Disaster Management and Prediction:An In-Depth Review of Modern Approaches

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Abstract—**As natural disasters increase in both frequency and intensity, there is an urgent need for innovative solutions in disaster management and prediction. This survey examines the role of machine learning (ML), Internet of Things (IoT), edge computing, and artificial intelligence (AI) in developing proactive and responsive disaster management frameworks. ML and AI enable predictive analytics that can foresee disaster patterns and identify critical risk factors, while IoT and edge computing facilitate real-time data gathering and processing closer to the source. These technologies work together to enhance situational awareness, improve emergency response times, and support efficient resource management during crises. By integrating these advanced technologies, disaster management systems are better equipped to anticipate, respond to, and recover from disasters, ultimately reducing impact and enhancing resilience. This survey highlights the strengths of these systems, along with challenges in data privacy, cost, and cross-platform interoperability, and calls for continued development in technology-driven solutions for global disaster resilience.**

Index Terms—**Machine learning, Disaster, Prediction**

I. Introduction

The increasing frequency and intensity of natural disasters, exacerbated by factors like climate change, urbanization, and population growth, demand more advanced disaster management and prediction systems. Traditional response systems often struggle with delays in communication, lack of real-time insight’s, and inefficient resource allocation. To address these challenges, recent research has focused on integrating machine learning (ML), Internet of Things (IoT), edge computing, artificial intelligence (AI), and big data analytics into disaster management frameworks. ML and AI provide predictive capabilities by analyzing vast datasets to identify potential disaster patterns, while IoT devices, equipped with sensors, gather real-time data that is processed closer to the source through edge computing. This integration allows for timely predictions, rapid information dissemination, and coordinated responses during critical situations, thereby reducing the impact of disasters on affected communities.

At its core, the platform utilizes advanced Machine learning algorithms and geospatial data analysis to forecast the probability , scale, and impact of events like earthquakes and floods. The early warning system component offers real-time notifications to at-risk areas, enabling communities and authorities to prepare in advance. Predictive models built into the platform analyze historical and real-time data to estimate disaster trajectories and severity, supporting proactive decision-making. Additionally, the post-disaster resource management feature organizes and optimizes resources such as food, medical supplies, and personnel, ensuring they reach affected populations swiftly and efficiently.

By consolidating these functions into one unified platform, this project seeks to empower disaster management agencies, communities, and first responders with the tools needed for swift action and well-coordinated responses. Ultimately,The system holds the potential to save lives and safeguard infrastructure., and facilitate faster recovery for affected communities. This report explores the platform’s design, technical architecture, key functionalities, and potential impact, aiming to showcase a contemporary approach to disaster management that focuses on technology and data-driven insights.

II. Literature Survey

For ease of study the literature are categorized based on the two strategies: 1. Disaster Management System, 2. Disaster Prediction and Alert System .

A. *Disaster Management System*

Amatya et al. [1] proposed a framework highlighting the vital importance of rehabilitation in disaster management, addressing the global increase in the frequency of disasters. Disasters are characterized as significant disruptions that lead to extensive human, material, and economic losses, surpassing the ability of affected communities to respond using their own resources. The rising prevalence of natural disasters, especially those linked to climate change, such as floods, storms, and heatwaves, underscores the pressing need for incorporating rehabilitation into disaster management. These disasters disproportionately impact low-resource areas, where fragile infrastructure and healthcare systems amplify the challenges. Rehabilitation services are essential for both immediate and long-term needs, such as treating injuries, addressing disabilities, and managing chronic conditions aggravated by disasters.

Key approaches and strategies include the World Health Organization’s Emergency Medical Team (EMT) initiative, which establishes a standardized plan for disaster response. This initiative facilitates coordinated care and focuses on integrating rehabilitation throughout the disaster management process, from initial acute care to community reintegration. The diagrams and figures in the study depict global trends, including the increasing frequency of disasters, their economic and human impacts, and the stages at which rehabilitation services face the heaviest burden.

Incorporating rehabilitation professionals early in disaster response is crucial for minimizing mortality, preventing long-term disabilities, and enhancing survivors' quality of life. Building robust rehabilitation capacity at both national and international levels requires strong leadership and collaboration to guarantee the presence of skilled professionals and sufficient resources resources. The references draw from global datasets and established guidelines, emphasizing the need for sustainable and inclusive disaster management practices that prioritize rehabilitation. Notably, Fig. 1 illustrates trends in the rehabilitation burden following sudden-onset disasters, as adapted from the World Health Organization's recommendations for emergency medical teams (2016).

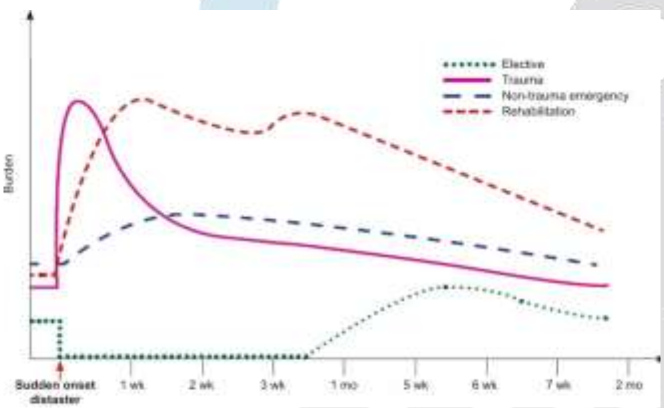

Fig. 1. Trends in the rehabilitation burden in sudden-onset disasters [1]

The authors advocate for increased international and national support to strengthen local capacities for rehabilitation in disaster settings. The study concludes by emphasizing the need to embed rehabilitation at all stages of disaster response to provide comprehensive, long-term care. Published in Annals of Rehabilitation Medicine under an open-access license, this article integrates visual data on disaster impacts to support its findings.

Bin Wu et al. [2] explore a procurement model that utilizes a quantity flexibility contract to handle disruptions in. emergency supply chains. The article emphasizes the critical role of effective supply chains in emergency situations, particularly when government and enterprises collaborate to provide essential supplies. Technologies highlighted include mathematical modeling of supply chains with flexibility contracts, addressing issues such as stockouts and cost-sharing to ensure responsiveness during disruptions. The emergency procurement process is illustrated in Fig. 2, detailing stages from pre-disaster tendering to post-disaster disposal. The conclusion underscores that supply disruptions reduce benefits for both governments and suppliers, stressing the importance of flexibility in contracts to mitigate risks.

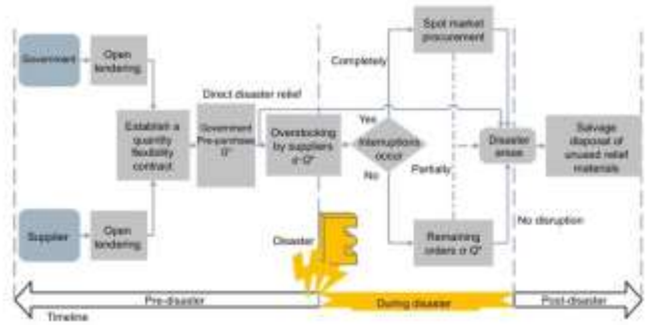

Fig. 2. Schematic diagram of the emergency supply procurement process [2]

Mai Wardeh et al. [3], in their review article titled Sustainability in Refugee Camps: A Systematic Review and Meta-Analysis, states that sustainability in refugee camps is a crucial concern as these camps, originally designed as temporary solutions, often become long-term settlements. A systematic review and meta-analysis of 72 peer-reviewed studies categorized findings across key sectors such as planning, health, education, water and sanitation, energy, and economic growth, with a focus on aligning interventions with Sustainable Development Goals (SDGs) under the 2030 Agenda. Challenges such as inadequate planning, limited access to essential resources, and lack of sustainable practices were highlighted, alongside the need for integrating innovative, culturally sensitive, and cost-effective solutions. Trends in research and publication frequency reflect a growing acknowledgment of the importance of addressing refugee crises, particularly in the context of increasing global displacement.

Integrated strategies such as sustainable shelter designs, improved healthcare access, educational opportunities, and clean energy solutions are identified as essential. Refugee camps require effective policies that consider social, cultural, and political factors to enhance living conditions and enable self-reliance for displaced populations. Aligning interventions with SDGs such as health and well-being (SDG3), quality education (SDG4), sustainable cities (SDG11), and gender equality (SDG5) is necessary to achieve meaningful progress. The analysis underscores the role of partnerships between governments, humanitarian organizations, and local communities in overcoming systemic challenges.

Strengthening collaboration among stakeholders, addressing policy gaps, and fostering innovation are vital steps toward ensuring sustainable living conditions in refugee camps. Comprehensive references in this study provide actionable insights into developing sustainable frameworks that address both immediate and long-term needs of displaced populations, supporting their inclusion in broader development goals. Water and sanitation research suggests innovative solutions to ensure safe drinking water, while economic growth initiatives highlight the potential contributions of refugees to host communities. The authors conclude that tailored, sustainable interventions are essential in refugee camps to meet immediate needs and support long-term resilience. They advocate for enhanced collaboration between international organizations, governments, and NGOs to optimize sustainability outcomes in refugee settings. This comprehensive review highlights critical gaps in current research and emphasizes the importance of adaptable, sustainable solutions in achieving the SDGs within refugee camps.

Vasileios Linardos et al. [4] discusses how machine learning (ML) and deep learning (DL) are increasingly used in managing natural and man-made disasters. It provides an overview of research since 2017 on how these technologies assist in disaster prediction, risk assessment, detection, early warning systems, monitoring, damage evaluation, and post-disaster response. It highlights the application of various ML and DL techniques, such as neural networks and support vector machines, in predicting hazards, improving early warning accuracy, and aiding in efficient disaster response and recovery. Fig. 3 presents the percentage distribution of research studies across the various disaster subphases. Additionally, this discussion emphasizes the potential of big data from sources like satellite imagery and social media to enhance decision-making during disaster events. Future research directions and case studies are also discussed.

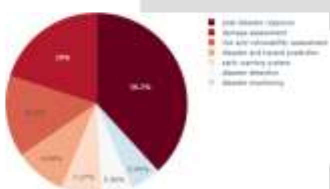

Fig. 3. Research publications by disaster sub phase in percentage form [4]

Mohamed et al. [5] provides a comprehensive review of edge technologies in disaster management. It highlights the application of IoT for data gathering, edge computing for efficient processing, and AI for analyzing the vast amounts of data generated during emergencies. Special focus is given to social media platforms, which act as crucial channels for real-time data collection and crowdsourcing, enabling individuals and communities to actively participate in disaster response efforts. AI algorithms, in turn, process this data to enhance the accuracy of detection and prediction systems. The authors emphasize the critical role of crowdsourcing in contributing real-time information during disasters, supported by smartphones and social media platforms. Despite these advancements, the paper identifies ongoing challenges, including ensuring user privacy, addressing data security concerns, reducing costs, and encouraging user engagement in such systems. Fig. 4 depicts the integration of advanced technologies such as social media analytics, edge computing, artificial intelligence (AI), big data, and the Internet of Things (IoT) is essential in managing emergencies. These technologies play a crucial role in enabling real-time data processing, situational awareness, and efficient decision-making during disaster scenarios. By utilizing these tools, disaster managers can predict, detect, and respond to crises more effectively, ultimately enhancing safety and minimizing response times.

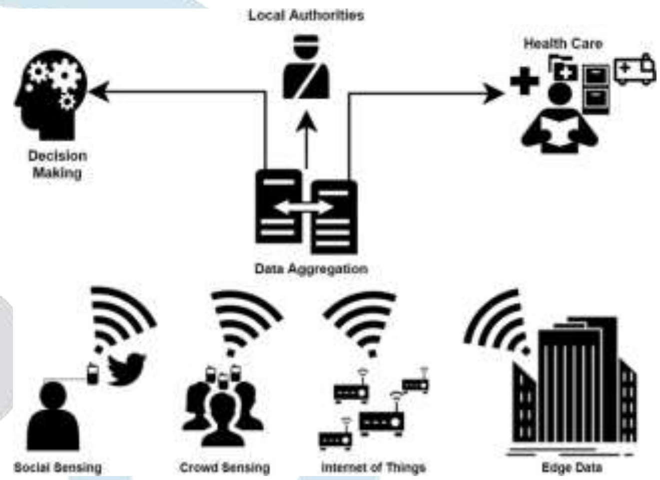

Fig. 4. Technologies used in emergency situations. [5]

The paper underscores the transformative potential of integrating AI and social media analytics into disaster management systems. It also calls for further research to address existing challenges, improve system efficiency, and strengthen public engagement. Supported by well-curated references, this work serves as a valuable resource for advancing disaster management technologies and strategies.

B. *Disaster Prediction and Alert System*

A Fares Hamad Aljohani et al. [6] Introduced an in-depth analysis of different modeling techniques for flood prediction. The study categorizes these methods into two primary types: hydrologic models, which simulate physical water systems, and machine learning (ML)-based models, which use data-driven techniques to forecast floods. It highlights the advantages and limitations of each approach and emphasizes the potential of hybrid models that combine both hydrologic and ML techniques to improve prediction accuracy. The review includes a bibliometric analysis of research trends and evaluates various methodologies, including one-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) hydrologic models, as well as popular ML models like artificial neural networks (ANNs), support vector machines (SVMs), and ensemble approaches. The study concludes with recommendations for further research, particularly the need for integrating hybrid strategies to enhance flood prediction and management.

Abd. Samad et al. [7] introduced the paper that focuses on addressing the limitations of current disaster alert systems by proposing the development of an SMS- predicated Intelligent Disaster Alert System(IDAS). This system aims to predict natural disasters analogous as cataracts, earthquakes, hurricanes, dearths, and lathers, and shoot beforehand warnings to affected dwellers via Short Messaging Service(SMS). The primary provocation behind IDAS is to overcome the inefficiencies of being systems, which constantly struggle with timely delivery of disaster warnings, especially in regions with limited communication structure. Likewise, current systems warrant robust forecasting tools, which limits their capability to predict the onset of disasters accurately. IDAS leverages Artificial Intelligence(AI) ways analogous as Rule- predicated Systems, Decision Tree Analysis, and a Guided Rule Reduction System to enhance its predictive capabilities. These AI styles allow the system to anatomize various environmental factors and induce accurate disaster vaticinations. Once a implicit disaster is detected, cautions are transferred in real-time to residers' mobile bias, allowing them to take necessary precautions. The system uses Microsoft Visual Studio.Net for development, along with a MySQL database to store information on dwellers and disaster-prone areas. By integrating AI with mobile communication technologies, IDAS offers an intelligent, effective, and scalable result to disaster operation, icing that early warnings reach the right people at the right time.Fig. 5 shows the navigation flux of IDAS

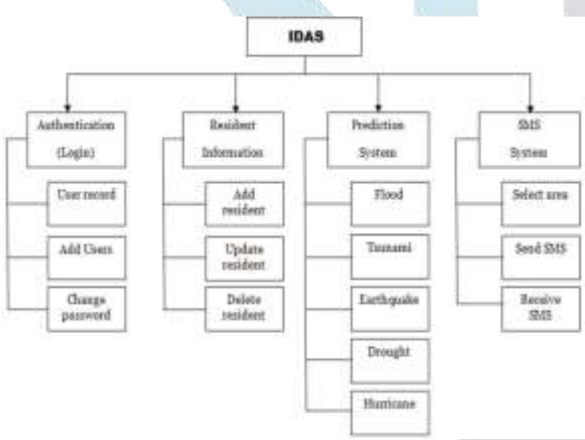

Fig. 5. IDAS Navigation Diagram [7]

The disquisition underscores the transformative eventuality of IoT in disaster operation by addressing critical challenges like early discovery and real- time adverts, By providing an effective and low- cost result, the system aims to empower communities to be more set for flood tide drift-related disasters. The references cited in the paper draw on a different range of former studies in IoT and disaster operation, furnishing a solid foundation for the development of this operation. The authors emphasize that while the current system is a significant step forward, there is room for further improvement, analogous as enhancing attack rigidity and expanding communication capabilities to reach a wider cult. This study contributes to the ongoing sweats in using IoT technology to palliate the risks and impacts of natural disasters effectively, setting a standard for future inventions in the field.

M. Gughan Raja et al. [8] propose a system that provides early disaster warnings and evacuation guidance to Android users through GPS and OpenStreetMap (OSM). The Disaster Management Server (DMS) provides real-time weather updates, sending alerts to registered users, while the Rescue Management Server (RMS) coordinates relief operations and helps users find the safest routes using Dijkstra's algorithm. The diagrams and figures in the paper illustrate the architecture of the system, showing how DMS and RMS work together to provide alerts and guide evacuations. The paper concludes that GPS enabled smartphones can greatly enhance disaster response, and future improvements could include automatic alerts for all mobile users. The references support the system's design, drawing from studies on mapping, tsunami warning systems, and route optimization algorithms.

Muhammad Darwis et al. [9] introduced the development of a low-cost flood detection system utilizing Internet of Things (IoT) technology. The research focuses on the development of an IoT-based early flood detection system designed specifically for flood-prone areas, offering a reliable, affordable, and scalable solution for mitigating flood risks. This system integrates Arduino microcontrollers with ultrasonic sensors to monitor water levels in real time. The sensors measure the distance between the water surface and the device, and when the water level crosses a predefined threshold, the system sends alerts to users via email, along with triggering an alarm through a buzzer. The functional and operational view of the system, depicted in Fig 6, provides a comprehensive representation of the interaction between hardware components, such as sensors and microcontrollers, and software components, including database systems and notification mechanisms. The seamless integration ensures effective communication between components, allowing real-time monitoring, data storage in MongoDB databases, and immediate notification delivery, which is crucial during emergencies. The development of the system employs advanced technologies such as C and Python programming languages for device control, alongside the IoT application design methodology by Arshdeep Bahga and Vijay Madisetti, ensuring structured and efficient system development. This system has been tested using the black-box method, and the results demonstrate its reliability, with all functions functioning as intended, including accurate water-level detection, data logging, and notification delivery. The system's architecture in this paper emphasizes the simplicity of the design, ensuring that it can be easily replicated, maintained, and further developed by researchers or end users. Additionally, the system has been designed with flexibility in mind, allowing notifications to be sent through alternative

communication channels like SMS or mobile applications, although email was used in this prototype. Future iterations could explore the use of industrial-grade components to improve durability while maintaining affordability.
Fig. 6 illustrates the functional and operational setup of the IoT-based flood detection system, showing the interaction between ultrasonic sensors, Arduino microcontrollers, and buzzers. It highlights how water-level data are captured, processed, and stored in the database, with alerts sent to users by email when thresholds are exceeded, ensuring timely flood detection and response.

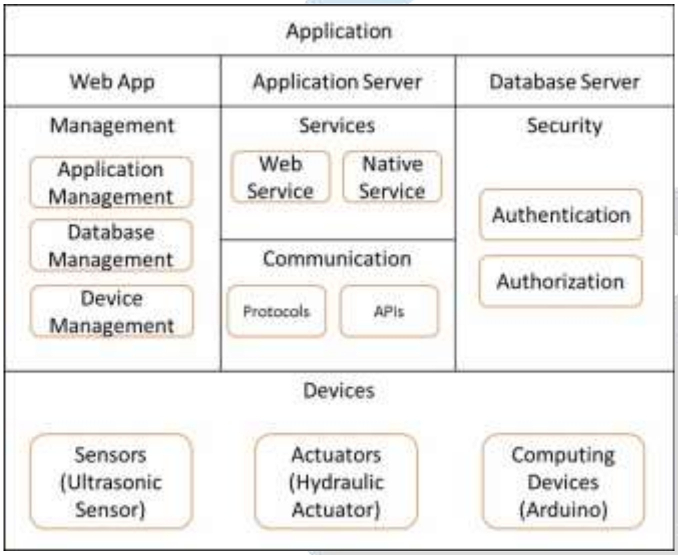

Fig. 6. Functional and operational view [9]

Muhammad Shoaib Farooq et al. [10] present a Flood Forecasting Model (FFM) using Federated Learning (FL) to enhance flood prediction while safeguarding data privacy and security. With flood events rising due to climate change, this model aims to deliver early and accurate forecasts by integrating local data models from different regions without transmitting sensitive data over networks. The system utilizes a local feed-forward neural network (FFNN) at client stations, where each local model is transmitted to a central server for aggregation and development of a global model. This FL-based approach addresses the limitations of traditional machine learning, such as data security risks and network latency, by transmitting only model weights rather than raw data. The FFM model architecture includes five core layers responsible for data collection, model training, and alert transmission. The model's effectiveness is illustrated in this paper, which depicts the internal structure of FFM and the interaction between layers. In conclusion, FFM's decentralized approach achieves 84 precantage accuracy, showcasing its potential to mitigate flood risks and reduce human and economic losses by enabling local data processing and aggregating results to improve predictive accuracy. Future enhancements could enable global adaptation, allowing the model to serve diverse regions, thus expanding its utility. The references section acknowledges prior research in flood prediction and federated learning, which informs this novel approach for secure, data-protective forecasting.

III. Comparative Study

Integrating advanced technologies such as machine learning (ML), the Internet of Things (IoT), and artificial intelligence (AI) into disaster management, comparing their roles in predictive analysis and real-time response. Machine learning and AI provide powerful predictive models that can analyze historical and real-time data to predict the progression and severity of disasters, thereby improving preparedness. Meanwhile, IoT devices combined with edge computing enable real-time data collection and local processing, ensuring rapid response in emergencies. Compared to these advances, traditional systems often suffer from latency and inefficiency because they rely on centralized data processing. However, advanced systems face challenges such as privacy issues, implementation costs, and interoperability issues. Although technology-driven frameworks have significantly improved disaster resilience, overcoming these barriers remains critical for global adoption.

TABLE I
Comparative Analysis of Disaster Management System

Sl. No	Author	Technology Used	Description
1	Bin Wu et al. [2]	Mathematical Modeling, Quality Flexibility Contracts.	Optimized resource allocation and Adaptive strategies for dynamic, uncertain situations.
2	Abd. Samad Hasan Basari et al. [7]	GSM	Send SMS alerts.
3	Muhammad Shoaib Farooq et al. [10]	Federated Learning, Feed-Forward Neural Network	Enhanced flood prediction accuracy.
4	Aboualola et al. [5]	Edge Sensing, IOT, Big Data, Social media analytics	Focuses on Prediction, Detection and Management of disasters during emergencies.
5	Aljohani et al. [6]	Hydrologic Models , Machine Learning	Evaluation of Flood Prediction Modeling.
6	Raja et al. [8]	Open Street Map(OSM), GPS	Provide Real-time Disaster Alerts.
7	Linardos et al. [4]	Federated Learning	Discusses recent flood prediction models.
8	Darwis7 et al. [9]	Hydrologic Models, ML	Improved Early Warning system, Advanced Flood prediction.

IV. Conclusion

Integrating machine learning, IoT, edge computing, and AI offers a transformative approach to both disaster prediction and management, enabling proactive monitoring, predictive analytics, and effective resource allocation. ML-driven models, supported by real-time data from IoT devices, allow for timely predictions and alerts, helping communities and response teams to prepare for imminent threats. Edge computing further strengthens these systems by processing data locally, which reduces latency and supports rapid decision-making in critical situations. Despite the evident benefits, there are ongoing challenges in maintaining data privacy, managing implementation costs, and ensuring seamless interoperability across platforms.

Future research must focus on addressing these issues to develop scalable, adaptable disaster management systems that can serve diverse regions globally, emphasizing the critical need for interdisciplinary collaboration to advance disaster resilience strategies effectively.

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