

Use of Emerging Technologies in Disaster Management

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Abstract

India, one of the most disaster-prone nations, faces increasing challenges from natural and man-made disasters. To address these risks, the country has developed a multi-tiered institutional framework, led by the National Disaster Management Authority (NDMA) and supported by state and local bodies. While these efforts provide a strong foundation, the integration of emerging technologies is reshaping disaster management. Technologies like Artificial Intelligence (AI), drones, and advanced early warning systems enhance disaster prediction, enable faster response, and support effective resource management. Despite their benefits, the widespread adoption of these tools is hindered by economic constraints, regulatory issues, and a lack of skilled operators. This paper examines the impact of these technologies on disaster preparedness and response, identifies challenges, and proposes solutions such as strengthening regulations, fostering innovation through public-private partnerships, and investing in training and capacity building. The study emphasizes that adopting advanced yet sustainable technologies can significantly reduce disaster impacts and enhance community resilience. This paper overall explores the application of advanced technologies in improving disaster management processes. It discusses various cutting-edge tools and systems, such as AI, IoT, drones, and GIS, highlighting their roles in risk assessment, disaster preparedness, response, and recovery. The document emphasizes the transformative potential of these technologies in minimizing disaster impacts and enhancing resilience.

Keywords: Disaster Management, emerging technologies, artificial intelligence (AI), drones and uavs, early warning systems (EWS), resilience, capacity building

INTRODUCTION

Disasters, both natural and man-made, are growing in frequency and severity, making effective disaster management essential. India, with its geographical and socio-economic vulnerabilities, is among the most disaster-prone nations, requiring a robust system to reduce risks and enhance resilience. Over time, India has developed a comprehensive institutional framework, including the Disaster Management Act of 2005 and the establishment of the National Disaster Management Authority (NDMA), to coordinate efforts across central, state, and local levels.

The emergence of technologies like Artificial Intelligence (AI), drones, and advanced early warning systems has revolutionized disaster management, enabling better prediction, prevention, and response. These tools enhance preparedness by providing real-time data, improving decision-making, and streamlining rescue operations.

This paper examines the role of these technologies in disaster management, addressing challenges like costs, regulatory barriers, and skill gaps, and offers recommendations to maximize their potential for building resilience and safeguarding communities Figure 1 [1–3].

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India due to its geographical position and its socio-economic vulnerability is one of the biggest disaster-prone countries in the world. This makes it necessary for India to develop its institutional framework for disaster management above expectations so that it cannot only help the affected regions within the country but also help other countries in the Indian subcontinent and other parts of the world. For this purpose, India has amended its framework over time by introducing acts for disaster management, focused not only at the national or state level but also to the local level.



Figure 1. Climate crisis causing floods, landslides, and coastal threats, stressing the need for disaster preparedness and resilience.

India's institutional framework for disaster management has undergone a very long change from the disaster management cell which came under the Ministry of agriculture in the 1990s to 2002 when the disaster management division was shifted under the Ministry of Home Affairs.

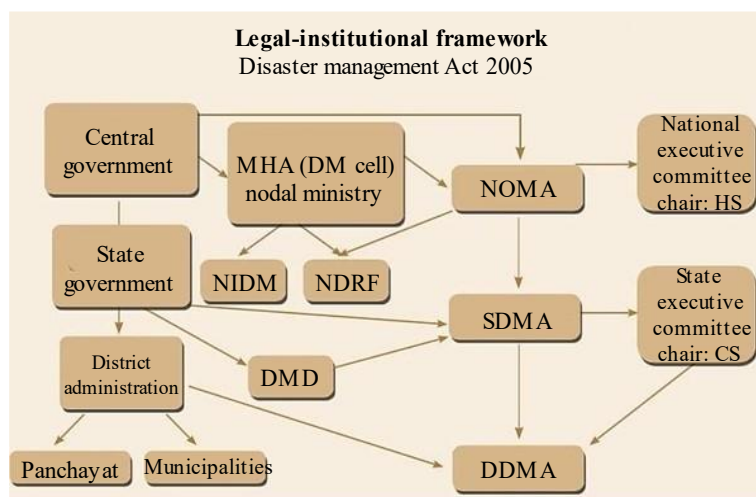


Figure 2. Institutional Framework for Disaster Management in India.

India's disaster management system is currently undergoing changes. A new structure is being set up under the Disaster Management Act, while the older system continues to function. As a result, both systems are working together for now. The National Disaster Management Authority (NDMA) has been created at the central level, and State Disaster Management Authorities (SDMAs) and District Authorities are gradually being established. Meanwhile, the National Crisis Management Committee from the previous setup is still active at the central level. Different nodal ministries handle specific types of disasters under the overall guidance of the Ministry of Home Affairs, which oversees disaster management. This setup involves coordination among multiple stakeholders at various levels [4-6]. Figure 2.

Two key features of this evolving system are:

1. *Hierarchical Structure*: It operates at four levels—central, state, district, and local. Both the old and new setups have structures at these levels, where each higher level provides guidance to the level below it.
2. *Multi-Stakeholder Involvement*: The system includes various ministries, government departments, and administrative bodies, ensuring collaboration across sectors.

Emerging Technologies in Disaster Management:

Early Warning Systems:

Early warning systems are essential for disaster management in today's world. They provide timely and accurate information about risks, enabling authorities, communities, and individuals to take proactive measures. These systems help prevent loss of life and minimize economic damage.

An effective EWS ensures that at-risk populations and industries receive, understand, and act on warnings. These systems play a crucial role in short-term disaster preparedness and response, often at the initial stages of a crisis. By enhancing preparedness, early warning systems also improve resilience, helping communities recover faster and reducing vulnerabilities.

The concept of "early warning and early action," also called anticipatory or forecast-based action, involves taking measures before a disaster occurs, based on advance warnings. This requires active participation and engagement with vulnerable communities to ensure the success of the system

Four Key Elements of Early Warning Systems in Disaster Management

1. *Disaster Risk Knowledge*: Understanding risks involves analyzing the interaction between hazards, populations, and assets in disaster-prone areas. This requires systematic data collection and evaluation, considering how risks may vary with different disaster scenarios.
2. *Detection, Monitoring, Analysis, and Forecasting*: Identifying and tracking hazards is central to disaster management. Early warning systems use sensors and data to detect and analyze potential threats. This allows communities to prepare and execute their disaster response plans with sufficient time.
3. *Warning Dissemination and Communication*: Alerts must reach the affected populations clearly and promptly. Messages should be simple, relevant, and actionable. Effective dissemination through the right channels ensures communities and organizations can respond appropriately, protecting lives and livelihoods.
4. *Preparedness and Response*: Educating communities about risks and safe practices is critical. People need to understand how to respond to warnings, safeguard their health, and navigate evacuation routes.

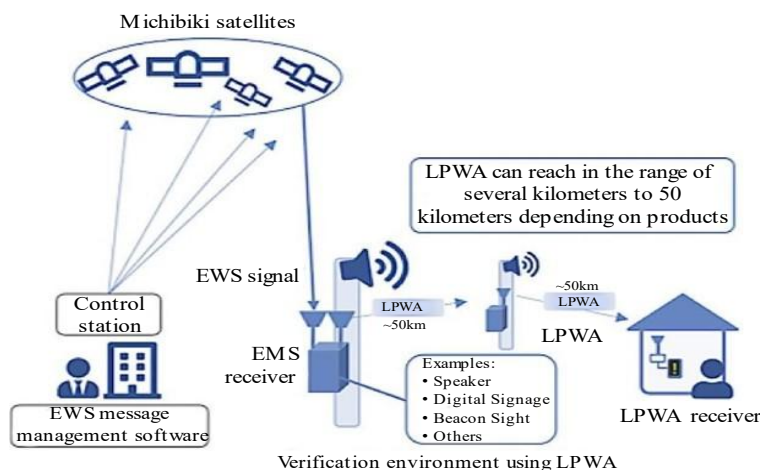


Figure 3. Overview of Michibiki-based EWS using LPWA for signal transmission and disaster alert dissemination.

Preparedness initiatives and awareness campaigns strengthen the effectiveness of early warning systems.

By providing advance information about hazards, EWS supports decision-makers in resource allocation and response planning, significantly reducing disaster impacts (Figure 3).

Technological advancements, such as Utimaco's public warning solutions, further enhance these systems, aiding governments and organizations in protecting at-risk populations.

Use of Drones and UAVs

We are living in an era of technology where the use of UAVs and drones is very common and in every sector drones are replacing the old technologies and reducing time and human efforts increasing efficiency and saving the lives of many. So the use of UAVs and drones proved to be a game changer in disaster management. The major benefits of using drones and UAVs in disaster-prone areas are firstly they can do a comprehensive and rapid areal assessment of affected areas, they can also be used to Enhance safety for responders by accessing hazardous zones remotely, also they Increase efficiency in search and rescue operations, they also help in Quick and targeted delivery of essential supplies to inaccessible locations, and most importantly they can help in Real-time data collection for informed decision-making and resource allocation (Figure 4).



Figure 4. Use of Drones and UAVs

Artificial Intelligence (AI) and Big Data

Artificial Intelligence (AI) significantly enhances disaster management across prediction, prevention, and response phases.

- *Disaster Prediction:* AI analyzes historical data and real-time sensor information to identify patterns and predict potential crises like earthquakes or disease outbreaks. These predictions help authorities act early, reducing risks and saving lives.
- *Disaster Prevention:* AI-driven tools play a key role in designing protective measures, such as flood barriers and early warning systems. By studying large volumes of data, AI forecasts where disasters might happen, allowing communities to prepare and implement strategies to minimize damage.
- *Disaster Response:* During emergencies, AI optimizes resource management, logistics, and coordination of rescue efforts. It ensures a swift and organized response by quickly processing information and helping decision-makers prioritize actions. These capabilities reduce the impact on affected areas and improve the efficiency of relief efforts.

This integration of AI in disaster management demonstrates its potential to significantly mitigate the effects of crises and enhance preparedness and response strategies.

Artificial Intelligence (AI) has revolutionized disaster prediction and management by offering advanced tools to forecast, detect, and respond to natural calamities with precision and efficiency.

For earthquakes, AI systems analyze seismic data to identify patterns, enabling the prediction of events and aftershocks. Deep learning models, such as Long Short-Term Memory (LSTM) networks, have been effective in detecting small to medium-sized earthquakes, while machine learning algorithms like Random Forest are used to estimate building damage quickly. These tools not only aid in early warnings but also enhance emergency response by providing actionable insights into potential structural risks.

In landslide management, AI leverages satellite and geological data for forecasting. Techniques like neural networks and regression models predict landslides with increased reliability, while hybrid systems, such as those combining support vector machines and environmental predictors, refine accuracy further. Similarly, flood prediction benefits from AI-driven models that analyze rainfall and soil data to simulate events. Deep learning frameworks assess flood severity and issue timely alerts, enhancing preparedness and response strategies.

Volcanic eruptions are another area where AI shows promise. By using seismic and geological information, AI predicts eruption events, often incorporating advanced imaging techniques like myography to visualize volcano structures. These tools help in early evacuation planning, minimizing risks to communities near active volcanoes. For hurricanes, AI tools analyze satellite data to predict paths and intensities, enabling emergency responders to allocate resources efficiently.

Wildfires are detected and tracked using AI systems that process satellite imagery to analyze features such as color and texture. Frameworks like Fire_Net achieve high accuracy in identifying wildfire events, while data-driven models simulate fire propagation, aiding in risk evaluation and containment strategies.

The integration of AI across these disaster scenarios demonstrates its transformative potential. By improving prediction accuracy, streamlining emergency responses, and enhancing preparedness, AI equips decision-makers with powerful tools to mitigate disaster impacts and safeguard communities. This progress highlights the importance of adopting AI solutions in disaster-prone regions to build resilience and reduce vulnerabilities. [7,8]

Examples of using emerging technologies in disaster management

In India, the National Disaster Management Authority (NDMA) used drones for the first time during the 2013 Uttarakhand floods. Four unmanned aerial vehicles (UAVs) were sent to survey areas in the flood-hit Himalayan foothills that rescue teams couldn't access. This groundbreaking operation allowed UAVs to inspect 50 locations, including 20 places where rescuers had not yet reached to assess the damage.

Students from IIT Madras have created a disaster management system called "Eye in the Sky" to assist with humanitarian aid. The team, part of the Centre for Innovation (CFI), is designing drones equipped with AI and computer vision technology. These drones can detect and pinpoint people trapped in disaster-hit areas and relay this crucial information to rescue teams for faster response.

In July 2024 a landslide in Wayanad, a hilly district in Kerala happened due to the heavy rainfall in the monsoon and because of the tough terrain of that region, it became very difficult to apply the traditional methods of disaster management here the drones are proven to be the life savior of many. Drones are used for many purposes like mapping the affected area, and delivering essential supplies to the remote region of the affected area, they also help in restoring communication to the areas where the communication was completely destroyed.

Challenges in Technology Integration

In this age of technology where AI, IoT, and other cutting-edge technologies are taking place in every sector and especially in the disaster prevention and management sector every technology comes with its own demerits if we talk about the use of UAVs and drones both of them have been proven as the best resource in many fields of disaster management but the cost of procuring and maintaining these kinds of drones and UAVs are so high that economically weak countries cannot simply afford them and even the big countries which are very prone to natural disasters do not have the desired amount of these drones and UAVs, also there are regulatory hurdles, also the lack of skilled operators to operate these kinds of UAVs.

If we talk about the use of AI in the same, AI is still an emerging technology and no one can completely rely on this technology fully, also there is a constant fear of security because AI uses a vast amount of data, and because of this there is a constant fear of losing data and of misusing that data.

Recommendations

To enhance disaster management through emerging technologies, it is essential to strengthen regulatory frameworks that allow for the seamless deployment of tools like drones, AI systems, and IoT devices. Clear and flexible policies should enable rapid approvals during emergencies while addressing regulatory hurdles. Additionally, increased funding and investments are crucial for procuring, maintaining, and scaling the use of advanced technologies. Governments should prioritize financial support for research and development initiatives in disaster management technologies, especially low-cost, indigenously developed solutions to ensure accessibility for disaster-prone and economically weaker regions.

Collaborative efforts are equally vital. Promoting public-private partnerships can bring innovative solutions to disaster management while fostering interagency coordination between the National Disaster Management Authority (NDMA), state bodies, and private tech companies. Establishing technology-focused cells within disaster management authorities can expedite decision-making and improve operational efficiency. Furthermore, fostering international cooperation is key to sharing best practices, resources, and technologies. India, as a regional leader, can drive initiatives to build capacity and enhance resilience in neighboring countries.

Technological advancements should focus on improving early warning systems (EWS) by expanding their reach to rural and remote areas through local communication networks. Leveraging AI and IoT can enhance prediction accuracy and automate warning dissemination using SMS, mobile apps, and social media platforms. Satellite-based monitoring and IoT devices should be integrated into a centralized digital platform for real-time data collection and better resource allocation. At the same time, robust data security measures are necessary to protect sensitive information and address privacy concerns associated with AI-driven technologies.

Capacity-building initiatives are another critical aspect of effective disaster management. Regular training programs should be conducted for disaster response teams, government officials, and community leaders to operate advanced technologies efficiently. Community awareness campaigns can educate the public about the benefits of these tools and ensure their active participation in disaster preparedness. Establishing centers of excellence focused on disaster management technologies can further build expertise and foster innovation.

Sustainability should be a priority when integrating technologies into disaster management. Governments and organizations should promote green technologies like solar-powered drones and energy-efficient systems to minimize the environmental impact of these efforts. AI and big data can also be used to identify vulnerabilities in infrastructure and plan disaster-resilient construction projects, building long-term sustainability and safety. These measures collectively ensure that emerging

technologies are utilized effectively, equitably, and sustainably in disaster management, contributing to enhanced preparedness and resilience globally [9, 10]

CONCLUSION

The integration of emerging technologies into disaster management holds immense potential to enhance preparedness, response, and recovery efforts. In India, technologies such as Artificial Intelligence, drones, and early warning systems are revolutionizing how disasters are managed, enabling faster and more efficient interventions. These tools are helping authorities predict disasters with greater accuracy, conduct safer rescue operations, and optimize resource distribution in real time.

Despite their advantages, the widespread adoption of these technologies is challenged by high implementation costs, regulatory complexities, and a shortage of trained professionals. Addressing these challenges requires a concerted effort from both the government and private sector.

Strengthening the regulatory framework, increasing investment in research and development, and prioritizing capacity-building initiatives will be crucial in ensuring that these technologies are accessible and effectively utilized, particularly in vulnerable and remote regions.

Looking ahead, India's commitment to leveraging emerging technologies can not only mitigate the impact of disasters domestically but also serve as a model for disaster management across the globe. With the right policies and infrastructure in place, these technologies can significantly improve the country's resilience to future crises and ensure the safety and well-being of its citizens.

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