidents along Nigerian inland waterways. Overloading, over-speeding, inadequate operator experience, negligence, poor knowledge of navigation routes, failure to use life jackets and non-compliance with safety regulations can substantially increase accident risks. Evidence from the South-South region particularly identifies overloading and over-speeding as major contributors to passenger-vessel accidents (Akpudo, 2021; Zakari et al., 2025).

The study further concludes that technical and mechanical conditions of vessels significantly influence accident occurrence and severity. Engine failure, steering failure, poor maintenance, structural deficiencies and inadequate vessel inspection can reduce navigational reliability and increase the probability of accidents. Consequently, the safety of inland-waterway transportation depends not only on the competence of vessel operators but also on the condition and regulatory certification of vessels (Idiapho & Awwal, 2020).

Environmental and geographical conditions are also important determinants of vessel accidents in Rivers State. Strong winds, storms, rainfall, poor visibility, currents, changing water levels, narrow channels, sedimentation and other navigational conditions can increase the risk of accidents. These factors may become particularly dangerous when combined with over-speeding, inadequate navigation skills and insufficient navigational aids (Idiapho & Awwal, 2020; Zakari et al., 2025).

The study concludes that marine vessel accidents exhibit identifiable spatial patterns rather than occurring randomly throughout Rivers State. Areas with high vessel traffic, busy jetties, intense commercial activities, difficult navigational conditions and high population concentrations are likely to experience greater accident exposure. Consequently, GIS-based hotspot analysis provides an important method for identifying locations where accident-prevention resources should be concentrated (Ogboeli et al., 2023; Obadina et al., 2025).

The analysis of historical accident records is also important for understanding the temporal behaviour of casualties. Examining accident frequencies, fatalities and injuries over time can reveal whether safety conditions are improving or deteriorating and can provide the basis for predicting future casualty levels. Such forecasting is particularly valuable because it enables government agencies and other stakeholders to develop preventive interventions before accidents occur rather than relying solely on post-accident responses (Akpudo, 2021).

The study therefore concludes that an integrated spatial, statistical and forecasting approach provides a stronger basis for inland-waterway safety management in Rivers State. Mapping accident hotspots can reveal where interventions are needed, determinant analysis can explain why accidents occur, and forecasting can indicate the likely future casualty burden. Combining these approaches can support evidence-based decision-making by maritime authorities, state agencies and local communities.

Based on the issues identified in the study, the following recommendations are proposed:

1. Relevant authorities, particularly the National Inland Waterways Authority (NIWA), should strengthen the enforcement of existing inland-waterway safety regulations.
2. All passengers and crew members travelling on commercial passenger vessels should be required to wear appropriate personal flotation devices.
3. Government maritime agencies should strengthen the inspection and certification of passenger boats, barges, tugboats and other vessels operating on Rivers State inland waterways.
4. A comprehensive Rivers State Inland Waterway Accident Hotspot Map should be developed using GIS.
5. Navigational aids such as buoys, channel markers, warning signs, lights and appropriate communication systems should be installed and regularly maintained along major inland-waterway routes
6. Government agencies should regularly assess and maintain navigable channels. Dredging and removal of obstructions should be undertaken where necessary,
7. All commercial vessel operators should undergo standardized training and certification before being permitted to operate passenger or commercial vessels.
8. Authorities should establish and enforce clearly defined passenger and cargo limits for different categories of vessels.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Akpudo, C. U. (2021). Trend analysis of boat accidents and causes in the waterways of Nigeria. International Journal of Scientific Research in Multidisciplinary Studies, 7(11), 24–29.

Akpudo, C. U. (2021). Trend analysis of boat accidents and causes in the waterways of Nigeria. International Journal of Scientific Research in Multidisciplinary Studies, 7(11), 24–29.

Idiapho, C. A., & Awwal, S. I. (2020). Investigative analysis of marine tugboat accident in Nigeria: A case study of Bayelsa, Delta and Rivers State. Journal of Engineering Research and Reports, 11(3), 30–45. https://doi.org/10.9734/jerr/2020/v11i317062

Idiapho, C. A., & Awwal, S. I. (2020). Investigative analysis of marine tugboat accident in Nigeria: A case study of Bayelsa, Delta and Rivers State. Journal of Engineering

Research and Reports, 11(3), 30–45. https://doi.org/10.9734/jerr/2020/v11i317062.

National Inland Waterways Authority. (2025). FG inaugurates Special Committee to curb boat mishaps in Nigeria. National Inland Waterways Authority.

National Inland Waterways Authority. (2026). NIWA, NSIB strengthen collaboration to enhance safety on inland waterways. National Inland Waterways Authority.

National Inland Waterways Authority. (2026). NIWA, NSIB strengthen collaboration to enhance safety on inland waterways. National Inland Waterways Authority.

Nze, I. C., & Nze, N. J. (2023). Risk analysis of inland waterways transportation on the Niger Delta Basin, Nigeria. International Journal of Research and Innovation in Applied Science, 8(7), 1–10.

Nze, I. C., & Nze, N. J. (2023). Risk analysis of inland waterways transportation on the Niger Delta Basin, Nigeria.

Obadina, S., Ogboeli, G. P., & Nimame, P. K. (2025). Mapping vulnerability and improving disaster response through inland waterways in Rivers State. Global Journal of Earth and Environmental Science, 10(6).

Ogboeli, G. P., Iyama, W. A., & Onuegbu, W. (2023). Incidences and trend of marine accident fatalities in various river routes connecting the major sea ports of Nigeria. British Journal of Environmental Sciences, 8(4), 109–122.

Ogboeli, G. P., Iyama, W. A., & Onuegbu, W. (2023). Incidences and trend of marine accident fatalities in various river routes connecting the major sea ports of Nigeria. International Journal of Research and Innovation in Applied Science, 8(4), 109–122.

Wang, et al. (2024). A data-driven ISM-BN model for safety analysis of inland shipping in the Pearl River Basin. Ocean Engineering.

Zakari, I. A., Ozakpo, O. A., & Kpang, M. B. T. (2025). Analytical cross examination of the causal factors of passenger's vessel accidents along inland waterways in South-South region, Nigeria. Advance Journal of Management and Social Sciences, 9(5), 38–56.