

Systematic Review on Risk Mitigation Strategies for Enhancing Operational Efficiency in Inland Waterways Transportation: The Nigerian Context

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ABSTRACT

This paper presents a systematic review of risk mitigation strategies to improve the operational efficiency of inland waterways transportation (IWWT) in Nigeria. It focuses on challenges specific to Nigeria's inland waterways and examines global strategies for operational efficiency. By comparing practices from Europe, Southeast Asia, and Africa, the study highlights solutions to funding constraints, piracy, human error and environmental risks. Strategies include GPS integration, port upgrades, infrastructure development, regulatory reforms, adoption of sustainable technologies and fostering public-private partnerships to address these challenges. The findings provide actionable recommendations and future research directions for enhancing the efficiency and safety of Nigeria's inland waterways system.

Keywords: *Infrastructure Development, Inland Waterways Transportation (IWWT), Operational Efficiency, Regulatory Frameworks, Risk Mitigation.*

1.0 INTRODUCTION

The economic and social progress of any country depends heavily on its transportation system, which facilitates the movement of people, commodities, and services (Cheng, Jiang, & Nielsen, 2023). As a more economical and environmentally friendly alternative to road and rail transportation, inland waterways transportation—a subset of the larger transportation network—is especially important in areas with vast river systems (Browne, Dubois, & Hulthén, 2023). Despite abundant waterways, Nigeria lags in exploiting this mode of transport due to systemic inefficiencies, including poor infrastructure and weak regulatory enforcement. Inland waterways, such as rivers, creeks, and lagoons, present significant opportunities to improve transportation efficiency, reduce road congestion, and foster economic growth in nations such as Nigeria (Afolabi, 2023).

However, Nigeria's inland waterways transportation (IWT) is confronted with numerous operational issues despite its great promise. These include environmental hazards, such as flooding and sedimentary flows, inadequate infrastructure, navigational challenges, and weak regulatory oversight (Adewumi et al., 2023; Akpudo, 2021). Furthermore, the sector's expansion has been hindered by safety concerns resulting from outdated navigation equipment, inadequate safety measures, and vessel overloading (Badejo, 2014). Unlocking the full potential of Nigeria's inland waterways and advancing

effective transportation networks depend on addressing these systemic issues.

To ensure operational efficiency and minimize vulnerabilities in Nigeria's IWT system, risk mitigation strategies are crucial. Globally, several tactics have proven successful in enhancing operational efficiency and reducing risks, including the adoption of modern navigation systems, strict enforcement of safety regulations, and infrastructure improvements (Syaiful, Pratikso, & Mudjanarko, 2023). However, implementing these strategies in the Nigerian context requires a deep understanding of the sector's unique risks and challenges.

The objective of this systematic review is to identify and synthesize existing literature on risk mitigation strategies with the aim of improving the operational efficiency of inland waterways transportation in Nigeria. This analysis evaluates global best practices and their applicability to Nigeria, providing a comprehensive understanding of the risks and mitigation strategies necessary to enhance the effectiveness and safety of Nigeria's inland waterways system. By assessing the relevance of global risk mitigation models to the Nigerian context, this review aims to bridge a critical gap in the literature.

2.0 METHODOLOGY

2.1 SEARCH STRATEGY

An organized method was used in this systematic review to find and compile pertinent material. Several electronic databases, including Google Scholar, IEEE Xplore, Scopus, and ScienceDirect, were used in the search. Combinations of keywords associated with the study's scope were used as the main search phrases, which included "inland waterways," "risk mitigation," "transportation efficiency," "Nigeria," and "operational risks." Boolean operators (AND, OR) were applied to refine the search results, focusing on studies that specifically addressed risk management in inland waterways. For instance, phrases like "risk mitigation AND inland waterways" were combined.

Studies focusing on air or land transportation were excluded unless they presented risk mitigation models that could be applied to waterways. This is because air and land transport differ significantly from inland waterways in terms of operational challenges and mitigation strategies, such as the nature of navigation, environmental risks, and infrastructure requirements.

The search was restricted to studies published between 2010 and 2024 to ensure the inclusion of the most up-to-date research on the subject. Only peer-reviewed articles, technical reports, and case studies were included to ensure quality and academic rigor, as illustrated in the PRISMA flow diagram (Figure 1).

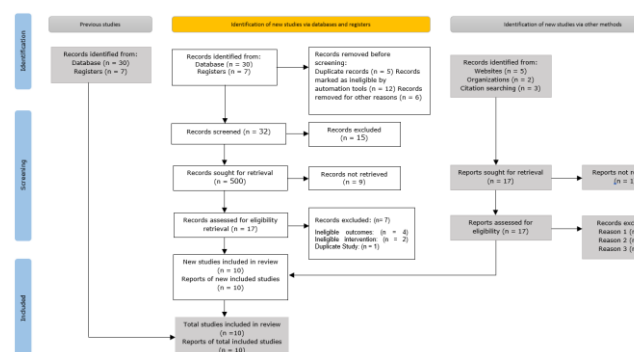


Figure 1: PRISMA Flow Diagram

2.2 INCLUSION AND EXCLUSION CRITERIA

To ensure relevance and quality, the following inclusion and exclusion criteria were applied:

2.2.1 INCLUSION CRITERIA

- Studies that directly addressed risk mitigation in inland waterways.

- Research focused on improving operational efficiency through risk management.
- Articles and reports published in peer-reviewed journals or as official reports.
- Research that evaluated risk mitigation strategies in developing countries or regions with similar transportation infrastructure to Nigeria.
- Studies were published between 2010 and 2024.

2.2.2 EXCLUSION CRITERIA

- Studies focusing solely on land or air transportation without mentioning inland waterways. These modes were excluded as they differ significantly in operational challenges, including navigation, environmental risks, and infrastructure requirements.
- Research outside the scope of operational efficiency or risk mitigation.
- Non-peer-reviewed literature, such as opinion pieces or conference abstracts without empirical data.
- Studies written in languages other than English.

2.3 DATA EXTRACTION PROCESS

The data extraction process involved systematically identifying and organizing key information from the selected studies. A data extraction form was used to capture relevant details from each study, including:

- Study details (e.g., author, year, country).
- Types of risks identified in inland waterways transportation.
- Risk mitigation strategies discussed.
- Outcomes of the risk mitigation measures on operational efficiency.
- Applicability of strategies to the Nigerian context.

2.4 QUALITY ASSESSMENT

To ensure the reliability and validity of the findings, the quality of the selected articles was assessed using a modified version of the Cochrane Risk of Bias tool. This tool evaluates factors such as:

- Methodological rigor (e.g., study design, sample size, data collection methods).
- Potential biases (e.g., selection bias, reporting bias).
- Relevance to the research questions (i.e., the extent to which the study focused on risk mitigation and operational efficiency in inland waterways).

Studies that scored poorly on these quality indicators were excluded from the final review to maintain the integrity of the systematic review process.

3.0 RESULTS

3.1 OVERVIEW OF INCLUDED STUDIES

A total of ten significant papers that examined operational difficulties and risk mitigation techniques in inland waterways transportation across different geographies were included in this systematic review. These studies emphasize critical elements such as inadequate infrastructure, navigational risks, safety infractions, and environmental hazards that influence the effectiveness of inland waterways systems. The findings underscore the necessity of comprehensive approaches, including infrastructure investments, regulatory frameworks, and technological advancements, to enhance the operational efficiency of inland waterways, particularly in developing countries like Nigeria. Table 1 provides a concise summary of the studies reviewed, highlighting their geographic focus, key findings, and relevance to Nigeria's inland waterways system.

TABLE 1: KEY STUDIES ON RISK MITIGATION AND OPERATIONAL CHALLENGES IN INLAND WATERWAYS

Study Reference	Year	Country/Region	Key Findings	Relevance to Nigeria
Gast et al.	2020	Global	Notification time significantly impacts risk mitigation in supply chain logistics	High
Nwaogbe & Ogorode	2024	Nigeria	Operational performance and service quality in inland waterways are influenced by infrastructure quality and staff	High

Akpuduo	2021	Nigeria	Human errors, natural factors, and mechanical failures are key causes of boat accidents in Nigeria	High
Nwanikwo & Ukoji	2015	Nigeria	Overloading, piracy, and poor weather are major causes of boat accidents in the Niger Delta	High
Idiapho & Awwal	2020	Nigeria	Human errors and technical failures are the primary causes of tugboat accidents	High
Portman	2018	Israel/Mediterranean	Integration of inland water and coastal management improves resilience to coastal erosion	Moderate
Pratas, Garriido, & Pimentel	2023	Brazil	A framework for sustainable inland waterways systems, focusing on multimodal	Moderate

Hassan & Xuefeng	2022	Bangladesh	Integration and government support	High
			Infrastructure deficiencies, such as low-depth channels and poor port facilities, hinder inland waterways transport	
David	2023	Europe	Sustainable goods transport	Moderate
			via inland waterways requires investment in fuel-efficient vessels and green technologies	
Rosset al.	2020	Netherlands, Sweden	Drivers for IWT include congestion relief and environmental benefits, but barriers such as poor hinterland connectivity remain	Moderate

3.2 IDENTIFIED RISKS IN INLAND WATERWAYS

Various hazards affecting inland waterways transportation systems were identified in the reviewed studies. These risks include environmental hazards, navigational challenges, human errors, and infrastructural

deficiencies. Table 2 presents the key risks along with their relevance to Nigeria.

TABLE 2: CATEGORIZATION OF RISK FACTORS IN INLAND WATERWAYS TRANSPORTATION

Risk Factor	Study Reference	Description	Relevance to Nigeria
Navigational Hazards	Akpudo (2021)	Poor navigation tools and unmarked channels lead to frequent accidents.	High
Human Errors	Idiapho & Awwal (2020)	Overloading and improper operation of vessels contribute to accidents.	High
Environmental Risks	Nwaogbe & Ogorode (2024)	Flooding and sedimentation disrupt inland waterways transport	High
Infrastructure Deficiency	Hassan & Xuefeng (2022)	Poor port facilities and low-depth channels limit the efficiency of transport	High
Regulatory Deficiencies	Rosset al. (2020)	Lack of regulatory support for inland waterways hinders operational efficiency	Moderate
Technical Failures	Idiapho & Awwal (2020)	Mechanical failures, such as engine breakdowns, are common in tugboat accidents	High
Natural Disasters	Portman (2018)	Coastal erosion and inland flooding threaten transportation	Moderate

Logistical Challenges	Gast et al. (2020)	Inadequate notification times affect the ability to mitigate logistical risks	Moderate	Management	monitoring and water management practice	High	High
				Public-Private Partnerships	Pratas et al. (2023)	Collaboration between government and private sector for infrastructure investment	

3.3 RISK MITIGATION STRATEGIES

The studies reviewed propose several risk mitigation strategies that can enhance the operational efficiency of inland waterways transportation systems.

TABLE 3: RISK MITIGATION STRATEGIES FOR INLAND WATERWAYS TRANSPORTATION

Mitigation Strategy	Study Reference	Description	Effectiveness	Applicability to Nigeria	Use of Sustainable Technologies	David (2023)	Adoption of green technologies like fuel-efficient vessels and route optimization software	Moderate	High
Improved Navigational Tools	Akpu do (2021)	Use of GPS and radar systems to improve navigation and avoid hazards	High	High					
Dredging and Port Upgrades	Hassan & Xuefe ng (2022)	Regular dredging and upgrading port facilities for better throughput	High	High	Training and Capacity Building	Nwagbo & Ogorode (2024)	Operator training and education programs on safety and risk mitigation	Moderate	High
Safety Regulation Enforcement	Idiapho & Awwal (2020)	Enforcement of safety protocols, including life jacket use and vessel inspections	High	High	Regulatory Reforms	Rosonet al. (2020)	Reforming regulatory frameworks to improve governance and oversight	Moderate	High
Environmental Risk	Portman (2018)	Implement flood	Moderate	Moderate					

Hydrographic Surveys	Gast et al. (2020)	Conducting regular hydrographic surveys to ensure navigability	Moderate	Moderate
Community Engagement	Nwanjoku & Ukoji (2015)	Engaging local communities to reduce piracy and improve compliance	Moderate	High

A thorough overview of the risk mitigation techniques considered in the study is given in Table 3, which also includes information on how they were implemented, how effective they were judged to be, and how applicable they were in the Nigerian setting. It highlights how these tactics may be used to tackle important issues in inland waterways transportation and provides information on how international best practices can be modified to improve operational effectiveness and safety in Nigeria.

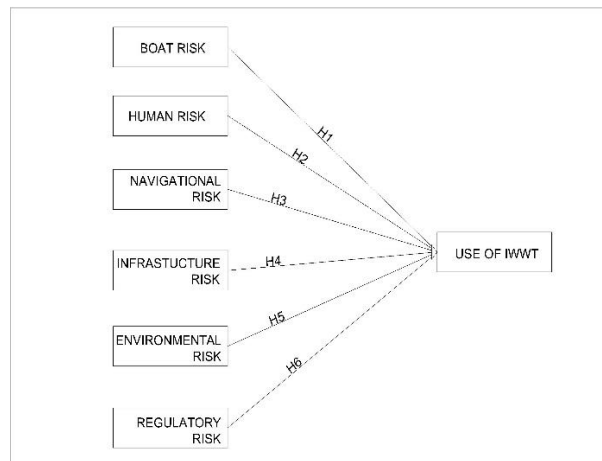


Figure 2: Conceptual Model Highlighting Key Risks in Nigerian's Inland Waterways

Figure 2 illustrates a conceptual model of key risks impacting the use of Inland Waterways Transportation (IWWT), categorized into six factors: Boat Risk (H1), which pertains to vessel conditions and maintenance; Human Risk (H2), arising from errors such as inadequate training or improper operation; Navigational Risk (H3), related to challenges with water hyacinth infestation and unmarked channels; Infrastructure Risk (H4), encompassing inadequate or poorly maintained jetties and waterways; Environmental Risk (H5), involving

natural hazards like flooding and sedimentation; and Regulatory Risk (H6), stemming from weak enforcement and governance. These risks collectively influence the safety, efficiency, and operational effectiveness of IWWT, highlighting the importance of targeted mitigation strategies to optimize this critical transportation mode.

3.4 APPLICATION TO NIGERIA

The global risk mitigation strategies identified in the review provide valuable insights for improving Nigeria's inland waterways transportation system. However, some of these strategies need to be adapted to the local context, considering Nigeria's unique challenges such as piracy, militancy, and infrastructural limitations.

TABLE 4: APPLICATION OF GLOBAL STRATEGIES TO NIGERIA

Global Strategy	Region Applied	Effectiveness (Based on Studies)	Adaptability to Nigeria	Barriers to Implementation
Improved Navigational Tools	Global (Akpu do, 2021)	High	High	Cost, lack of technical expertise
Dredging and Port Upgrades	Bangladesh (Hassan & Xuefeng, 2022)	High	High	Funding constraints, bureaucratic delays
Safety Regulation Enforcement	Nigeria (Idiapho & Awwal, 2020)	High	High	Weak enforcement, corruption
Sustainable Technologies	Europe (David, 2023)	Moderate	High	High cost of fuel-efficient vessels
Public-Private Partnerships	Brazil (Pratas et al., 2023)	High	High	Limited private investment
Hydrographic Surveys	Global (Gast et al., 2020)	Moderate	Moderate	Insufficient funding, expertise

Regulatory Reforms	Netherlands (Roso et al., 2020)	Moderate	High	Political instability, outdated laws
Training and Capacity Building	Nigeria (Nwagbo & Ogorode, 2024)	Moderate	High	Limited access to resources

Table 4 outlines the global strategies and their potential application in Nigeria, highlighting key barriers such as funding constraints, weak regulatory enforcement, and limited technical expertise.

4.0 DISCUSSION

4.1 GLOBAL PRACTICES VS. NIGERIAN CONTEXT

Global best practices in inland waterways transportation, particularly from regions like Europe, Southeast Asia, and Africa, demonstrate effective risk mitigation strategies focused on enhancing infrastructure, implementing safety regulations, and leveraging advanced technologies to improve operational efficiency. For example, Europe has significantly enhanced the sustainability and efficiency of inland waterways through the adoption of fuel-efficient vessels, GPS navigation systems, and route optimization software (David, 2023; Roso et al., 2020). However, while these technologies are highly effective, their adoption in Nigeria is hindered by prohibitive costs and limited technical expertise, which restrict the capacity to operate and maintain such systems effectively.

In Southeast Asia, substantial investments in dredging and inland port construction have successfully addressed challenges such as siltation and inadequate port infrastructure (Hassan & Xuefeng, 2022). These strategies could greatly benefit Nigeria, where similar challenges persist. However, the implementation of such large-scale projects in Nigeria is impeded by funding constraints and bureaucratic inefficiencies.

Africa's inland waterways systems, though less advanced, share similar challenges with Nigeria, including weak regulatory enforcement and limited funding for infrastructure improvements. Initial attempts at regulatory reform in African nations have shown some promise, but Nigeria struggles with underfunded agencies like NIWA and NIMASA, which lack the resources and authority to enforce safety standards effectively (Idiapho & Awwal, 2020).

While advanced technological solutions, such as radar systems and GPS navigation, have the potential to

mitigate navigational hazards, their implementation in Nigeria is further hampered by a shortage of skilled professionals to operate and maintain these technologies. Thus, tailoring these global strategies to Nigeria's context requires addressing its unique challenges, including funding deficits, governance gaps, and environmental vulnerabilities.

TABLE 5: COMPARATIVE ANALYSIS OF RISK MITIGATION STRATEGIES BY REGION

Region	Key Risk Mitigation Strategies	Effectiveness	Challenges	Applicability to Nigeria
Europe	- Adoption of sustainable technologies (e.g., fuel-efficient vessels, GPS navigation) - Route optimization software	High	High costs of green technologies Infrastructure upgrades required	Partially applicable, but requires significant investment in technology and infrastructure
South east Asia	- Dredging and port upgrades - Infrastructure development and siltation control	High	Maintaining infrastructure Environmental challenges like siltation	Highly applicable, especially for addressing infrastructure challenges in Nigeria
Africa	- Basic infrastructure improvements - Initial attempts at regulatory reform	Moderate	Weak regulatory enforcement Limited funding for large-scale projects	Similar challenges to Nigeria, particularly in regulatory enforcement

				and funding
Nigeria	- Limited infrastructure development (dredging, port upgrades) - Regulatory improvements (but weak enforcement)	Low to Moderate	Weak enforcement Limited technological adoption Funding constraints	Requires tailored strategies focused on infrastructure development and regulatory reform

A thorough comparative study of risk reduction techniques used in Nigeria, Europe, Southeast Asia, and Africa is given in Table 5. It draws attention to the tactics' efficacy, the difficulties that each region encounters, and how these strategies might be applied to Nigeria's inland waterway system.

4.2 CHALLENGES IN IMPLEMENTATION

Several challenges restrict the successful adoption of global best practices in Nigeria's inland waterways transportation system:

- Funding Constraints:** Advanced technologies like GPS navigation systems and fuel-efficient vessels require significant investment, which is often unattainable due to Nigeria's limited public and private funding (Nwankwo & Ukoji, 2015).
- Weak Regulatory Frameworks:** Unlike Europe or Southeast Asia, where regulations are stringently enforced. Nigeria's regulatory bodies face challenges like inadequate funding and corruption, limiting their ability to implement and monitor safety standards effectively (Idiapho & Awwal, 2020).
- Technical Expertise Gaps:** Many of the global practices rely on skilled personnel to implement and sustain them. In Nigeria, a lack of trained professionals hinders the adoption of advanced systems like route optimization software and sustainable technologies (David, 2023).
- Environmental Challenges:** Frequent flooding, sedimentation, and other natural hazards disrupt inland waterways operations. These challenges are exacerbated by a lack of comprehensive hydrographic surveys and flood

monitoring systems (Nwaogbe & Ogorode, 2024).

4.3 POLICY AND PRACTICE IMPLICATIONS

Addressing the challenges and aligning global practices with Nigeria's context requires targeted policy and practical interventions:

- Infrastructure Investments:** Large-scale investment in dredging, port upgrades, and channel maintenance is essential. Public-private partnerships (Pratas et al., 2023) can play a pivotal role in mobilizing resources and technical expertise for these projects.
- Strengthening Regulatory Frameworks:** Regulatory bodies like NIWA and NIMASA must be empowered with adequate funding, resources, and authority to enforce safety standards. Introducing incentive-based compliance programs could also encourage adherence to regulations (Idiapho & Awwal, 2020).
- Capacity Building and Training:** Investing in operator training programs is critical for addressing skill shortages. Such programs should focus on advanced navigation tools, safety protocols, and green technologies to ensure operators are equipped to manage risks effectively (Nwaogbe & Ogorode, 2024).
- Adopting Technological Solutions:** Although the high cost of GPS navigation systems, fuel-efficient vessels, and route optimization software poses a challenge, these technologies offer long-term benefits in reducing accidents and improving efficiency (Rafalias, 2024). Funding mechanisms like government subsidies or international aid could offset initial costs.
- Environmental Risk Management:** Comprehensive hydrographic surveys and flood monitoring systems are crucial for predicting and mitigating the impacts of natural disasters. Adopting water management practices, such as sediment control, could enhance resilience against environmental disruptions (Portman, 2018).

CONCLUSION

This systematic review highlights the critical risks affecting Nigeria's inland waterways transportation system, including inadequate infrastructure, weak regulatory enforcement, and navigational hazards. While global best practices, such as the use of advanced technologies, infrastructure upgrades, and strict enforcement of safety regulations, have proven

successful elsewhere, their implementation in Nigeria faces significant challenges due to funding limitations and a lack of technical expertise.

To address these challenges, immediate efforts should focus on cost-effective, context-specific solutions. For example, future studies should prioritize the development and deployment of low-cost GPS navigation systems tailored to Nigeria's waterways. Public-private partnerships must be actively pursued to mobilize resources for dredging projects and port upgrades, while capacity-building programs should focus on equipping operators with the necessary skills to adopt and maintain advanced technologies.

Additionally, targeted regulatory reforms are essential to empower agencies like NIWA and NIMASA with adequate funding and authority to enforce safety standards. To mitigate environmental risks such as flooding and sedimentation, comprehensive hydrographic surveys and flood monitoring systems should be prioritized. Addressing piracy and militancy will require engaging local communities and introducing incentive-based compliance programs to foster cooperation. By aligning global best practices with Nigeria's unique challenges and leveraging tailored implementation pathways, the operational efficiency and safety of the country's inland waterways system can be significantly enhanced.

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