NASS
NAN YANG ACADEMY OF SCIENCES

**Sustainable Marine Structures**
https://journals.nasspublishing.com/index.php/sms

**REVIEW ARTICLE**

# Trend Analysis of Marine Construction Disaster Prevention Based on Text Mining: Evidence from China

**Yin Junjia[1*], Aidi Hizami Alias[1], Nuzul Azam Haron[1], Nabilah Abu Bakar[1]**

[1] Department of Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang 43400, Selangor, Malaysia

**Abstract:** Global climate change has led to frequent natural disasters such as tsunamis and earthquakes, making offshore construction risky. In this paper, high-level papers from the Web of Science (WoS) were searched, and critical terms were identified and categorized using text-mining techniques. To ensure the resilience and safety of marine structures, we discuss the challenges of marine clays, marine eco-civilization construction, and disaster prevention databases. The recommendations presented provide valuable insights for engineers, researchers, and other stakeholders involved in marine construction projects.

**Keywords**: Text mining; Web of Science; Marine construction; Disaster prevention; Literature review

## 1. Introduction

Marine construction is a key global infrastructure sector, contributing significantly to economic development and trade [1]. However, the industry also faces inherent challenges, particularly regarding disaster preparedness. Natural disasters, such as hurricanes, tsunamis, and storm surges, pose a significant threat to marine structures, jeopardizing their integrity with severe economic and environmental consequences [2]. Between 1998 and 2017, tsunami losses totaled 251,770 people and $280 billion [3]. Over the past decade, the annual direct economic losses caused by marine disasters in China's coastal cities have reached an average of 10.004 billion yuan, with storm surges causing particularly serious losses, accounting for about 97% of the total [28]. With such disasters' increasing frequency and intensity, exploring innovative approaches and recent advances in disaster prevention in marine building construction has become imperative. In recent years, there has been a growing awareness of the vulnerability of marine structures and the need for solid disaster prevention measures, particularly in Indonesia, Sri Lanka, Thailand, and Maldives [4]. This awareness is underscored by the proliferation of high-

*Corresponding Author:
Yin Junjia,
Department of Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang 43400, Selangor, Malaysia;
*Email: gs64764@student.upm.edu.my*

**Received:** 23 January 2024; **Revised:** 15 March 2024; **Accepted:** 20 March 2024; **Published Online:** 31 March 2024

**Citation:** Yin, J.J., Alias, A.H., Haron, N.A., et al., 2024. Trend Analysis of Marine Construction Disaster Prevention Based on Text Mining: Evidence from China. *Sustainable Marine Structures*. 6(1), 20–32. http://dx.doi.org/10.36956/sms.v6i1.1026

DOI: http://dx.doi.org/10.36956/sms.v6i1.1026

level research articles available through platforms like the Web of Science [5]. These articles delve into many topics, including structural engineering, materials science, and environmental factors, and provide valuable insights into the marine construction industry's challenges [6-10]. Li-ping et al. [27] used seawater and coral sand instead of freshwater and river sand to prepare highly ductile cementitious composites and obtained good ductility and toughness. Døskeland et al. [29] found that response forecasting can improve the accuracy of weather-sensitive offshore construction decisions. Using calibrated noise loggers to characterize broadband noise levels and AIS data integrated with engineering records to characterize ship activity, Benhemma-Le et al. analyzed the large-scale response of harbor porpoises to piling and ship activity during the construction of an offshore wind farm [31]. Xu et al. [32] developed a four-quadrant conceptual framework for analyzing extended producer responsibility in offshore prefabricated construction, considering the scope and scale of responsibility and procurement methods. According to the latest Scopus data (21 March 2024), as shown in Figure 1, the literature related to offshore construction has expanded in size in nine years, from 517 to 665 per year.

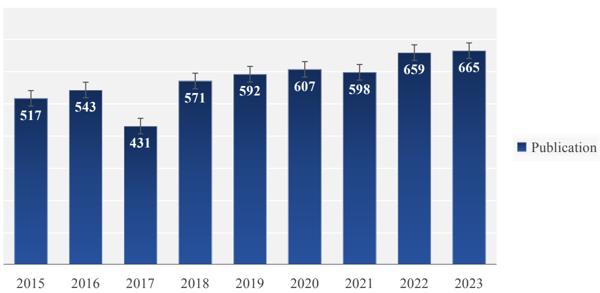


**Figure 1.** Annual number of offshore construction articles published.

As a result, many scholars have conducted literature reviews on offshore construction. Paiva et al. [30] analyzed the current state of scientific research on wave energy converters (WEC) through bibliometric methods. They found that Brazilian universities are leading in productivity, accounting for more than 36% of the scientific results on WEC. Amaechi et al. [31] analyzed trends in marine hose research through scientometrics analysis and found difficulties in the adaptation, acceptability, qualification, and deployment of marine hoses in the offshore marine industry. However, no study has comprehensively reviewed disaster reduction in offshore construction. This study aims to fill this gap. The study synthesizes and analyzes the vast amount of information available on the Web of Science, using text-mining methods to extract meaningful patterns and trends in disaster prevention strategies for marine building construction. This study is set in China, where it has completed many offshore construction projects. For example, the Penang Second Crossing Bridge in Malaysia, the longest cross-sea road bridge in Southeast Asia, was implemented by a Chinese company and is 22.5 kilometers long, with a total investment of about US$1.45 billion. Some of the projects currently under construction are shown in Table 1.

**Table 1.** Large offshore construction projects under construction in China.

| Project name | Descriptions |
| --- | --- |
| Carbon sequestration demonstration project for enping 15-1 oilfield | China's first million-ton offshore carbon sequestration demonstration project is located in the waters of the Pearl River Estuary. The project marks China's initial formation of drilling and completion technologies and equipment systems for offshore carbon dioxide injection, storage, and monitoring. |
| Enping 10-2 platform | China's first independently designed and built standardized unmanned platform with 20 sound slots and an oil and gas handling capacity several times that of traditional unmanned platforms. |
| Deep ocean one energy station | China's first independently designed and built 100,000-tonne, deepwater semi-submersible production and storage platform. |
| Floating offshore wind projects | China's first large-scale deep and distant sea offshore wind power project started in Wanning City, Hainan Province. With a total installed capacity of one million kilowatts, an average water depth of 100 meters, and a planned area of 160 square kilometers, the project is one of the world's most significant commercial floating offshore wind projects. |

Note: All information from https://news.cctv.com/

The complexities inherent in marine building construction necessitate a comprehensive understanding of the challenges engineers, policymakers, and stakeholders face. From outdated design standards to environmental uncertainties, this paper aims to shed light on the multifaceted nature of disaster prevention in marine construction. The core research questions are as follows:

1). Which disasters are currently more frequent in offshore construction?

2). What research topics are popular in the field of disaster reduction in offshore construction?

3). How can current offshore construction disaster reduction practices be improved?

By consolidating information from high-level articles, we strive to offer a nuanced perspective on the current state of knowledge and explore recent advances that pave the way for more resilient and sustainable marine structures. Ultimately, this research contributes to the ongoing dialogue on disaster prevention, offering insights to inform future policies, practices, and innovations in marine building construction. The rest of this study is structured as follows: Section 2 describes the research methodology; Section 3 describes the results of the survey, including thematic analyses; Section 4 discusses the improvement strategies for offshore construction hazard mitigation and future research directions; and Section 5 concludes the study and points out limitations.

## 2. Materials and Methods

Referring to many reviews of text mining (TM) based approaches, the study is divided into five steps based on TM techniques [51,52].

1). Database Selection: Articles between the WoS data are recognized as high-level articles globally. Therefore, it is chosen as a database to collect relevant literature for this paper. Ensure that the quantity and quality of the literature are sufficient to support this study.

2). Literature Search: 168 kinds of literature were retrieved from the WoS database using the keywords “disaster prevention”, “disaster”, “marine construction”, and “offshore construction” in combination with each other. After retrieval, the collected literature was initially screened according to Table 2, leaving those that fit the research theme and removing those that were irrelevant based on the relevance of the title and abstract. Then, further screening was done by reading the retained literature’s full text to exclude literature irrelevant to the research topic or of low quality.

**Table 2.** Literature selection criteria.

| Items | Criteria |
|---|---|
| Language | English |
| Area | China |
| Year | 2015-2024 |
| Article type | Research articles |
| Thematic relevance | Strong correlation |

3). Data Extraction: Data and information related to the research topic, such as keywords, methods, results, etc., were extracted from the screened literature. Then, the extracted text data were cleaned and pre-processed to remove noise and irrelevant information and standardize the format.

4). Data Analysis: Analyses were performed using text mining tools and techniques with keyword extraction and topic construction [11,12]. The co-occurrence network in Figure 2 shows the main articles, with pink representing classic papers, green representing core papers, and cyan representing key papers. LDA analysis shows the current hot topics in marine building disaster prevention.

**Figure 2.** Related literature co-occurring network.

5). Trend Analysis: based on the results of the studies, improvement strategies for current marine disaster prevention and future research frameworks are proposed.

The LDA (Latent Dreichler Allocation) analysis used in this study is a statistical technique to reveal the hidden topic structure in a collection of text documents. It works on the assumption that each document is a mixture of multiple topics, and each topic is a distribution of words. By analyzing the co-occurrence patterns of words in a document, LDA can identify these potential themes and their prevalence in the corpus. Through this process, researchers can gain insight into the dominant and sub-themes present in the documents, which can lead to a deeper understanding of the themes and help to organize and classify large amounts of information.

## 3. Results

### 3.1 Common Hazards in Marine Construction

Many types of disasters are common in marine construction. The following Table 3 shows two cases of offshore construction accidents from the official website of the China Maritime Safety Administration:

Table 4 illustrates the climatic characteristics of the significant sea areas in China. Storm surge is the most critical disaster, particularly in offshore oil and gas exploration construction [35]. It is an abnormal rise and fall phenomenon of the sea surface caused by tropical cyclones, temperate cyclones, and cold tidal gales, which may trigger the influx of seawater into the land, leading to inundation and destruction [34]. The second is tsunami. It is undersea crustal movement caused by geological activities such as earthquakes, volcanic eruptions, or submarine landslides, which can generate massive waves and cause severe damage to marine construction [39,41]. The effective wave height in near-shore waters is usually greater than 2.5 meters. The third is red tide. It is a harmful ecological phenomenon in which marine plankton reproduces violently under certain conditions, causing seawater to change color. The fourth is an oil spill. It refers to accidents or operational errors during oil development, processing, storage, and transport, resulting in the leakage of crude oil or oil products into the sea [46]. The fifth is salt erosion and corrosion. Salts and chemicals in seawater may cause corrosion and damage to construction materials, increasing maintenance costs and cycles [40]. Finally, unstable submarine geological conditions may lead to settlement, sliding, or tilting of submarine structures, affecting the stability and safety of the project [36].

**Table 3.** Typical offshore construction accidents.

| Item | Time | Description |
|---|---|---|
| Qingdao “4–27” ship pollution accident | 27 April 2021, 8:51 am. | The Panamanian general cargo vessel SEA JUSTICE and the Liberian oil tanker A SYMPHONY collided when anchored in Qingdao Chaolian Island’s southeastern waters. As a result, the bow of the vessel “Yihai” was damaged, and the 2nd cargo hold on the port side of the vessel “Symphony” was broken; about 9,400 tons of cargo oil leaked into the sea, resulting in pollution of the sea area, which constituted a particularly major ship pollution accident. |
| Accident involving dredger Guangdong Zhongshan Gong 8666 in Guangzhou harbor. | 6 May 2021, 9:10am to 9:30am. | When the dredger Guangdong Zhongshan Gong 8666 was dredging in Area A of the channel dredging project outside the mouth gate of Longdong Island, Nansha Harbor District, Guangzhou Harbor, two operators on board died of asphyxiation during the inspection of the second empty compartment on the port side of the vessel. The person in charge of the ship died of asphyxiation during the process of going down to the compartment to help the vessel, which resulted in a total of three deaths. The incident constituted a major water traffic accident. |

Note: The above examples are from https://www.msa.gov.cn/

**Table 4.** Meteorological information for major Chinese seas.

| Sea area | Climate characteristics | Rainfall | Wind speed | Temperature | Direction of tides | Severity of natural disasters |
|---|---|---|---|---|---|---|
| East China Sea (including Yellow Sea and Bohai Sea) | Influenced by subtropical monsoons. Summers are rainy and windy, while winters are relatively dry. | Varied, higher in summer months, influenced by typhoons. | Moderate to strong, especially during typhoon season. | Varied, warm in summer, cool in winter. | Primarily follows the coastal contours. | Moderate to high risk, particularly during typhoon season. |
| South China Sea | Influenced by tropical monsoons. Hot and humid climate with frequent typhoons. | High, especially during summer and typhoon season. | Moderate to strong, with frequent typhoons. | Warm throughout the year. | Tidal currents are influenced by coastal geography and monsoon winds. | High risk due to frequent typhoons and storm surges. |
| North China Sea | Influenced by temperate monsoons. Summers are warm and rainy, while winters are cold and dry. | Moderate, higher in summer months. | Moderate to strong, influenced by monsoon winds. | Varied, warmer in summer, colder in winter. | Tidal patterns follow coastal contours. | Moderate risk, particularly during winter storms. |

## 3.2 Popular Research Topics

In this study, the metadata was extracted with the help of WeiCiYun® with a total of 283,262 words, a size of 276.62 KB, 1296 valid entries, and 42,785 total words. Among them, the number of feature words is 1934. In this study, the first 50 keyword proper nouns are selected for co-occurrence, and the results are shown in Figure 3. Different colors in the graph represent different clusters [44]. The lines between each circular node represent the connection between each keyword. The size of the nodes also reflects the frequency of the keywords. The greater the frequency, the larger the diameter of the node [43].


**Figure 3**. Keyword co-occurrence network.

The number of topics was then chosen to be 6. Six core topic words were extracted, and the perplexity of the LDA model was 246.3. Table 5 shows the score for six theme words: "disaster database", "marine eco-civilization construction", "BIM/VR", "marine environmental air currents", "marine clay" and "dry work".

**Table 5.** Theme word score.

| Topic name | Item count | Total score | Average score |
|---|---|---|---|
| Disaster database | 126(9.72%) | 77.83 | 0.62 |
| BIM/VR | 131(10.11%) | 86.52 | 0.66 |
| Marine eco-civilization construction | 112(8.64%) | 61.92 | 0.55 |
| Marine environmental air currents | 197(15.20%) | 123.40 | 0.63 |
| Marine clay | 131(10.11%) | 81.71 | 0.62 |
| Dry work | 130(10.03%) | 70.49 | 0.54 |

Figure 4 shows the probability distribution of the relevant subject terms to visualize the study. The vertical coordinates in the graph represent the probabilities and the horizontal coordinates represent the number of lines of text in which the subject words are located.

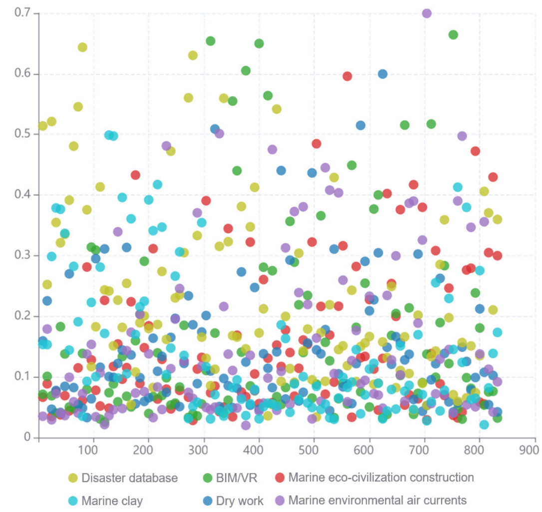


**Figure 4**. Probability distribution of topic words.

### *Disaster Database*

Developing a database on offshore construction disaster preparedness begins with collecting comprehensive data on past offshore construction projects, including detailed information on environmental conditions, geological features, construction methods, and any accidents or disasters [13]. Utilize data from regulatory agencies, industry reports, and project documents. Incorporate information on structural design, safety protocols, and emergency response measures for various hazards. Include data on weather patterns, sea state, and any notable geologic challenges specific to each project site. Implement a standardized data structure and coding system to organize information uniformly [14]. Utilize a relational database management system for efficient data storage, retrieval, and analysis. Regularly update the database with new project data, incident reports, and lessons learned to continually improve disaster prevention strategies for offshore construction based on real-world experience. Collaborate with industry stakeholders to ensure that the database remains comprehensive and relevant and serves as a valuable resource for enhancing safety measures in future offshore constructions. Table 6 presents the databases used by the scholars.

### *Application of BIM and VR*

Applying Building Information Modeling (BIM) and Virtual Reality (VR) to offshore construction disaster prevention requires the creation of a detailed BIM model of an offshore project that contains environmental and structural data [15,16]. This digital twin model can be used as the basis for VR simulations, allowing stakeholders to experience disaster scenarios and assess risk immersivity. VR-based simulation training can also be developed to train personnel in emergency response procedures to enhance preparedness. Real-time sensor data can be integrated into BIM models for continuous monitoring, and VR can provide immersive visualization of crucial parameters. Collaborative decision-making can be facilitated through VR platforms that enable stakeholders to discuss disaster preparedness strategies. the 4D capabilities of BIM help visualize construction sequences, while VR applications help identify safety issues and optimize the process. VR presentations allow stakeholders to learn about safety measures, and the iterative design process incorporates feedback from the VR simulation for continuous improvement. the combination of BIM and VR provides realistic simulations, improves communication, and facilitates the use of VR for constant improvement. The combination of BIM and VR provides realistic simulations, enhances communication, and promotes a collaborative, data-driven approach to offshore construction safety, improving disaster prevention.

## *Marine Environmental Air Currents*

Marine environmental currents can significantly impact offshore construction by affecting construction activities' stability, safety, and efficiency. These currents, including prevailing winds and localized breezes, can present challenges during lifting and installation operations, affecting crane positioning, material transport, and construction vessel stability [17]. Winds can impose lateral loads on structures, making accuracy and control critical during critical construction phases [18]. In addition, the interaction of ambient air currents in the ocean with the complex geometry of offshore structures can create aerodynamic effects that must be carefully considered during the design and engineering process. Understanding and mitigating the impact of these currents is critical to ensuring the safety and success of offshore construction projects.

## *Marine Ecological Civilization Construction*

Building a marine ecological civilization involves developing and implementing sustainable practices to ensure the health and balance of marine ecosystems. The concept emphasizes the harmonious coexistence of human activities with the marine environment and promotes responsible resource management, conservation, and environmental protection [19]. Efforts to build an ecological civilization of the oceans include the reduction of pollution, sustainable fisheries management, the protection of biodiversity, and the adoption of eco-friendly technologies in marine industries. It requires a holistic approach that considers the interconnectedness of marine ecosystems and recognizes the importance of ecological balance for the well-being of the environment and human societies dependent on marine resources [20]. International cooperation, regulatory frameworks, and public awareness play a crucial role in promoting an ecological civilization of the oceans that supports the long-term health and sustainability of the world's oceans.

## *Dry Work*

In offshore construction, dry work is defined as activities performed on structures or components above the waterline that are not submerged in the marine environment [21]. This includes construction tasks performed in areas of an offshore facility that remain dry or above sea level under normal operating conditions. Dry operations include various activities such as welding, painting, equipment installation, and structural modifications that can be performed without direct contact with seawater. Unlike wet work, which involves underwater operations, dry work provides a more controlled and accessible work environment, streamlines the construction process, and ensures the efficiency and safety of the workforce. In recent years, research on dry operations for offshore construction has covered a wide range of fields, with the following research hotspots:

**Table 6.** Offshore construction disaster database.

| Source | Database | Factors |
|---|---|---|
| [53] | 296 major accidents and disasters from the World Offshore Accident Database (WOAD). | Concrete structures, loading buoys, and conduit racks. |
| [54] | 1072 cases from the major European industrial accident databases ARIA (2006), FACTS (2006), MARS (2008), MHIDAS (2001), and TAD (2004), and the US National Response Centre (NRC) database (2008). | Earthquakes: peak ground motion parameters (peak ground acceleration (PGA), peak ground velocity, peak ground displacement) and spectral acceleration.<br>Floods: height of inundation and velocity of water flow. |
| [55] | 170,000 data from various hazards on offshore platforms in the Bohai Oilfield from 2012 to 2022 in CSV format. | Swaying of pipes and flanged joints caused by strong winds and waves; lack of warning signs, lights, and other necessary equipment. |

1). Lightweight Repair Operations of Subsea Wellheads: Research focuses on maintaining and repairing subsea wellheads, including innovations in technology and equipment. Thomer [60] developed unique subsea transmitters and receivers to cover Dolphin Energy's 48-inch and 36-inch subsea pipelines; this allowed the pipelines to be decommissioned and isolated on the seabed so that repairs could be carried out in dry conditions.

2). Analysis and Numerical Simulation of Offshore Floating Wind Turbines: Researchers focus on the power response of floating wind turbines at sea to optimize design and operation. Yang et al. [61] investigated a new concept of motion stabilizer, a completely passive device consisting of several undulating plates.

3). General-Purpose FPSO Topside Modules: Researchers address principles and best practices for interfacing with Floating Production Storage and Offloading Vessel (FPSO) topside modules. Jin et al. [62] developed new procedures to provide a new concept of cumulative failure frequency for assessing the structural safety of upper modules.

4). Pile Sinking for Monopile Foundations for Offshore Wind Turbines: Research in this area focuses on the critical points of sinking pile construction for offshore wind turbine monopile foundations to ensure safety and stability. Liu et al. [63] developed a vibration model of a tubular pile in a marine pile sinking system and found that the energy dissipated by external damping can be reduced, and the efficiency of pile sinking can be improved by modulating the input frequency and optimizing the tubular pile structure.

5). Hydrogen Production from Offshore Wind Power: Researchers explore the technologies and paths for hydrogen production from offshore wind power to promote the use of renewable energy. Luo et al. [64] analyzed methods for hydrogen production from offshore wind power, including alkaline water electrolysis, proton exchange membrane water electrolysis, and solid oxide water electrolysis.

6). Deepwater Semi-Submersible Production Platform (DSPS) Column Oil Storage Structures: Research in this area is concerned with the structural design and application of deepwater DSPS platforms to meet energy needs. Chuang et al. [65] calculated the hydrodynamic response of a semi-submersible submersible to first- and second-order wave forces by combining three-dimensional radiation/diffraction theory and Morison's equations to develop a practical methodology for investigating the collision risk of risers.

## *Marine Clay*

Marine clay, also known as marine sediment or sea mud, is a fine-grained sedimentary material that accumulates at the bottom of the ocean or other bodies of water [22]. It mainly comprises clay minerals, silt, and organic matter and is characterized by a smooth, sticky texture and high plasticity when wet [23]. Marine clay is deposited in low-energy aquatic environments where suspended particles settle slowly to form fine-layered sediments. Marine clay is a typical geological formation in coastal areas and continental shelves. It plays an essential role in various geotechnical and environmental processes, including forming sedimentary rocks, habitats for marine organisms, and essential materials in coastal engineering and construction projects. Marine clay significantly impacts offshore construction due to its unique geotechnical properties. When encountered in submarine sediments, marine clays can present challenges for foundation engineering, as their high plasticity and low shear strength can make it challenging to obtain a stable base for structures such as offshore platforms [24]. The viscous nature of marine clay also presents challenges for construction activities such as drilling, piling, and subsea excavation [25]. Over time, sediments' compressibility and consolidation potential can affect structures' long-term stability. In addition, the interaction between marine clays and offshore infrastructure can lead to problems such as foundation settlement or lateral movement. Engineers and construction planners must carefully evaluate and address these geotechnical issues when designing and implementing offshore construction projects to ensure marine structures' integrity, safety, and longevity [26]. Research on marine clay in recent years has focused on the following aspects.

1). Physical Properties of Seabed Sediments: Researchers have analyzed them from different sea areas in detail for their physical properties, including density, compressibility, and shear strength. These parameters are critical to the design and stability of marine engineering and subsea infrastructure. Shan et al. [56] conducted dynamic triaxial laboratory tests on man-made marine clays containing various clay minerals under the same test conditions and confirmed that clay minerals, especially montmorillonite, significantly affect the dynamic properties of large strains.

2). Microstructure and Thixotropy: The researchers conducted an in-depth study of the microstructure of marine clays to understand their thixotropic properties. Thixotropy is the transformation of soil from solid to fluid under stress. This is important for the safety and reliability of subsea engineering. Bo et al. [57] found that the modifiers affected the unconfined compressive strength of marine clays in the following order: potassium hydroxide > silica > quicklime > burnt plaster.

3). Engineering Properties of Marine Clays: Researchers have explored the behavior of marine clays in different engineering environments, such as subsea anchoring, subsea pipelines, and subsea tunnels. They studied clays' deformation properties, strength, and stability to guide engineering practice. Sun & Yi [59] utilize incinerated bottom ash, waste marine clay, and ground granulated blast furnace slag as building materials.

4). Seafloor Geological Environment: The researchers have investigated the geological environment of different sea areas, including seafloor geomorphology, sediment types, and seismic activities. This helps to understand the formation and distribution of marine clays. Guan et al. [58] found that low sedimentation rates and hydrodynamic perturbations have a greater impact on sedimentary processes in marine clays than climatic fluctuations.

# 4. Discussions

Based on the results of the previous analyses, this study proposes the following future improvement strategies and research directions.

## 4.1 Conduct Thorough Construction Planning and Evaluation

Adequate planning and risk assessment are required before undertaking offshore construction. This includes a thorough understanding of the project objectives, geographical conditions, climatic features, and marine environment, and the use of modern technology and modeling tools to assess the potential impact of natural hazards such as storms and tsunamis that may be faced, as well as the potential implications of human factors such as vessel traffic and pollution [45]. Gaogeng et al. [38] are mainly focused on the prevention and control of severe weather, support structure damage, and seal integrity. At the same time, safety standards and precautions are implemented in cooperation with professional teams and local government authorities to minimize risks and ensure smooth construction.

## 4.2 Adopting Advanced Technologies and Materials

The government should vigorously promote high-quality materials such as carbon fiber composites, high-strength concrete, and corrosion-resistant steel, which are widely used in offshore buildings and have good compressive, tensile, and corrosion-resistant properties and can enhance the structural strength and durability of the building. Advanced construction technologies, including three-dimensional printing, modular construction, unmanned aerial vehicles, and robotics, can improve construction efficiency, reduce costs, and ensure construction quality, thus enhancing the disaster-resistant performance of offshore buildings. Ngo et al. [47] applied a probabilistic approach to calculate the scour depth (SD) and the probability of seismic events to establish a fragile surface at the base of a suction barrel. Finally, the damage probability of suction drum foundations for offshore wind turbines is obtained by combining the product of scour and seismic hazards and the fragility curves. Advanced construction technologies, including three-dimensional printing, modular construction, and drone and robotics, can improve construction efficiency, reduce costs, and ensure construction quality, thus enhancing the disaster resistance of offshore buildings. The integration of multiple sensing and communication technologies, such as Global Navigation Satellite Systems (GNSS), high precision leveling, seismic monitoring, physical datasets (including magnetometers, gravimeters, geo-electromagnetics, resistivity tomography, HPL data), and drones are highly conducive to early warning of hazards in offshore construction [50].

## 4.3 Establishing Environmental Monitoring and Early Warning Systems

To establish an effective environmental monitoring and early warning system, it is first necessary to deploy various sensors and monitoring equipment, including monitoring devices for marine meteorology, geology, and marine biology, to collect marine environmental data in real-time. Advanced data processing and analysis technologies are used to monitor and analyze these data in real-time and identify possible disaster risks. In the case of offshore wind farms, for example, geological drilling should be carried out at each turbine foundation location and analyzed and simulated accordingly to adjust the design parameters [42]. Finally, a sound early warning mechanism is established to issue timely warning information and remind relevant personnel to take countermeasures. At the same time, regular drills and training are conducted to ensure the effectiveness and reliability of the early warning system.

### 4.4 Developing Emergency Preparedness and Training

Establishing a sound emergency response plan for marine construction first requires a comprehensive assessment of all types of disaster risks that may occur and the formulation of corresponding disaster response measures and rescue plans. Subsequently, the emergency response organizational structure and command system must be established, and the duties and tasks of relevant personnel must be clarified. Conduct targeted training and drills to ensure that all relevant personnel understand the contents of the emergency response plan, familiarize themselves with the response process and operational procedures, and improve their ability and efficiency in responding to disasters. Regularly review and update the emergency response plan and adjust and improvements according to the actual situation to ensure its adaptability and effectiveness. Canada has introduced new legislation to increase the liability of offshore construction companies to C$1 billion, but liability for negligence will remain unlimited [48].

### 4.5 Enhancing Public Awareness and Participation

The key to strengthening public awareness of disaster prevention for offshore construction lies in carrying out extensive publicity and education activities, conveying to the public the importance and potential risks of offshore construction through various media channels, and guiding the public to realize the importance of disaster prevention. Sato & Nagatomi [37] identified the need for an international workshop venue at sea to collect various research results and discuss them cross-sectional. At the same time, relevant volunteer activities for environmental protection and disaster response should be organized to encourage the public to actively participate in marine environment monitoring, cleaning up marine rubbish, and supporting disaster rescue to make joint efforts to protect the marine ecological environment and achieve the goal of sustainable development [49].

### 4.6 Adopting a Whole-life Approach to Seawater Corrosion

Firstly, seawater-resistant low-alloy steel or other materials with good corrosion resistance should be used. These materials have better corrosion resistance in the atmospheric and splash zones and can extend the structure's service life. Secondly, coatings can prevent corrosion in the atmospheric and wave splash zones. Select coatings suitable for marine environments and regularly inspect and maintain them to ensure their effectiveness. Cathodic protection is also an effective anti-corrosion method to prevent localized and total corrosion. By applying an electric current, the metal surface of the structure is protected. In addition, corrosion prevention methods should be emphasized at the early stages of construction. For example, the recoating construction process of partial descaling plus top coating is adopted to extend the service life of primer, reduce descaling, and save money.

## 5. Conclusion

The world's increasing reliance on marine infrastructure underscores the urgent need for solid disaster prevention measures in marine building construction. As the frequency and intensity of natural disasters continue to grow, the challenges facing marine builders have never been more complex. This study examines the field's pressing issues and highlights recent advances that promise to mitigate these challenges. One of the primary challenges facing marine construction is the impact of climate change, which is causing sea levels to rise. Builders must now meet the need for structures to withstand the dynamics associated with these environmental changes. The second challenge is the increasing frequency and severity of hurricanes, typhoons, and cyclones. Constructing marine buildings that can withstand the destructive forces of these extreme weather events is a daunting challenge that requires innovative engineering solutions. The third is the constant threat to the integrity of marine structures posed by saltwater corrosion. Conventional building materials are susceptible to degradation over time, necessitating the development of corrosion-resistant materials to improve the corrosion resistance of structures.

Current breakthroughs in materials science have led to the development of high-performance corrosion-resistant materials explicitly designed for the marine environment. These materials enhance structural integrity and contribute to sustainable building practices. Secondly, engineers are adopting cutting-edge design principles that consider the dynamic nature of aquatic ecosystems. Floating structures, modular construction, and adaptive design are increasingly essential to provide resilience under changing environmental conditions. Indeed, by integrating remote sensing technology, marine structures can be monitored in real-time. This allows early detection of potential problems, facilitating timely maintenance and intervention to prevent disaster escalation. Advanced computer simulation and modeling techniques enable builders to assess the impact of various environmental conditions on marine structures. This allows for design optimization and enhances its ability to withstand extreme weather events and changing sea conditions.

In addition, there are limitations to this study. Since the literature was all from the Web of Science, future studies could consider additional literature sources such as PubMed, ScienceDirect, and Emerald as supplements.

## Author Contributions

Yin Junjia: Conceptualization, Project administration, Methodology, Formal analysis, Investigation, Data curation, Visualization, Validation, Writing - original draft, Writing - review and editing. Aidi Hizami Alias: Conceptualization, Project administration, Supervision. Nuzul Azam Haron: Supervision. Nabilah Abu Bakar: Supervision.

## Funding

This research received no external funding.

## Acknowledgments

The authors thank Universiti Putra Malaysia for providing the research platform.

## Data Availability

All study data were obtained from the cited bibliography.

## Conflict of Interest

All authors disclosed no conflict of interest.

## References

[1] Li, H., Liu, Y., Liang, B., et al., 2022. Demands and challenges for construction of marine infrastructures in China. Frontiers of Structural and Civil Engineering. 16(5), 551–563. DOI: https://doi.org/10.1007/s11709-022-0839-8

[2] Sui Pheng, L., Raphael, B., Kwan Kit, W. 2006. Tsunamis: Some pre-emptive disaster planning and management issues for consideration by the construction industry. Structural Survey. 24(5), 378–396. DOI: https://doi.org/10.1108/02630800610711979

[3] Imamura, F., Boret, S.P., Suppasri, A., et al., 2019. Recent occurrences of serious tsunami damage and the future challenges of tsunami disaster risk reduction. Progress in Disaster Science. 1, 100009. DOI: https://doi.org/10.1016/j.pdisas.2019.100009

[4] Suppasri, A., Goto, K., Muhari, A., et al., 2015. A decade after the 2004 Indian Ocean tsunami: The progress in disaster preparedness and future challenges in Indonesia, Sri Lanka, Thailand and the Maldives. Pure and Applied Geophysics. 172, 3313–3341. DOI: https://doi.org/10.1007/s00024-015-1134-6

[5] Mongeon, P., Paul-Hus, A., 2016. The journal coverage of Web of Science and Scopus: A comparative analysis. Scientometrics. 106, 213–228. DOI: https://doi.org/10.1007/s11192-015-1765-5

[6] Whelchel, A.W., Reguero, B.G., Van Wesenbeeck, B., et al., 2015. Advancing disaster risk reduction through the integration of science, design, and policy into eco-engineering and several global resource management processes. International Journal of Disaster Risk Reduction. 32, 29–41. DOI: https://doi.org/10.1016/j.ijdrr.2018.02.030

[7] Jorge, V.A., Granada, R., Maidana, R.G., et al., 2019. A survey on unmanned surface vehicles for disaster robotics: Main challenges and directions. Sensors. 19(3), 702. DOI: https://doi.org/10.3390/s19030702

[8] Desai, N., 2015. Dynamic positioning: Method for disaster prevention and risk management. Procedia Earth and Planetary Science. 11, 216–223. DOI: https://doi.org/10.1016/j.proeps.2015.06.028

[9] Defu, L., Guilin, L., Fengqing, W., et al., 2017. Typhoon/hurricane disaster prediction and prevention for coastal, offshore, and nuclear power plant infrastructure. Hurricanes and Climate Change. 3, 135–165. DOI: https://doi.org/10.1007/978-3-319-47594-3_6

[10] Cunyi, L., Zhicheng, Z., Zhanheng, G., et al., 2021. Assessment and application of geological disaster risk in offshore wind farms. China Safety Science Journal. 31(S1), 181–186.

DOI: https://doi.org/10.16265/j.cnki.issn 1003-3033.2021.S1.032
[11] Citexs., 2024. Literature Research Analyzer [Internet] [Accessed 2024 Jan 22]. Available from: https://www.citexs.com/Paperpicky
[12] StudyRecon Keyword Graph., 2024 [Internet] [Accessed 2024 Jan 22]. https://keywords.groundedai.company/?q=Max+Weber.
[13] A Study on the Construction of the Tsunami Hazard Database for Mooring Vessels in the Ports [Internet]. Available from: https://asmedigitalcollection.asme.org/OMAE/prwoceedings-abstract/OMAE2022/85888/V004T05A023/1147757
[14] Cho, J., 2024. Construction of a spatial information data catalogue for coastal red tide disaster management in Korea. Journal of Coastal Research. 116(SI), 230–234.
DOI: https://doi.org/10.2112/JCR-SI116-047.1
[15] Cheng, J.C., Tan, Y., Song, Y., et al., 2018. Developing an evacuation evaluation model for offshore oil and gas platforms using BIM and agent-based model. Automation in Construction. 89, 214–224.
DOI: https://doi.org/10.1016/j.autcon.2018.02.011
[16] Pedram, S., Ogie, R., Palmisano, S., et al., 2021. Cost-benefit analysis of virtual reality-based training for emergency rescue workers: a socio-technical systems approach. Virtual Reality. 25(4), 1071–1086.
DOI: https://doi.org/10.1007/s10055-021-00514-5
[17] Towards mitigation of environmental risks. Preventive Methods for Coastal Protection. Springer, Heidelberg: Heidelberg. pp. 1–27.
[18] Offshore Operation Facilities: Equipment and Procedures [Internet]. Available from: https://www.sciencedirect.com/book/9780123969774/offshore-operation-facilities
[19] Jiang, Q., Feng, C., Ding, J., et al., 2020. The decade long achievements of China's marine ecological civilization construction (2006–2016). Journal of Environmental Management. 272, 111077.
DOI: https://doi.org/10.1016/j.jenvman.2020.111077
[20] Lin, Y., Yang, Y., Li, P., et al., 2022. Spatial-temporal evaluation of marine ecological civilization of Zhejiang Province, China. Marine Policy. 135, 104835.
DOI: https://doi.org/10.1016/j.marpol.2021.104835
[21] Fernandez, R., Pardo, M., 2013. Offshore concrete structures. Ocean Engineering. 58, 304–316.
DOI: https://doi.org/10.1016/j.oceaneng.2012.11.007
[22] Shirlaw, J., Tan, T., Wong, K., 2005. Deep excavations in Singapore marine clay. Geotechnical Aspects of Underground Construction in Soft Ground: Proceedings of the 5th International Symposium TC28. Amsterdam, the Netherlands, 15-17 June 2005. CRC Press: Boca Raton, Florida. pp. 13–28.
[23] Kim, Y., Jeong, S., Won, J., 2009. Effect of lateral rigidity of offshore piles using proposed PY curves in marine clay. Marine Georesources and Geotechnology, 27(1), 53–77.
DOI: https://doi.org/10.1080/10641190802625551
[24] Yang, Q., Ren, Y., Niu, J., et al., 2018. Characteristics of soft marine clay under cyclic loading: A review. Bulletin of Engineering Geology and the Environment. 77, 1027–1046.
DOI: https://doi.org/10.1007/s10064-017-1078-4
[25] Zainuddin, N., Yunus, N., Al-Bared, M., et al., 2019. Measuring the engineering properties of marine clay treated with disposed granite waste. Measurement. 131, 50–60.
DOI: https://doi.org/10.1016/j.measurement.2018.08.053
[26] Al-Bared, M, Marto, A., 2017. A review on the geotechnical and engineering characteristics of marine clay and the modern methods of improvements. Malaysian Journal of Fundamental and Applied Sciences. 13(4), 825–831.
DOI: https://doi.org/10.11113/mjfas.v13n4.921
[27] Li-ping, G., Xiang-peng, F., Jian-dong, W., et al., 2024. High ductility cementitious composites incorporating seawater and coral sand (SCS-HDCC) for offshore engineering: Microstructure, mechanical performance and sustainability. Cement and Concrete Composites. 147, 105414.
DOI: https://doi.org/10.1016/j.cemconcomp.2023.105414
[28] Xing, H., Xiaoyin, Z., Qingqing, L., et al., 2023. Evaluation of synergy ability and reconstruction of synergy organization for marine disaster monitoring and early warning in coastal cities, China. Soft Computing. 27(23), 18245–18262.
DOI: https://doi.org/10.1007/s00500-023-08080-5
[29] Døskeland, Ø., Gudmestad, O.T., Moen, P., 2023. Use of response forecasting in decision making for weather sensitive offshore construction work. Ocean Engineering. 287, 115896.
DOI: https://doi.org/10.1016/j.oceaneng.2023.115896
[30] Paiva, M. da S., Silveira, L. da S., Isoldi, L.A., et al., 2021. Bibliometric study applied to the overtopping wave energy converter device. Sustainable Marine Structures. 2(1), 35–45.
DOI: https://doi.org/10.36956/sms.v2i1.306

[31] Amaechi, C.V., Ja'e, I.A., Reda, A., et al., 2022. Scientometric review and thematic areas for the research trends on marine hoses. Energies. 15(20), 7723.
DOI: https://doi.org/10.3390/en15207723

[32] Benhemma-Le Gall, A., Graham, I.M., Merchant, N.D., et al., 2021. Broad-scale responses of harbor porpoises to pile-driving and vessel activities during offshore windfarm construction. Frontiers in Marine Science. 8, 664724.
DOI: https://doi.org/10.3389/fmars.2021.664724

[33] Xu, J., Ye, M., Lu, W., et al., 2021. A four-quadrant conceptual framework for analyzing extended producer responsibility in offshore prefabrication construction. Journal of Cleaner Production. 282, 124540.
DOI: https://doi.org/10.1016/j.jclepro.2020.124540

[34] Ismail, Z., Kong, K.K., Othman, S.Z., et al., 2014. Evaluating accidents in the offshore drilling of petroleum: Regional picture and reducing impact. Measurement. 51, 18–33.
DOI: https://doi.org/10.1016/j.measurement.2014.01.027

[35] Zhu, G., Chen, G., Zhu, J., et al., 2022. Modeling the evolution of major storm-disaster-induced accidents in the offshore oil and gas industry. International journal of environmental research and public health. 19(12), 7216.
DOI: https://doi.org/10.3390/ijerph19127216

[36] Woolfson, C., 2013. Preventable disasters in the offshore oil industry: from Piper Alpha to Deepwater Horizon. New solutions: A Journal of Environmental and Occupational Health Policy. 22(4), 497–524.
DOI: http://dx.doi.org/10.2190/NS.22.4.h

[37] Sato, S., Nagatomi, K., 2023. Proposal for a floating offshore base for disaster prevention and multipurpose use. Geomate Journal. 24(101), 134–142.
DOI: https://doi.org/10.21660/2023.101.g12152

[38] Gaogeng, Z, Guoming, C., Yufei, Z, et al., 2021. Research on evolution hierarchy of major accidents in offshore oil and gas industry in storm disasters. China Safety Science Journal. 31(7), 172.
DOI: https://doi.org/10.16265/j.cnki.issn 1003-3033.2021.07.024

[39] Ryu, G.H., Kim, H., Kim, Y.G., et al., 2021. GIS-based site analysis of an optimal offshore wind farm for minimizing coastal disasters. Journal of Coastal Research. 114(SI), 246–250.
DOI: https://doi.org/10.2112/JCR-SI114-050.1

[40] Offshore Safety in the Wake of the Macondo Disaster: the Role of the Regulator [Internet]. Available from: https://ssrn.com/abstract=2425667

[41] Sui Pheng, L., Raphael, B., Kwan Kit, W., 2006. Tsunamis: some pre-emptive disaster planning and management issues for consideration by the construction industry. Structural Survey. 24(5), 378–396.
DOI: https://doi.org/10.1108/02630800610711979

[42] Chou, J.S., Liao, P.C., Yeh, C.D., 2021. Risk analysis and management of construction and operations in offshore wind power project. Sustainability, 13(13), 7473.
DOI: https://doi.org/10.3390/su13137473

[43] Junjia, Y., Alias, A.H., Haron, N.A., et al., 2023. A Bibliometric review on safety risk assessment of construction based on CiteSpace software and WoS database. Sustainability. 15(15), 11803.
DOI: https://doi.org/10.3390/su151511803

[44] Junjia, Y., Alias, A.H., Haron, N.A., et al., 2023. A Bibliometrics-Based systematic review of safety risk assessment for IBS hoisting construction. Buildings. 13(7), 1853.
DOI: https://doi.org/10.3390/buildings13071853

[45] Junjia, Y., Alias, A.H., Haron, N. A., et al., 2024. Identification and analysis of hoisting safety risk factors for IBS construction based on the AcciMap and cases study. Heliyon. 10(1). E23587.
DOI: https://doi.org/10.1016/j.heliyon.2023.e23587

[46] Dong, J., Asif, Z., Shi, Y., et al., 2022. Climate change impacts on coastal and offshore petroleum infrastructure and the associated oil spill risk: A review. Journal of Marine Science and Engineering. 10(7), 849.
DOI: https://doi.org/10.3390/jmse10070849

[47] Ngo, D.V., Kim, Y.J., Kim, D.H., 2023. Risk assessment of offshore wind turbines suction bucket foundation subject to multi-hazard events. Energies. 16(5), 2184.
DOI: https://doi.org/10.3390/en16052184

[48] Brkić, D., Praks, P., 2021. Probability analysis and prevention of offshore oil and gas accidents: Fire as a cause and a consequence. Fire. 4(4), 71.
DOI: https://doi.org/10.3390/fire4040071

[49] Yan, K., Wang, Y., Wang, W., et al., 2023. A system-theory and complex network-fused approach to analyze vessel-wind turbine allisions in offshore wind farm waters. Journal of Marine Science and Engineering. 11(7), 1306.
DOI: https://doi.org/10.3390/jmse11071306

[50] Ercilla, G., Casas, D., Alonso, B., et al., 2021. Offshore geological hazards: charting the course of progress and future directions. Oceans. 2(2), 393–428.
DOI: https://doi.org/10.3390/oceans2020023

[51] Olukolajo, M.A., Oyetunji, A.K., Amaechi, C.V., 2023. A scientometric review of environmental valuation research with an altmetric pathway for the future. Environments. 10(4), 58.
DOI: https://doi.org/10.3390/environments10040058

[52] Zhu, H., Li, J., Yuan, Z., et al., 2023. Bibliometric analysis of spatial accessibility from 1999–2022. Sustainability. 15(18), 13399.
DOI: https://doi.org/10.3390/su151813399

[53] Ibrion, M., Paltrinieri, N., Nejad, A.R., 2020. Learning from failures: Accidents of marine structures on Norwegian continental shelf over 40 years time period. Engineering Failure Analysis. 111, 104487.
DOI: https://doi.org/10.1016/j.engfailanal.2020.104487

[54] Krausmann, E., Renni, E., Campedel, M., et al., 2011. Industrial accidents triggered by earthquakes, floods and lightning: lessons learned from a database analysis. Natural Hazards. 59, 285–300.
DOI: https://doi.org/10.1007/s11069-011-9754-3

[55] Liu, K., Cai, B., Wu, Q., et al., 2023. Risk identification and assessment methods of offshore platform equipment and operations. Process Safety and Environmental Protection. 177, 1415–1430.
DOI: https://doi.org/10.1016/j.psep.2023.07.081

[56] Shan, Y., Wang, X., Cui, J., et al., 2021. Effects of clay mineral composition on the dynamic properties and fabric of artificial marine clay. Journal of Marine Science and Engineering. 9(11), 1216.
DOI: https://doi.org/10.3390/jmse9111216

[57] Bo, Q., Liu, J., Shang, W., et al., 2024. application of ann in construction: comprehensive study on identifying optimal modifier and dosage for stabilizing marine clay of Qingdao coastal region of China. Journal of Marine Science and Engineering. 12(3), 465.
DOI: https://doi.org/10.3390/jmse12030465

[58] Guan, Y., Chen, Y., Sun, X., et al., 2023. The clay mineralogy and geochemistry of sediments in the Beibu Gulf, South China Sea: a record of the Holocene sedimentary environmental change. Journal of Marine Science and Engineering, 11(7), 1463.
DOI: https://doi.org/10.3390/jmse11071463

[59] Sun, X., Yi, Y., 2022. Utilization of incineration bottom ash, waste marine clay, and ground granulated blast-furnace slag as a construction material. Resources, Conservation and Recycling. 182, 106292.
DOI: https://doi.org/10.1016/j.resconrec.2022.106292

[60] Subsea Pipeline Temporary Decommissioning & Recommissioning for an Emergency Repair [Internet]. Available from: https://onepetro.org/SPEADIP/proceedings-abstract/20ADIP/2-20ADIP/D021S036R001/452576

[61] Yang, W., Tian, W., Hvalbye, O., et al., 2019. Experimental research for stabilizing offshore floating wind turbines. Energies. 12(10), 1947.
DOI: https://doi.org/10.3390/en12101947

[62] Jin, Y., Jang, B.S., 2015. Probabilistic fire risk analysis and structural safety assessment of FPSO topside module. Ocean Engineering. 104, 725–737.
DOI: https://doi.org/10.1016/j.oceaneng.2015.04.019

[63] Liu, L., Wang, Y., Wang, Z., et al., 2022. Energy dissipation by external damping in marine vibratory pile sinking. Ocean Engineering. 259, 111896.
DOI: https://doi.org/10.1016/j.oceaneng.2022.111896

[64] Luo, Z., Wang, X., Wen, H., Pei, A., 2022. Hydrogen production from offshore wind power in South China. International Journal of Hydrogen Energy. 47(58), 24558–24568.
DOI: https://doi.org/10.1016/j.ijhydene.2022.03.162

[65] Chuang, Z., Chang, X., Li, C., et al., 2020. Performance change of a semi-submersible production platform system with broken mooring line or riser. Engineering Failure Analysis. 118, 104819.
DOI: https://doi.org/10.1016/j.engfailanal.2020.104819