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Pre-Disaster Preparedness/Prevention and Mitigation Strategies for Floods: A Use Case of Lagos, Nigeria

Ayuba Job Danladi^{1*}, Muritala Kolade Yusuf², Gilles Dusserre¹, Nasir Baba Ahmed², Luc Vechot³

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ABSTRACT

Climate change-induced phenomena are increasingly becoming frequent and intense causing global challenges. Urbanization and population growth continue to aggravate flood events, making building resilient cities a vital way to combat them. This research reviews flood preparedness and mitigation strategies employed in developed countries to reveal flood risk management practices that promote resilience in these countries to allow adoption in struggling and developing countries such as Nigeria. The review from previous and current studies followed three methods consisting of Inclusion & Exclusion criteria, Abstract screening, and Full-text review. The findings from past studies present multifaceted measures taken to prepare for and mitigate floods and how they have enabled people and cities to live with floods, however, developing countries still face a major risk of a severe impact from flood inundation. The use case area, Lagos, was found to be continuously inundated by floods and is in grave need of better management strategies to mitigate the impact resulting from floods. The results from the review show that flood risk mitigation is primarily affected by risk perception, indicating its effect on response measures which are either structural or non-structural. This research concludes by proposing an approach or framework that is an outcome of a comparative assessment of flood risk management from developed countries to consider for the implementation of preparedness and mitigation strategies in the use case area.

INTRODUCTION

Climate-related events such as floods are becoming increasingly frequent and intensified, owing to rapid changes in climate, posing continued threats and discomfort to livelihoods and existing infrastructures (Raikes *et al.*, 2019). The growing need for settlement due to population increase, urban migration, and urbanization continues to escalate the impact of disasters, as people tend to settle in severely exposed areas increasing their vulnerability and undermining the integrity of existing preparedness and mitigation measures (Konami *et al.*, 2021; Krongthao *et al.*, 2021). This vulnerability contributes to the severe impact that results from flooding - one of the most common natural disasters - that continues to plague societies and economies, drawing global attention since its effect is felt in both developed and developing countries (Echendu, 2023). The growing uncertainties of weather patterns due to climate change is a wakeup call to develop, improve existing, and implement strategies that prevent or mitigate flooding events (Fernández *et al.*, 2023; Hashim *et al.*, 2021; Rofiah *et al.*, 2021; Vivita *et al.*, 2023). The best way to live with and adapt to floods, despite their increased frequency and impact, is through resilience. Several societies are now developing and implementing measures/strategies that enable them to thrive in a rapidly changing climate, primarily through establishing flood risk management strategies that strengthen their preparedness and mitigation measures to become resilient to this devastating climate-induced hazard. Pre-disaster preparedness and mitigation

strategies are critical aspects of flood risk reduction that promote more resilient and smart societies (Hatori *et al.*, 2023; Raikes *et al.*, 2019). Thus, measures such as building early warning systems, community education/awareness, and construction of engineering structures, etc., form a bedrock for building disaster resilience (Nguyễn *et al.*, 2023; Rofiah *et al.*, 2021).

According to the United Nations Office for Disaster Risk Reduction (2015), “every one dollar spent on disaster preparedness, saves up to fifteen dollars on reconstructing disaster-affected communities”. This indicates how vital disaster preparedness and mitigation are in reducing flood impacts. Since preparedness and mitigation are the first actions of defense against potential disasters in disaster management, it is important to explore the different innovative ideas and advance preparedness and mitigation measures that safeguard cities and societies to limit the impact of these devastating floods (Nguyễn *et al.*, 2023). This can be achieved by uncovering current knowledge and research recommendations proposed to meet the demand placed on cities and societies to alleviate and minimize the impact and challenges faced by people from floods. A study on various literature has been conducted to review and assess the various practices that have been recommended and implemented to prepare for and mitigate floods from impacting cities, especially in developing countries.

LITERATURE REVIEW

One objective of disaster-stricken regions is to anticipate the probability of occurrence of disasters and set

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up measures that reduce or prevent them. Disaster preparedness is defined by Siriwardhana *et al.* (2021) as “a set of activities, measures, and capacities developed by governments, private sectors, communities, and individuals before a disaster, to support vulnerable populations to mitigate the impact of hazards and to enable their effective response and recovery including developing early warning systems, evacuation plans, formulating emergency preparedness plans, conducting education/training programs, and prepositioning resources”. In several scientific studies and peer-reviewed articles, flood preparedness is mostly focused on assessing population readiness for disasters (Appleby-Arnold *et al.*, 2021; Forsyth *et al.*, 2023; Hatori *et al.*, 2023; Nguyễn *et al.*, 2023; Yildiz *et al.*, 2021), and consequent community resilience through direct actions from individuals (Echendu, 2023; Nakai & Nakano, 2023). Some studies have focused on more specific topics, such as flood preparedness through school intervention programs, community engagement (Fernández *et al.*, 2023; Hasbi *et al.*, 2023), response measures for specific population groups (Krongthaeo *et al.*, 2021), and on the inclusion of vulnerable groups during flood events (Rofiah *et al.*, 2021). This shows that flood preparedness strategies are multifaceted, nonetheless, research in comparative analysis of flood risk management and mitigation strategies appears to be limited, indicating a gap that provides knowledge of how communities and cities can adopt and implement frameworks from resilient societies to better their flood management approach. In an aspect of individual preparedness, Hashim *et al.* (2021) note that risk perception strongly influences individual preparedness for floods, but individual preparedness does not mean actual evacuation during disasters, providing a need for the development of better disaster preparedness awareness, and/ or policy enforcement measures. Embedding preparedness measures into the cultural behavior of individuals has been proposed to influence public participation and preparedness for disaster by some authors. For example, Appleby-Arnold *et al.* (2021) strongly suggest that embedding disaster preparedness attitudes in everyday life enables an understanding of the set of actions to take during an actual disaster. Similarly, Hatori *et al.* (2023) agree that the best form of disaster preparedness is through everyday practice; giving an overview of the level of influence of hazard perception of citizens on responsive actions in the face of disasters. Furthermore, Nguyen *et al.* (2023) suggest that social relationships and community assets sharing are vital in shaping individual disaster preparedness through a study of disaster preparedness of residents in Seattle United States; suggesting that disaster preparedness efforts necessitate supplementing with daily resources provision and sharing between individuals to enable quick recovery. Nonetheless, studies by Nakai and Nakano (2023) argue that community collaborative preparedness presents a better approach to flood preparedness, expounding the practice of the ‘individual

emergency relief box’ - an initiative of a community in Japan - for tsunami inundation preparedness. This unique approach allows individual households to prepare and package relief materials in boxes to store in a common storage facility managed primarily by the community authorities. This practice has the potential to reinvigorate disaster preparedness practices in cultural behaviors. On a similar note, Appleby-Arnold *et al.* (2021) conclude that daily disaster preparedness behavior by individuals can be strengthened by community-individual collaboration through the establishment of the recommendations;

(i) Family should set up emergency plans, simple reminders, easy communication medium, and convergence points in situations of disasters,

(ii) Individuals should lookout for publicly displayed information on how to prepare for disasters and form a habit of reading and memorizing this information,

(iii) Enquire for and attend community workshops on disaster preparedness programs,

(iv) Create bonds with individuals of other cultural backgrounds to foster better communication during an evacuation,

(v) Inform other participants and trainers of personal skills during workshops that could be useful to the community during disaster response.

Such strategies can improve the cognitive behavior of individuals toward disaster preparedness, as well as foster community-individual participation during flood disaster response. Meanwhile, other studies have focused on applying a practical approach to inform community preparedness. For example, Nakano *et al.* (2020) used movie clips to simulate school evacuation drills in the event of floods from tsunamis. These tools can strengthen the perception of citizens to deal with disasters themselves, thus promoting alternative measures of preparedness implementation.

Whilst non-structural approaches for flood risk management such as individual preparedness remain crucial to preventing severe consequences (casualties) from floods, mitigation measures such as policymaking, infrastructural development, and spatial planning are paramount for effective risk or disaster reduction/management. Although preparedness and mitigation are interchangeably used in many contexts, specific distinctions have considered preparedness to be ‘actions taken’ by communities and cities to “get ready” for potential disasters, and mitigation to be structural architectures and policy frameworks that ‘prevent or reduce’ the impact of disasters. Traditional mitigation structures such as levees and embankments have been considered as the most important measures in mitigating floods. For example, as Thielen *et al.* (2016) report, that mitigation measures implemented after the August 2002 floods in Germany that caused damages of more than €11.6 billion, were effective in preventing a similar scale of damage from the severe floods in 2013. These measures included decentralized flooding control strategies such as reclaiming floodplains, renaturation of

surface water bodies, unsealing of lands, etc. Thielen *et al.* (2016) also verified that traditional defense systems (e.g. embankments, controlled flood retention basins, and dams) strengthened the flood resilience of communities affected by extreme hydraulic load in 2013. In another research, Bubeck *et al.* (2017) describe how flood mitigation systems such as embankments and levees regarded as technical measures have a sustained tradition of protecting areas from being inundated by floods. Such traditional measures demonstrate their vitality in preventing floods, nonetheless, breaches and overtopping of these structures provide a concern for the integrity of these structures to efficiently protect cities against floods, prompting requirements to improve existing frameworks and defense systems whilst encouraging precautionary and preparatory actions from individuals living nearby waterbodies (Thielen *et al.*, 2016). In other contexts of flood mitigation measures, sustainable urban drainage systems (SUDS), and stormwater harvesting are proposed to better mitigate against and manage floods, especially for pluvial floods and for developing countries that lack the financial capacity to build traditional defense systems. For example, Ortega *et al.* (2023) suggest that promoting sustainable urban drainage systems holds the capacity to build more flood-resilient communities. SUDS are believed to present better solutions for reducing surface run-offs and improving biodiversity in urban areas. However, its advantage does not convince some cities, as SUDS implementation is slow-paced (Ortega *et al.*, 2023) with several authors attributing lack of transition to SUDS implementation over conventional approaches to socio-political hindrance or perception (Li *et al.*, 2020; Thorne *et al.*, 2018).

In all these papers reviewed so far, and also in others not included in this summary, we observed limited research in comparative assessment of flood risk management practices in different countries. This prompted the need to conduct an assessment and comparison of different flood preparedness and mitigation strategies to establish a foundation for the efficient adoption and transfer of approaches from resilient societies to struggling societies, particularly developing countries. This research will potentially unveil the strengths of flood mitigation and management strategies in developed and resilient societies, allowing other countries to adopt and implement the same strategies in their flood risk management. In response to the identified gap, this paper focuses on conducting an in-depth investigation of recent research

to assess effective and feasible flood risk mitigation and management measures in developed countries. The aim is to propose a flood risk management strategy/framework that can be recommended to implementation in the use case region Lagos Nigeria, by considering the following research question.

- (1) How do individuals and communities ‘get ready’ and ‘respond’ to perceived flood events
- (2) What are the existing government policies/frameworks that promote and enhance sustainable flood risk mitigation?
- (3) Which conclusion can be drawn to improve flood disaster preparedness and mitigation in Lagos Nigeria?

MATERIALS AND METHODS

Publication Selection and Collection

To carry out this research we started by identifying academic databases that contain relevant peer-reviewed articles and appropriate governmental websites “grey literature” of some countries to access information and data relevant to the study. Statical data were extracted from primary data available on the governmental website since they contain authentic information. Search strategy and selection criteria for the identification of relevant studies were developed (as seen in Table 1). Mixed search strategy was adopted for the collection of relevant studies; the first stage focused on utilizing academic database search engines such as Web of Science, ScienceDirect, and Google Scholar. The search began using some predefined keywords such as “Disaster preparedness”, “Disaster mitigation”, “Hazard mitigation”, and “pre-disaster preparations”, but the search terms were later redefined to be more specific to flood disasters because previous terms returned studies on general and all kind of disasters (natural and man-made). The redefined keywords were thus, “Flood hazard mitigation”, “Flood preparedness strategies”, “Flood management approaches”, and “Flood risk management”.

Many of the articles focused on individual-community preparedness for disasters, according to the search terms, only a few articles contained research on flood mitigation strategies by countries. Additionally, the generated articles from the search were screened by reviewing the title and abstract to determine whether the paper was relevant to the study. If the paper was relevant to the study, the year of publication is then considered to either obtain the full-text version of the article or exclude the article based on specific reasons.

Table 1: Inclusion and Exclusion criteria for generated papers

Inclusion criteria	Exclusion criteria	Reasons
Sources published in English language	Sources not published in English	English is the widely used language in academic research
Sources published from 2013 – 2023	Sources published before 2013	Avoiding obsolete research, and focusing on recent studies
Research domain; Environmental science, social sciences.	Research domain; Computer science, Health science, economic science	Studies related to natural disasters

Disaster preparedness related flood disasters	Disaster preparedness related to man-made disasters, and other natural disasters	Paper is focused on flood disaster preparedness strategies
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In the second phase, a focused search was conducted for articles related to flood risk management in some countries. This was done to establish a comparative assessment of flood risk mitigation strategies by examining studies that focused on specific countries such as the United Kingdom (UK), the United States (US), and the Netherlands.

Secondary Data Collection

Subsequently, after the relevant articles were collected, numerical data of past flood disasters in the US were extracted from the Federal Emergency Management Agency (FEMA) database to assess the performance of the flood risk management framework in the country. The included data were those recorded from economic losses, casualties (deaths), and infrastructural damages from 1980 to 2023. These data were used to present the trend of flood impact and losses before and after implementation of the flood risk management framework. Furthermore, a graph of ‘Billion-Dollar’ flood disasters in the US was plotted using Microsoft Excel (Fig.1) to assess the performance of the framework.

Description of Use Case Region (Lagos, Nigeria)

Communities and cities situated close to coastlines are continuously facing threats and damages from floods. Climate change has intensified This disastrous natural phenomenon in recent years, with increasing the frequency and intensity of extreme rainfall being a major player. These affected regions (such as Lagos) are left counting economic losses, population displacement, deaths, and disruptions to public services year-in-year-out (Ekoh *et al.*, 2022). It is a known fact that natural hazards cannot be prevented but mitigation and adaptation practices have become sustainable actions to reduce the impact and damages from natural hazards through preparedness and mitigation strategies.

Lagos one of the flood-prone regions in West Africa, is located in the Southwestern part of Nigeria near the Atlantic Ocean, it has several inland waterbodies including a lagoon that flows into the Atlantic. According to Nkwunonwo *et al.* (2016), its proximity to the ocean favors rapid economic growth, which has been a major factor in its rapid urbanization. However, the increased influx of migrants continually exerts pressure on the available infrastructures leading to rapid urbanization, with the poor population forced to settle in areas that are extremely vulnerable to floods (Echendu, 2023). Flood disasters in Nigeria are mostly fluvial (river) or pluvial (rainfall) related, however, most recent floods in Lagos have been linked to rainfall events (Nkwunonwo *et al.*, 2016), and the poor population are the group that bears the majority of the flood impact; as a result of poor awareness and communication measures to this group. Assessing the flood disaster preparedness and mitigation of Lagos is important because of its low-lying landscape

and proximity to the ocean. Its dense population also presents a concern for improved flood management as socioeconomic factors of the state have had major constraints on flood mitigation.

RESULTS AND DISCUSSION

The rising global need to prevent the severe impact of disasters on economies, public and private infrastructures, and more importantly human health and sustainability has been the driving force behind diverse flood risk mitigation actions from individuals, communities, and governments. These actions span from flood risk governance, flood risk communication and awareness, response and evacuation drills and training programs, flood risk warning actions such as hazard monitoring etc., The Research findings from this study present below the factors that influence/promote flood preparedness and mitigation.

Flood Hazard Knowledge and Risk Perception

Floods are mostly characterized as slow-onset disasters, thus preparing for these types of disasters mostly depends on individual perception of the hazards associated with floods especially those related to rainfall (Appleby-Arnold *et al.*, 2021). The level of disaster awareness and communication by stakeholders who are aware of the potential impact of floods is a tool that can be used to shape and improve how individuals perceive extreme rainfall events (Hashim *et al.*, 2021). Since hazard identification indicates awareness of individuals’ possible hazard impact, perception of risk is a determinant factor that links the identification of hazards to disaster preparedness (Kamarulzaman *et al.*, 2016). People tend to prepare for what they believe has a severe impact on them. Most times, the experience of similar events has an influence on the behavioral pattern of individuals during potential flooding (Albano *et al.*, 2016) such experiences play a good role in solidifying the preparedness and mitigation measures of individuals and societies. Risk perception indicates that preparedness and mitigation measures against disasters possess a strong link to resilience and adaptation.

Flood Hazard Monitoring

Monitoring involves continuous observation of water level in terms of coastal and river floods, and for pluvial floods measurement of the influx of rainfall with specialized equipment to predict flood events. River and coastal floods are easier to monitor as opposed to floods from extreme rainfall events, which are mostly influenced by several factors such as infrastructures, and precipitation pattern (Echendu, 2023). However, floods are generally hazards that can be predicted, observed, and evaded because the gradual increase in water/precipitation level gives people time to prepare for them (Krongthao *et al.*, 2021). Flood monitoring provides important information

on the possibility of its impact and more importantly development of measures to reduce its impact. This is possible through instrumentations and installation of systems such as sensors, and river gauges in river banks or coastal areas (Silva Souza *et al.*, 2017; Ufuoma *et al.*, 2021) satellite data, and weather forecast systems (Liu *et al.*, 2022; Oduah *et al.*, 2023) to predict and detect futuristic flood events. These early warning systems allow adequate response to disasters both for individual and emergency management agencies.

Flood Warning and Communication

Early warning systems are an integral component of disaster preparedness and mitigation as these systems can collect real-time data and communicate potential flood disasters (Silva Souza *et al.*, 2017), facilitating timely response. Flood warning systems are primarily interconnected with monitoring systems that record these events and transmit the observations to give on-time information that alerts concerned stakeholders. Souza *et al.* (2017) demonstrate how early warning systems disseminate flood warning information, through connecting monitoring sensors to the internet cloud that stores and disseminates these data based on the signals from the sensors. Most hazard communications systems commonly use colors (green, yellow, and red) to indicate the degree of severity of potential flood events. Moreover, traditional measures are utilized to provide warning and communication to individuals and communities that may not have access to modern channels (Krongthao *et al.*, 2021), although it requires constant checking and monitoring of water levels by designated authorities, primarily in seasons when precipitation levels are high. Other communication channels such as mobile apps, SMS alerts, and siren-mounted vehicles enable flood information dissemination seamlessly whilst reaching a large number of people at the same time (Kamarulzaman *et al.*, 2016; Rollason *et al.*, 2018), these channels are effective at sending first-hand information to citizens, thus enabling vigilance and swift response to floods. Furthermore, integrating flood monitoring and warning systems into disaster emergency frameworks is necessary to promote rapid and coordinated actions (Rollason *et al.*, 2018).

Flood Risk Management

Governance and policymaking are integral aspects of building resilient societies in a world where natural and man-made hazards are on the increase. Formulating robust strategies for managing and mitigating floods has been on the increase, as climate change persistently alters precipitation patterns and causes intensified flood events. Most flood governance is primarily centered on prevention and mitigation with the use of structural measures such as dikes, embankment systems, etc. over non-structural solutions like land use planning and insurance (Raikes *et al.*, 2019). Such governmental strategies for flood risk management have led to its adoption in many countries including the United States, the Netherlands, and the

United Kingdom. For instance, flood prevention in the Netherlands is most notably focused on structural measures, thus governance and policies are aimed at constructing and improving engineering structures that impede the occurrence and impact of floods (Bubeck *et al.*, 2017; Kolen *et al.*, 2013), While in France, prevention emphasis is on planning for engineering measures failure, a contingency plan that absorbs risk and promotes timely recovery through insurance mechanisms (Gersonius *et al.*, 2016; Kolen *et al.*, 2013), but a more balanced flood risk management strategy involving pre-disaster planning and preparedness, response, and recovery is practiced in the United States and the United Kingdom (Gersonius *et al.*, 2016; Raikes *et al.*, 2019). Flood governance is widely and primarily dependent on the risk conception/perception of public authorities and policymakers, a major contribution that may have led to disparities in disaster preparedness measures in states and even local levels of government.

Flood Risk Policy Frameworks (The European Flood Directive framework case)

Policies and frameworks are the non-structural components of disaster preparedness and mitigation strategies that enable governments and societies to proffer sustainable solutions to prevent the negative consequences of disasters (Dash & Punia, 2019; Vij *et al.*, 2020). Most policies consider economic, environmental, and human health sustainability, and these actions are now top priorities among nations to combat rising climate change and frequent occurrence of disasters. For example, disparities and ineffective flood risk management particularly in transboundary communities is a primary factors that led to the formulation of the European Union Flood Directive (EUFD) to assess and manage flood risk to prevent undermining of the European Union's goal of sustainable economies, environment, and human health (Priest *et al.*, 2016). The directive emphasizes the establishment of a common framework for better flood management across borders, thereby improving transboundary coordination and cooperation, especially in communities situated within the boundaries. Table 2. gives a summary of the assessment of the EUFD framework.

It is important to note that the directive does not rule over national policies or frameworks on flood risk management, it was however, established to provide a minimum common framework for managing flooding and to reduce the impact on European societies (Priest *et al.*, 2016). Although the flood directive admits that floods are unpredictable natural events, improved management of societal activities is feasible to reduce the risk of flood events and their consequences. The creation of the European FD, which is in response to severe flood events that hit Europe between 1998 and 2007, causing more than 50 billion in economic losses and more than 1000 loss in lives, has since led to accurate assessment and creation of river basin hazard maps (Bonasia & Lucatello, 2019) essential to establish flood risk management plans and guidance on policy improvement.

Table 2: Assessment of the European FD for flood risk management

Criteria	Judgment
Governance effectiveness	FD embraces the river basin scale as the primary management unit and employs a multilevel strategy for establishing goals and standards, contributing positively to adaptive governance. Nevertheless, the absence of adequately institutionalized instruments within the legal framework could impede transboundary collaboration. Additionally, disparities in legal structures, political perspectives on flood risk management, and variations in economic, social, and physical contexts may hinder effective coordination and cooperation across different scales.
Robustness	One of the FD declared objectives is to encourage a more varied approach to flood management. Nonetheless, countries have the autonomy to establish their own goals, and there are no set standards for the variety of flood management strategies.
Adaptability	There is a lot of latitude under the FD for nations to choose appropriate risk thresholds and flood risk control goals. However, if certain FD standards are novel and dissimilar from already-used methods, they will be more challenging and complex to implement, such as creating plans for flood risk management and introducing participatory techniques.
Effectiveness towards goal	Even with coordinated transboundary approaches being the goal, there remains variation across national borders. This variation can be linked to variations in concept definitions, legal frameworks and obligations, political perspectives on flood risk management, and physical, social, and economic environments.

Comparative Assessment of Flood Management Strategies (UK, US, and Netherlands)

Flood risk management system in different countries is mostly driven by demand and support for distinct characteristics of landscapes and types of flood risk. Countries often, by trend, rely more on structural systems when flood hazard is characterized by high impacts, and short warning time, even when having the least probability of occurrence. In contrast, countries faced with more frequent flood hazards with minimal impact and sufficient prediction time are more likely to have flexible frameworks (Bubeck *et al.*, 2017; Dash & Punia, 2019). In the past, flood hazards were believed to be exclusively resolved by technical engineering measures, and this belief in engineering defense systems has been challenged by the occurrence of flood events in regions that were considered ‘protected’ against floods (Bubeck *et al.*, 2017). Moreover, climate change and aggravated rainfall have shifted sole reliance on technical flood defense, towards greater emphasis on non-structural measures such as governance and spatial planning (Bubeck *et al.*, 2017; Vij *et al.*, 2020).

Flood Management Strategy in the UK

The institutional bodies for flood risk management in the UK were established based on risk analysis, and quantifying the likelihood of flooding based on an annual exceedance probability (AEP). The central government institution responsible for flood policy is the Department for Environment, Food and Rural Affairs (DEFRA), while a non-departmental government body, the Environmental Agency (AG) makes in-depth assessment, planning, and implementation of flood risk and management at national and regional scale (Miller & Hutchins, 2017; Rubinato *et al.*, 2019). Furthermore,

there are local institutional bodies with responsibilities to manage floods caused by inadequate sewage, comprising mainly of privatized companies. Other local authorities are responsible for local emergencies, spatial planning, and emergency response to floods. Finally, private insurance companies provide cover for damages offloods to residential and most commercial properties (Bubeck *et al.*, 2017; Rubinato *et al.*, 2019). The broadness of flood management in the UK ensures shared responsibility between the government, local authorities, and communities. Natural solutions such as SUDS are more commonly used to manage floods in the UK (Li *et al.*, 2020), however, their ability to effectively manage excessive flooding is still under deliberation. Nevertheless, traditional flood defense systems (engineering structures) are still valid options considered by institutions especially having historical importance in mitigating floods (Rubinato *et al.*, 2019).

Flood Management Strategy in the US

The United States Federal Emergency Management Agency (FEMA) in 2002 created the National Flood Insurance Program (NFIP) that mandates communities to abide by a predefined set of floodplain management standards and to offer insurance to communities with significant flood risk (FEMA, 2023). This act promotes the engagement of states to assume major roles in floodplain management by adhering to the NFIP standards, helping them to advise and support participating local communities to adhere to the standards (Tyler *et al.*, 2019). The program standardizes flood risk management by imposing minimum building and flood zoning requirements on communities across the US. The importance of the NFIP is that it gives local governments the authority to restrict development in flood-risk areas, and

mandates ground floor of new or substantially renovated buildings be elevated if ‘unprotected’ by levees (Bubeck *et al.*, 2017; Tyler *et al.*, 2019). FEMA unlike the DEFRA in the UK, has the sole responsibility to identify flood-hazard areas, provide flood risk maps, insure properties, create construction design standards in flood plains, and fund mitigation projects (FEMA, 2023). Additionally, the NFIP

does not restrict participating communities, hence, states and local governments can impose additional building codes and flood-zoning regulations on individuals (Bubeck *et al.*, 2017). To assess the performance of the NFIP program, data from past and recent flood events from FEMA were analyzed and plotted for flood disasters in the US from 1980-2023, as seen in Figure 1.

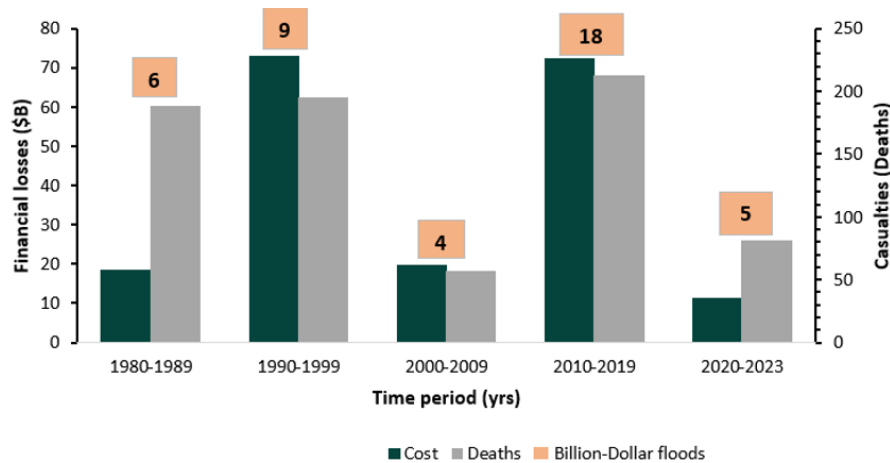


Figure 1: Billion-dollar flood disasters in the US from 1980-2023 (FEMA, 2023)

Flood Management Strategy in the Netherlands

The responsibility of flood risk management in the Netherlands is predominantly of the central government and committed water board (Bubeck *et al.*, 2017), primarily relying on flood defense measures due to the development of land reclamation of almost 800 years, resulting in the establishment of dyke ring areas; areas that have fixed boundaries with embankments or other flood defenses. The Netherlands is one of the most vulnerable flood-prone countries with over 60% of the land coverage in floodplains (Van Herk *et al.*, 2015). The flood safety is well structured but massive and continuous effort is required to protect the country against future flooding. Flood management frameworks focus on large-scale to local-scale protection consisting of flood embankments and channelization. This protection approach ranks among the highest in the world. Protection against storm surges and river floods is enhanced by the reinforcement of the country’s flood defense system comprising coastal dunes, dikes, and storm surges (Edelenbos *et al.*, 2017; Van Herk *et al.*, 2015). The focus of the flood risk management system in the Netherlands of ‘managing the flood’ rather than ‘managing the risk’ has undergone a transition to an integrated flood risk management and lies on the minimum standard requirement of the EUFD (Bubeck *et al.*, 2017). The transition led to a Multi-layer Safety framework that identifies three layers: namely, flood protection, sustainable spatial planning, and emergency management. The degree of adoption of the framework announced in the Netherlands’ National Water Plan (Bubeck *et al.*, 2017) is yet to be realized since there has not been a major flooding event since the 1953

storm surge, indicating that the flood-defense strategy is considerably successful.

Flood Mitigation Strategies and Architectures

Structural flood risk mitigation strategies are the most widely used defense systems against inundation from extreme water levels and rainfall events. The approach of flood management has proved its effectiveness in mitigating disastrous flood impacts on cities and societies. Implementation of structural and non-structural systems of flood risk management has enabled more resilient societies since most residual floods can be dealt with by the non-structural aspect of flood management (Bubeck *et al.*, 2017). For example, dikes are the main structural defense system, but they are backed up by contingency plans that allow smooth recovery (Richert *et al.*, 2019). These defense systems are predominantly accepted by the public as efforts to mitigate the impact of floods, giving them the confidence to follow and abide by policies and frameworks set up by governments. The most common structural mitigation systems are: namely levees, embankments, and dikes which are mostly constructed to impede river and coastal inundations (Edelenbos *et al.*, 2017). However, recent flood mitigation strategies such as sustainable urban drainage systems, polders, stormwater harvesting, unsealing lands, reclamation of flood plains, etc. have gained wide practice in preventing the severe impact of floods (Albrecht & Hartmann, 2021; Li *et al.*, 2020; Nick *et al.*, 2023; Thielen *et al.*, 2016). Additionally, individuals living close to coastal and river areas have adopted mitigation strategies in constructing houses, such as creating floating foundations, building

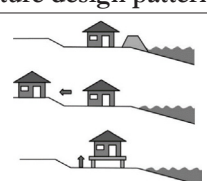
mounds around buildings, or even raising basement that allows individuals to live on the upper floor during flood disasters (Creach *et al.*, 2020; Krongthaeo *et al.*, 2021). Table 3. shows some architectural design patterns that are adopted for flood risk mitigation.

Flood Risk Management Strategies in Lagos Nigeria

Perception of risk is a main driver in preparedness and mitigation of disasters. Understanding the flood risk, probability and potential associated disaster has over time influenced the decision of what flood risk

management strategy to adopt and implement. The flood risk management strategy in Lagos has been based on the prevention and control of floods with primary measures being the implementation of structural strategies (Nkwunonwo *et al.*, 2016). Most recent flood risk management strategies have shifted attention to flood risk analysis rather than disaster control, which has strengthened flood mitigation in several countries (Bubeck *et al.*, 2017; Rubinato *et al.*, 2019), this has not been the case in Lagos until a few years ago when non-structural strategies were initiated with a major focus on flood risk

Table 3: Architectural design patterns adopted for flood risk mitigation (extracted from Creach *et al.*, 2020)

Mitigation strategy	Architecture design patterns
(a) Protection: construction of protective structures that reduce the probability of flooding in a particular zone.	
(b) Retreat: moving exposed building to a safer zone (higher elevation).	
(c) Accommodate: reconstructing or renovating the building to minimize flood impact.	

assessment and reduction.

Flood risk management is defined by Sayers *et al.* (2013) to range from information gathering, and risk analysis to continuous societal risk assessment and adoption of policies. This broad range of flood management is rather less considered during the formulation of preparedness and mitigation strategies, which has mostly constituted structural measures for flood mitigation. Negligence to enforce established frameworks and policies that enhance flood risk management contributes to the vast number of Lagos population living in flood-exposed and prone areas with the urban poor being the most vulnerable groups (Adelekan, 2016). Therefore, it is not only sufficient to build structural barriers and establish frameworks that deal with flood mitigation, but it is also important to carry out effective and efficient sensitization of the public that encourages participatory and collaborative efforts against flood disasters. Consequently, most structural efforts towards flood risk management in Lagos have centered primarily on the construction of SUDS, which can retain and dispense rainfall water into waterbodies, but notable constraints to this measure have been the poor waste management system in the state that sees the voluminous amount of trash disposed of in the drainages (Nkwunonwo *et al.*, 2016). On the contrary, contingency measures such as insurance have been skewed to multinational companies in the city with a majority of the population (the urban poor) having to feel the heat in recovering from floods (Adelekan, 2016). On a general note, flood management in Lagos Nigeria, has gained much attention with increased efforts from the public and private sectors that have drastically increased and improved flood mitigation efforts, however, increased participation of citizens is a vital requirement to sustainably prepare for and mitigate flood disasters in Lagos. Additionally, technical early warning systems such as water gauges, sensors, and transmitters, satellite

data are non-structural measures that are lacking and have a visible impact on flood management mitigation (Adelekan, 2016). Such instrumentation and installations can provide rapid and timely early information regarding the potential inundation of the city. In summary, flood risk mitigation in Lagos state is far beyond expectations, especially in the face of a rapidly changing climate which is a wakeup call to increase efforts that mitigate and reduce the impact of flooding.

Discussion

The rise in frequency and intensity of flooding events in several nations is an indication of advancing development and enforcement in preparedness and mitigation measures against this ever-devastating event. With significant evidence of aggravated preparedness and mitigation measures from governments, communities are more resilient to natural disasters. Findings from this research show that individual readiness and willingness to take action against flood events have of significant effect in limiting the impact of floods (Appleby-Arnold *et al.*, 2021; Hashim *et al.*, 2021; Kamarulzaman *et al.*, 2016). Since people constitute the most important part of societies, their access to information and knowledge on flood disaster preparedness is vital in ensuring resilient societies (Yildiz *et al.*, 2021), this indicates the necessity to educate and train people and create easy access to flood information. Flood preparedness and mitigation strategies are strengthened when they are an integrated and collaborative effort between citizens and institutional governing bodies because the direct implementation of frameworks established by governance is largely dependent on the response and acceptance of citizens. Noteworthy, a shift of attention from technical flood risk management measures to non-structural measures such as policy-making has proven to provide more sustainable solutions to mitigate flood disasters (Bubeck *et al.*, 2017;

Li *et al.*, 2020; Rubinato *et al.*, 2019). Figure 1. Shows how the NFIP program formed by the US government has performed in flood risk management. We see that before the NFIP formation, losses from flood disasters were high despite having a considerably low number of events. Although there seems to be great economic loss in the aftermath of the NFIP formation, this can be attributed to an increased number of weather events, which is a result of climate change. The framework can be said to have performed well so far in flood risk management in the US, however, increased effort is required to further strengthen the engagement of citizens, allowing the program to achieve its purpose. Nonetheless, the shift in attention towards non-structural measures of flood mitigation strategies has rather strengthened structural measures as they are still much in use and considered important in preventing flood disasters. Such is seen in the flood risk management approach in the Netherlands, where there is more focus on structural measures since a large part of the country is situated in a floodplain zone. However, there have been recent efforts to integrate both measures (Van Herk *et al.*, 2015), which are in response to the requirements set by the EUFD. Flood risk management strategies in the United States and the United Kingdom lie more on governance, which is a broad approach that ensures flood risk avoidance in the first instance. The disparity in strategies demonstrates that flood risk management is specific to flood risk probability and potential impact in each country. Nevertheless, adopting structural building patterns (Creach *et al.*,

2020) are effective measures to prepare for and mitigate floods. Findings from this research indicate that flood preparedness and mitigation is multifaceted, therefore adopting an already existing framework in a more resilient society may prove vital in mitigating and managing floods in less resilient societies.

Proposed Approach for Flood Risk Management in the Use Case Area

The proposed approach is a systematic way of analyzing a system to reveal its strengths and weaknesses and then suggest a solution that improves its operation to further strengthen the system. In the context of flood risk management, it entails the adoption of an existing working framework from a region with similar risk or challenge, and implementation to better improve flood risk management in that specific region. The comparative assessment of flood risk management strategies in three different countries (the UK, the US, and the Netherlands) has established an overview of the strategy that can be adopted to manage flood risk in Lagos, the proposed strategy suggests a framework that allows collaboration and partnership from all sphere of the society. The framework is focused on providing support and guidance to efficient flood management such as enforcing adherence to policies and standards in implementing strategies. This allows public authorities to exert restrictions and sanctions on perpetrators. This management strategy has the potential to mandate Lagos state inhabitants to adhere to and abide by the policies

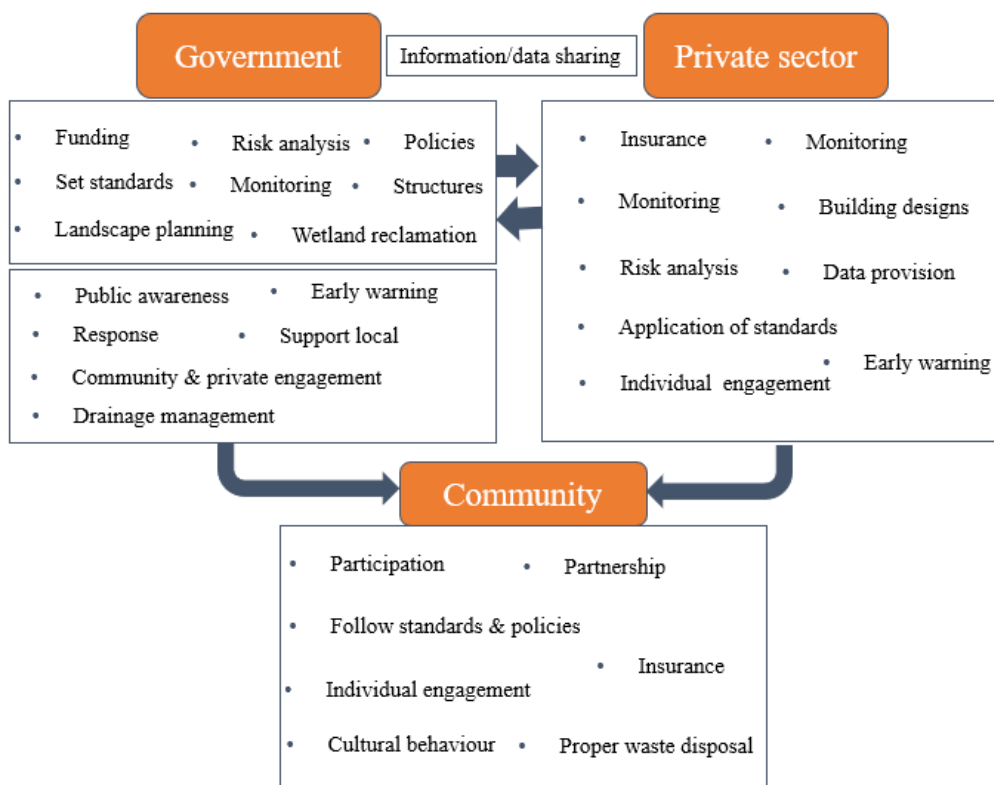


Fig 2: Proposed framework for flood mitigation strategies in the use case area

established by the governments.

The framework also allows the government to provide coverage for the population living in floodplain areas, especially for the urban poor. Such measures will enable the urban poor population to adhere to government policies and have access to a contingency plan that helps them recover easily from flood disasters. Nonetheless, adopting a framework or policies is not as simple as it seems, several factors like economic system, geographic landscape, flood risk, technical know-how, performance of framework, etc., need to be considered (Bubeck *et al.*, 2017) before adopting a flood risk management framework.

CONCLUSION

Floods are becoming more frequent and intense, necessitating enhanced preparedness and mitigation strategies to minimize their devastating effects. In response to flood risks, several economies, especially developed ones, have come up with innovative solutions ranging from structural barriers to non-structural measures that improve flood risk management efficiency. This research has been able to reveal the extent of flood preparedness and mitigation measures, and how they affect the lives of people. Flood preparedness and mitigation can be improved by highlighting the factors that affect preparedness and mitigation of flooding and making this information readily available to individuals and authorities that are concerned with preparing and preventing floods. Perception is one of the most important factors to consider when preparing for flood disasters, which affects how individuals, societies, economies, and countries prepare. People and countries would be able to respond more effectively to flooding events if sustainable measures were implemented. This research has been able to demonstrate that non-structural measures possess the same importance as structural measures in flood risk management, and the effort towards mitigation of flood impact is rather a participatory and collaborative process than sole reliance on public authorities.

Lagos by its location is an extremely vulnerable state to flooding events, and there remains a great demand on the citizens and the government to strengthen their efforts in preparedness and mitigation strategies against this natural phenomenon. A notable setback is the citizen's perspective and lack of participation and collaboration with the government of the state. This lack of collaboration will always be a hindrance to the effective implementation of policies and standards established by the government. Directing attention toward citizens' awareness and participation in flood preparedness and mitigation will serve a great deal to achieve the goal of frameworks and policies set by the government and also an alignment with the sustainable development goals (SDG) 11.

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