



# Techno-Social Synergy for Disaster Resilience in Coastal Communities : A Sustainable Approach

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## ABSTRACT

Disasters are inevitable for the coastal community due to their geographical closeness to the vast ocean. Sea-level rise, coastal floods, cyclones, hurricanes, tsunamis, and even high tides affect coastal communities across the globe. It leads to substantial economic loss and loss of human lives and properties, affecting the coastal communities' livelihood and sustainability. Often the warning time and the preparation time to take action are relatively short. The community needs to be prepared to move to a safer location in this short duration. This work addresses the disaster risk reduction methods that need to be adopted by the coastal communities in India to reduce the impact of natural disasters and climate change risks they are susceptible. We propose an AI-based chatbot to provide accurate and up-to-date information about the spatiotemporally varying disaster scenarios and the vulnerability and resilience indexes. The AI-based chatbot will enhance the user experience and user safety by providing accurate information about disaster alerts through their smartphones.

## CCS CONCEPTS

• **Computer systems organization** → **Real-Time systems**; • **Human-centered Computing** → *Interaction Design*; • **Social and Professional topics** → User characteristics.

## KEYWORDS

Coastal community participation, Disaster risk reduction, Emergency response, AI chatbot, Neural networks

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## 1 INTRODUCTION

The frequency and severity of natural and climate change-related disasters are increasing rapidly, resulting in more loss of lives and properties. These frequent disasters affect the livelihood of the community and displace them. Coastal communities all around the globe face floods and coastal erosion due to low-elevation shorelines, making them more vulnerable than those living in elevated rural and urban regions. Additionally, the developing nations are engaged in urban expansion and haphazard planning, resulting in the decline of livelihood and economic resources [4]. Fast-paced coastal urbanization and poor housing units can also aggravate the disaster risk possessed by the community [4]. Apart from this, occupation-related risks are higher in the coastal communities as they go fishing in the deep ocean to meet their livelihood. Due to this, coastal communities have to adopt various disaster risk reduction methods to reduce their risk and vulnerabilities.

This work focuses on the disaster risk reduction methods for the coastal communities in India by preparing them to take quick decisions and actions to reduce the impact of natural disasters and climate change effects. Furthermore, this work identified that proper coordination between the different stakeholders (coastal community, local government, NGOs, self-help groups, disaster management team) and the socio-technical approach is inevitable for building a sustainable smart digital community. Similarly, adopting technological solutions and social policies for disaster risk reduction requires long-term planning and community participation for a longer duration.

This work is streamlined into two major categories: (a) to establish a synergy between stakeholders through social participation. (b) to establish synergy between the various sources of technical and social knowledge to transform the coastal community into a smart digital community. To support this, we propose an AI Chatbot as a disaster risk reduction (DRR) support system that allows the community to receive site-specific information. This approach is a blend of technological solutions and community participation with the help of local government. This research reviews several case studies in the literature and identifies the various technologies and policies to transform coastal communities into sustainable smart communities. Community participation plays a significant role in any disaster response solution development. This research develops strategies to address a valid question “How to imbibe spontaneous responsiveness and action-oriented behaviours in the coastal communities to develop a smart, resilient community”. Similarly, the

community needs to be aware of the importance of coastal reefs, mangroves, and seagrasses, which are part of the natural coastal ecosystem. It helps in the long-term risk reduction process and in developing intelligent coastal communities that can handle any adverse situations with minimal loss and a faster recovery process with members from all walks of the community. Our proposed AI-based chatbot provides accurate spatiotemporal information about disaster scenarios with the vulnerability and resilience indexes in their local language. It enables the community to participate in disaster risk reduction methods to overcome the risk associated with their region.

The rest of the paper is organized, so that section 2 discusses the related work. Section 3 discuss the various community risk reduction challenges and opportunities. Section 4 discusses the major hierarchical requirements of actors for disaster management within the community. It explains the need for vulnerability and social cohesion index, and section 5 discusses how chatbot will act as a decision support system and data dissemination method for the coastal community. Section 6 concludes the paper.

## 2 RELATED WORK

Factors such as rapid coastal urbanization [4], poor housing infrastructures [4], coastal pollution, coastal ecosystem degradation and so on result in increased risk possessed by the coastal communities in terms of sea-level rise and destruction of housing in the coastal area. Existing research shows that continuing degradation of reefs has contributed much to coastal flooding and has more significant consequences than the sea-level rise [13]. Another problem coastal communities face is storms, which constitute a significant threat to the area as they may provoke substantial beach erosion and over-wash [7]. Most often, the risk involved in natural disasters is assessed at the national level or regional level, and risk response and reduction are happening at the local level.

The importance of a rescue system for post-disaster scenarios for communication is discussed in [12]. Various nature-based solutions (coastal reefs reduce coastal floods due to rain and high tides) can potentially transform climate resilient strategies across the globe and the spatial information about the ecosystem and vegetation of each area is also important to reduce the risk associated with the coastal community. Mapping the spatial region into various categories will help to define regulations, policies and training according to the availability of this [13]. Similarly, the requirement of an emergency response system for ocean disasters and its advantages to the coastal communities, especially for the fishermen and their family, has been discussed in [2], which uses Oceannet[11] architecture for data dissemination in the ocean. This work also discusses the various advantages of communication and emergency response systems for the fisher communities that are predominantly from the coastal regions.

Another important factor to disseminate information is to include an adaptive middle-ware context-aware ecosystem that is required to receive context-based information [10]. Similarly, the ontology-based context modelling approach provides relevant information at the right time [9]. This context-awareness helps to build smart applications to establish a smart ecosystem[8]. Indigenous and local knowledge integration for disaster risk reduction is



**Figure 1: Factors leading to Delayed Actions by the Community**

inevitable. Most of the coastal and island communities have deep knowledge of the environmental changes and the best practices based on their long-term observation closely related to the environmental changes [6].

For any participatory methodology, stakeholder identification is a key factor [3]. Apart from this, the key disaster drivers are lack of coastal cohesion, lack of long-term preparations, poverty, unsustainable development, haphazard planning, and poor urban expansion. To reinstate resilience building and risk reduction methods in an adaptive way, it is important to learn from the mistakes and implement viable solutions. To achieve that, long-term planning and integrated actions after a disaster are required to ensure a sustainable way of living and development in the community.

## 3 COMMUNITY RISK REDUCTION CHALLENGES AND OPPORTUNITIES

This section apprehends the various challenges and opportunities to enhance the resilience of the coastal communities towards unforeseen risks. We categorize the disaster risk reduction methods for the coastal community into three phases as follows : (a) design and development of technology for the community; (b) the solution deployment methods ; (c) Approaches for technology adoption and social cohesion. The phases stated above require substantial interaction with the community for an extended period to formalize resilience-building strategies. Our frequent involvement with the coastal communities is flourishing with Oceannet communication for fishermen [11] and AmritaSREE an established women's self-help group [14] providing an endless opportunity to build community resilience. Using these two solutions, we formulated disaster management activities to enhance community self-reliance and continuous engagement to bridge the digital divide. From the experience of our actual implementation, this work focuses on understanding the requirement between data dissemination approaches and the community's executors and actors'.

During a disaster, there exists a need for proper information flow between the stranded citizens and the disaster mitigation body. Figure 1 shows the different factors that affect the cause of delay in disaster response and the effect of their action, resulting in severe casualties. Similarly, during the onset of a disaster, new volunteers

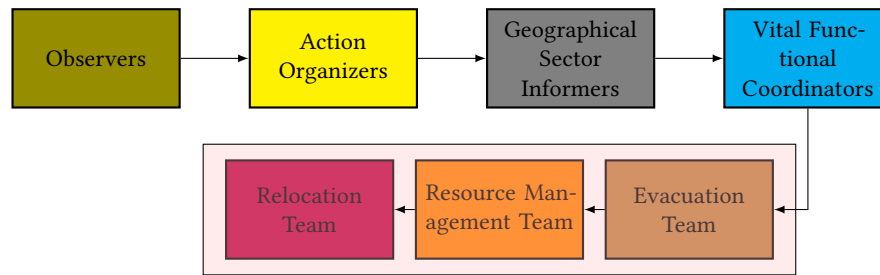


Figure 2: Community Actors

from the local community will emerge to mitigate the risk without proper disaster management guidelines and timely information. This lack of information, mitigation skill, and coordination will slow down the process.

During a disaster, alerts and warnings from the officials reach the ground level lately, and the community cannot respond promptly. It was predominantly due to a need for more clarity on the impact of the disaster in each geographical location and proper guidelines to act. During the 2018 Kerala floods, which resulted in the death of 400+ citizens [1], the root cause was a lack of proper information dissemination and prompt response from the citizens to unexpected warnings. It was due to a lack of awareness, training, social cohesion, trust in the warnings, and community resilience.

From the above studies, coastal community resilience building plays a major role in disaster response. The key factors of coastal resilience building include : a) knowledge about location-based risk factors on disasters, awareness of the citizens about the various government policies and agencies that help the community; b) resilience-building activities such as indigenous methods and other occupational methods adopted by the community; c) cooperation between the community stakeholders at various levels; d) collaboration between the government and the local community and NGOs for the betterment of the community; e) enhance the social cohesion of the community for disaster management and mitigation activities; f) the willingness of the community to participate in the resilience building and mitigation strategies by the various government and non-government organizations; g) technology adoption by the community; To achieve the above goals, the community has to select the actors and the executors from the community to drive the various initiatives. The following section describes the role of executors and coordinators at different hierarchies of the coastal community.

#### 4 COMMUNITY PARTICIPATION FOR RISK REDUCTION APPROACH

Key roles should be assigned to the participants in a crisis or risk situation to perform prompt actions. Most frequently, the action or roles are organically determined during the onset of the events causing the delay of action during an emergency. This situation gets intensified due to their lack of knowledge. Because roles, assignments, and actions are frequently handled on the spot based on necessity. At the end of an event, community actors realize the need for different requirements to be sorted prior could have helped them decrease the disaster impact. Another requirement during

an unusual crisis is the need for a formal template to take simple actions to save more lives. It enables easy and accurate responses to save a life during a pre-disaster. When the community recognizes the holistic perspective of disaster scenarios, their specific roles and resources will help to take action at the first indication of an event. In Figure 2, we identified the different categories of community-level actors who are part of building a resilient coastal community. The roles of each actor are defined as follows:

- **Observers:** This is the set of observers assigned to monitor the various apps and websites to provide any disaster-related information within the community.
- **Action Organizers:** This includes the local institutions and sectors, government bodies and the vital Functional sector coordinators to arrange resources in an organized way.
- **Vital Functional Coordinators:** People responsible for the evacuation setup and arranging basic amenities and temporary shelters or relief camps. These coordinators will be responsible for executing the instruction from the action organizers.
- **Geographical Sector Informers:** A set of selected members from a particular geographical area of the community responsible for micro-level information dissemination.

In a disaster scenario, citizens are willing to participate in rescue operations when the need arises. This participatory approach imbibe societal responsibility, energy and enthusiasm in them. These volunteers in the community will help to reduce the disaster impact. These volunteers are assigned with specific roles as described above will increase their sense of responsibility in the community and can act as vital functional coordinators and actors within the community. In turn, such participants can provide help and support where the disaster management actors cannot reach. In order to reduce the disaster's impact on the community, we need to identify more local citizens as various actors from each geographical location. It leads to strengthening disaster risk governance and coordination.

##### 4.1 Vulnerability and Social Cohesion indexing of the Coastal Communities

We emphasize the importance of a digital twin of the coastal communities in mapping vulnerability and social cohesion indexes. The vulnerability of a community depends on various factors such as lack of nature-based risk reduction opportunities, low seashore, lack of indigenous knowledge, poor housing units, and number of bridges to move to the other side in case of water bodies at

the other side of the coastal region, and transportation facility in each geographical region. Vulnerability also depends on the number of elderly living, young children and women, and fewer youth who can participate in the response operation during the onset of an event. Identification of vulnerable groups based on geography, coastal degradation, dependency only on fishing, no alternative livelihood, and social cohesion mapping has to be defined based on interventions. Mapping this vulnerability index based on the above factors will give the right risk reduction methods and planning to each geographical area. It helps to suggest site-specific warning messages to the coastal communities based on the vulnerability indexing. The social cohesion of the community depends on various factors, including the coordination between the various sectors of the community—the higher the social cohesion, the lower the vulnerability index.

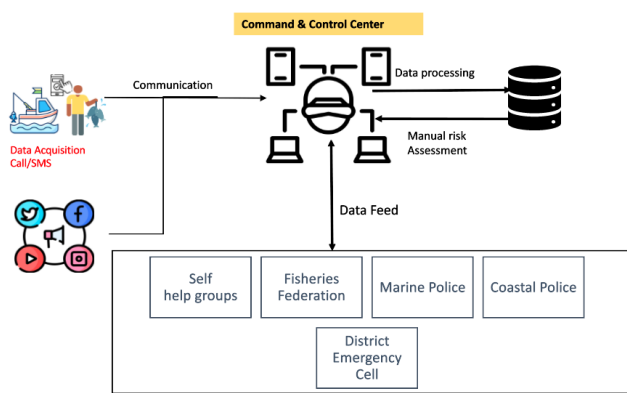


Figure 3: Information Dissemination Complexity

## 4.2 Risk Reduction Index Mapping

We propose a new measurement called Risk Reduction Index Mapping (RRIM), it is defined as the mapping of community capability to improve resilience over time based on social cohesion within a sector of the community, vulnerability index, sensitivity analysis of each geographical area and each community. The RRIM shows us the community and sectors which need additional help during a disaster. If RRIM is higher in a community or geographical region, indicates less support and help from outside is required as the community itself is capable of handling most of the crisis during an emergency. However, on the other hand, if the RRIM is low in specific communities, they need more resources during the onset of an emergency. So the government and disaster management team can focus more on this RRIM community/geographical region.

As the community gets more training and more participants as actors for the various risk reduction categories mentioned in the previous section, their RRIM will increase. The more volunteers, the more chances of transforming from a low RRIM community to a high RRIM community. Similarly, if the community get more training and instructions on how to act during a disaster, its RRIM index will increase. Another factor that enhances the RRIM of a community is the technology adoption by the community to receive emergency alert messages on time.

## 4.3 Dissemination of Disaster Information

A good disaster information system is also inevitable to produce the intended actions based on the situation of the risk possessed by the community during a disaster. A Synergy between technology and community participation is necessary for disaster information dissemination.

From our previous study experience, [1], the current information dissemination to the community is provided by the Command & Control Center(3C), as shown in Figure 3. The 3C mainly uses call center and other information collection sources such as social media feed and various instant messaging services. This centralized 3C is very useful during a disaster, however, the manual handling and estimation of the risk assessment from various information sources will result in a delayed response by the actors. To solve this problem, we propose using a dynamic AI chatbot to disseminate the information to the various actors and the coastal community based on the RRIM. The details of the proposed solution and the advantages over the Command & Control Center alone for disaster management is discussed in the following section.

## 5 CHATBOT FOR INFORMATION DISSEMINATION

During an emergency, people used to gather information about the risk from every source such as the forwards they receive from instant messaging and social media services. This leads to fake information spreading within the community and creating panic situations. The impact of these alarming situations can be reduced by using a chatbot for information dissemination about disasters. Thus the authority needs to focus only on providing the correct information to the chatbot engine. A chatbot is the simplest and basic form of an Intelligent Human Computer Interaction System. A chatbot built on a context-aware system was introduced to assist tourists, which provides recommendations for products and services based on the context and the visitor profile [5].

Similarly, a chatbot is made available to the coastal communities, and they can receive site-specific information and alerts to act based on the context and situation of the geographical region and the various index factors such as VI and RRIM. Our effort is to use chatbots as a disaster management support system for the coastal communities by providing them with authentic disaster-related information and instructions on specific actions based on the warning. This will reduce the dependency on too many unreliable sources of information.

If the various actors and community stakeholders, as shown in Figure 2 are well trained in the AI chatbot on retrieving the information or the intended actions according to the situation. Then this chatbot will serve as an information dissemination service tool for the coastal community. We assume that the chatbots for coastal community disaster management are intelligent and dynamic to the spatio-temporal varying information, and it has sources to feed in the correct information from the ground level within the community. The chatbot can make all the verified and confirmed latest information available. It will give an idea about their current risk and resilience during a crisis. It provides ample time to prepare for evacuation and collectively tackle the situation by society and the authority. However, this is not a holistic solution, but it can act



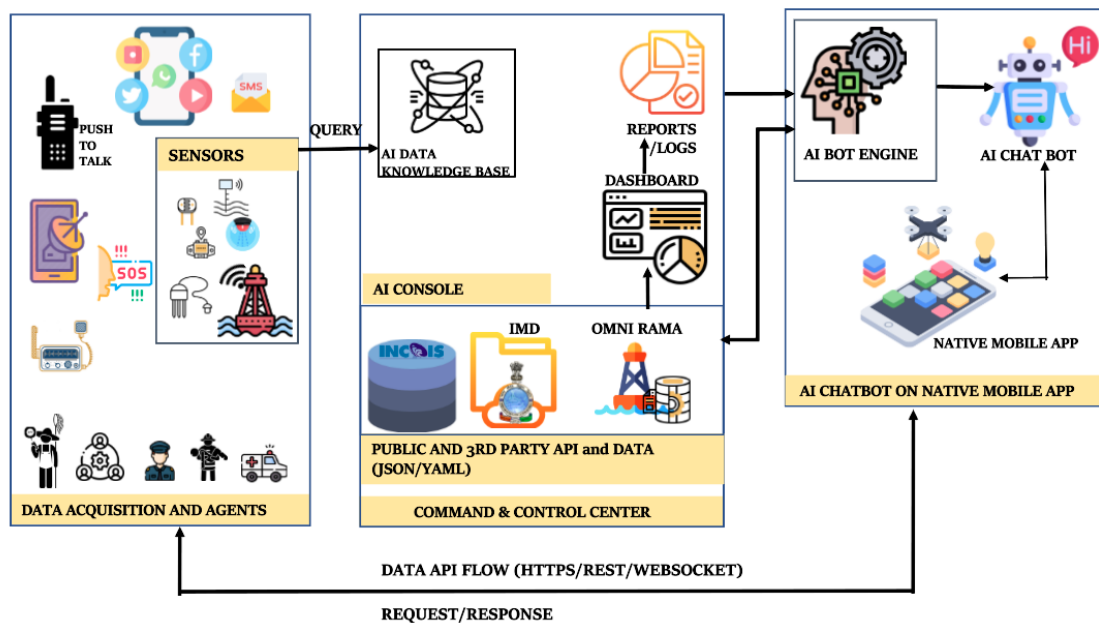


Figure 4: Chatbot enabled Information Dissemination

as a significant information dissemination route from the authority to the people and the actors within the community.

Assuming that the community knows how to act on these messages, multi-stage safety warnings can be brought in as future work. In case of a serious warning for any community sector, the chatbot will notify the users. Each location will have a sector code or place name to identify their safety state. Multiple states will indicate the impending disaster/risk level based on proposed VI and RRIM. The above idea is similar to the yellow and red alerts, usually announced during the rainy season by the disaster management authority. We intend to reduce the time duration commonly present in the disaster warning dissemination to the community. People expect an immediate response from the authority if they have any queries on any alarming event. Suppose the disaster management team, in conjunction with the local authority and community actors, can provide authentic real-time information about each locality with ground truth. This will enhance disaster management's whole process and action with less uncertainty and ambiguity.

Through chatbots, authorities can provide a consistent and common interface for all levels of disaster information from various sources. Leveraging the chatbot framework in disaster information is a handy solution to reduce human intervention and ensure error-free information of relevant sources. It will largely assist in avoiding misinformation. In Figure 4, we provide an integrated framework to disseminate information to the public with the help of AI data, public and third-party API to acquire information from various data acquisition tools used in Ocean and also from the volunteers such as fishermen, police and other disaster response teams. The native mobile app data is sent to Command & Control Center's AI knowledge database. After various data pre-processing and applying AI algorithms provide structured data as reports and logs based on different tools and can be visualized in the dashboards. Same

way as public and third party API integrated to the framework provided to the dashboard. The cloud-native mobile apps enabled by AI chatbots emulate relevant data regarding disaster contexts to the various sector informers and the public.

Here the community only understand the various action-related information based on the situation of the geographical region. For instance, the vital function coordinators' actions are classified into six categories based on the situation, RRIM and VI, as follows:

- **NORMAL:** This indicates that the current situation will not create any risk to the community.
- **Be Watchful:** This is the state in which all the stakeholders have to be alert and watchful for further instructions as the cases are under control, but there is a chance to get worse and progress to a state of level 1 disaster.
- **Be prepared for help:** This indicates that some level of help is required by the community in general and prepare for the help.
- **Execute Help:** If the warning message is "execute help", the community actors can execute "help" with the support of all the stakeholders.
- **Be prepared for Evacuation:** This message indicates that a disaster is inevitable, and the community has to be prepared for immediate evacuation.
- **Execute Evacuation:** This is an indication that the risk possessed by the community is high, and they have to execute an evacuation within a few hours with the help of disaster management stakeholders.

We generated different types of questions users might ask and put them in the JSON intents format tag, patterns and response. Here tag is the classification type, patterns are the questions users might ask, and response is the chatbot's reply to the user. The experiment

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Start messaging with the bot (type quit to stop)!
User: Hello
ChatBot: Hello
User: What is your name?
ChatBot: I'm Whether Informer
User: Is climate ok at Azheekal?
ChatBot: There is a moderate rainfall in Azheekal and it has been declared as Yellow Alert
User: Is there any risk at Azheekal?
ChatBot: There is no much risk currently at Azheekal, but be watchful
User: Thank you
ChatBot: Any time!
User: Bye
ChatBot: Have a nice day
User: quit

Start messaging with the bot (type quit to stop)!
User: ഹലോ
ChatBot: ഹലോ
User: എന്താണ് നിന്റെ പേര് ?
ChatBot: ഏതെങ്കിലും ജന്മപദാർത്ഥം എന്ന് വിളിച്ചാൽ മതി
User: ആലപ്പുഴ കാലാവസ്ഥ ശരിയാണോ ?
ChatBot: ആലപ്പുഴ ജില്ലയിൽ കനത്ത മഴ തുടരുന്നതിനാൽ ഓറഞ്ച് പ്രഖ്യാപിച്ചിട്ടുണ്ട്
User: ആലപ്പുഴ വല്ല അപകടവും ഉണ്ടോ ?
ChatBot: ആലപ്പുഴ ഉൾപ്പെടെ അപകടസാധ്യത കുറവാണ്, അതിനാൽ ജാഗ്രത പാലിക്കുക
User: നന്ദി
ChatBot: എന്തെങ്കിലും സന്ദർശനം
User: ബൈ
ChatBot: ബൈ! വീണ്ടും വരിക
User: quit

```

Figure 5: Multi-lingual AI chatbot based on intent

has been conducted using TensorFlow's inbuilt function for neural networks. We use a sequential model to create a deep learning model by adding layers to it. Each layer has exactly one input tensor and one output tensor. If the response intent can be made dynamic by using a database instead of json, the value of the corresponding key is changed as per the context to provide site-specific time-based relevant information. The alerts will vary according to the changes in the intents of the AI chatbot.

First, the user provides the input or query to the chatbot. The input is passed to the model, and predicts the question pattern from which the model has been trained and gets the corresponding tag. From the response tag in the JSON dataset, it selects a response from the corresponding tag which was predicted from the model and gives the output shown in Figure 5. This chatbot can be further extended to support Multi-Lingual chatbot, and for the experiment, we used only one local language. Similar to the above dataset, we use the same 3 keys but the question pattern would be in the Malayalam language. It can also give a response in Malayalam in the dataset itself, or it could use Google Translator in python while generating the output. In future work, we plan to integrate a rule-based component and voice-based chatbots for the common coastal communities who may not use text-based chatbots. Additionally, we intend to study the acceptance of a chatbot for information dissemination in a small coastal village "Parayakadavu" Kerala, where we plan to test the proposed chatbot in the fisher community and in a few ladies' self-help groups in that community.

The novelty of this work is the use of community members as the pillars for disaster preparedness and emergency management by providing them proper awareness and training on the various disasters. Similarly, a chatbot for disaster management with community participation is a new approach to the best of our knowledge. However, the proposed solution will work only if the community actors are identified, educated, and trained periodically with the help of the local government. If any actors or a subset of actors are not performing their desired actions, it will affect the overall working of the desired disaster preparedness and response.

## 6 CONCLUSION

To adopt different disaster risk reduction methods for information dissemination in the coastal community, we present a set of solutions and methods. We present the importance of community participation and community actors for resilience building within the community. For information dissemination, we propose a multi-lingual AI chatbot accessible to the various community disaster management function coordinators and the coastal population. It will enhance the user experience and safety by providing accurate information about disaster alerts through their smartphones. In the future, we will include Risk Reduction Index Mapping (RRIM) and Vulnerability Index mapping to enhance the performance of the proposed framework. This approach can be extended to other communities facing natural disasters.

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