

Review Article

Disaster Management and AI: Harnessing Technology For The Greater Good

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ABSTRACT

Background: Artificial intelligence (AI) is increasingly applied in disaster management, which encompasses mitigation, preparedness, response, and recovery. AI technologies offer opportunities to enhance hazard forecasting, early warning systems, event mapping, and recovery planning. Despite these advances, challenges related to data quality, availability, and governance continue to limit the integration of AI in disaster management, particularly in regions such as Saudi Arabia.

Methods: This literature review synthesizes recent studies and reports on the applications and challenges of AI in disaster management. The review adopts a thematic approach, organizing findings across the four phases of disaster management and highlighting regional insights, with special emphasis on Saudi Arabia.

Results: AI supports disaster mitigation through hazard forecasting, risk assessment, and infrastructure resilience. In preparedness, AI-powered early warning systems provide timely alerts, enabling proactive interventions. During response, AI facilitates real-time event mapping and damage assessment, aiding decision-making. In recovery, AI contributes to impact evaluation, efficient resource allocation, and structured recovery planning. A case study on flood management in Saudi Arabia demonstrates AI's potential to strengthen early warning systems and response strategies. However, gaps in data completeness, accessibility, quality, and supportive policies hinder effective AI deployment.

Conclusions: AI has the potential to significantly improve disaster management outcomes across all phases. To fully harness its benefits, targeted efforts are required to address data-related challenges and develop supportive policy frameworks, particularly in regions with limited infrastructure

such as Saudi Arabia. Advancing research and collaboration will be essential for integrating AI as a core component of disaster management.

Keywords: *Artificial intelligence, Disaster management, Early warning systems, Flood management, Saudi Arabia, Risk reduction*

INTRODUCTION

Disasters are catastrophic events that result in massive disruption to communities and their infrastructure (1). It can have far-reaching consequences on the affected populations, including life loss, physical injuries, emotional trauma, and economic disruption (2). There are two main categories for disasters: Natural Disasters, often referred to as "Acts of God," such as earthquakes, floods, hurricanes, and wildfires, and Man-made disasters, including industrial, socio-technical, and warfare disasters (3). Disaster management is a systematic approach to deal with natural and man-made disasters. It aims to increase resilience, reduce vulnerability, and minimize the consequences of disasters (1). It is divided into different steps, including disaster mitigation and preparedness (before the disaster), disaster response (during the disaster), and disaster recovery (after the disaster) (2).

The first step in disaster management is mitigation, which aims to prevent the occurrence of disasters or to reduce their effects. The second step is preparation activities, which aim to equip communities with the knowledge and tools to minimize infrastructure damage and ensure people can meet their basic needs in the aftermath of a disaster. The third step is response activities, including operational decisions to save lives, reduce economic losses, and reduce suffering. The recovery is the last step, and it is often characterized as "long-term," including restoring the affected areas, which is the main activity of the government and non-governmental organizations (2).

During a disaster, vast volumes of data are collected, including real and simulation data. Efficient and effective disaster management should rely on processing big data and information in a short time (4). Therefore, utilizing artificial intelligence (AI) to extract and analyze information has emerged as a powerful tool to support informed decisions (5). AI is defined as "a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (6). AI plays a significant role in disaster management, from mitigation to response, and it offers promising solutions to address the challenges posed by disasters (7). This review explores Artificial intelligence's role in disaster management steps, examining its applications and challenges. Additionally, it will present a case study focusing on the application of AI in floods in Saudi Arabia.

METHODS

This literature review aims to examine the role of AI in disaster management by synthesizing and analyzing a wide range of scholarly articles. The initial step was a systematic search to extract relevant articles; databases used in this research include Google Scholar, and PubMed. The search was conducted using a combination of keywords such as

"Disaster management", "preparedness", "prediction", and "Artificial intelligence" Boolean operators (AND, OR) were used to combine these keywords appropriately. Additionally, to encompass the Saudi context within this literature review, supplementary searches were conducted using the specified keywords "Saudi" and "Saudi Arabia".

To maintain consistency in the analysis, the search was limited to literature published in English and within the timeframe of January 2018 to September 2023 to ensure the inclusion of recent and up-to-date research. A predetermined inclusion and exclusion criteria were applied to select studies. The criteria for inclusion were original research articles that discussed the use, application, or challenges of AI in disaster management. Conversely, conference proceedings, news articles, and non-relevant publications were excluded.

As this review focused on the role of artificial intelligence in disaster management and did not involve the use of human or animal subjects, Therefore, ethical considerations regarding human or animal research participants did not apply to this study.

LITERATURE REVIEW

The Role of Artificial Intelligence in Disaster Management:

In recent years, there has been a growing recognition of the transformative power of artificial intelligence (AI) in disaster management (8–10). Utilizing AI technologies in different disaster management activities can enhance preparedness, response, and recovery efforts, ultimately saving lives and minimizing damages.

Before the disaster, AI technologies can enhance the mitigation and preparedness activities. One way to achieve this is by forecasting hazards and assessing the risks. For instance, Adikari et al (2021) utilized AI by analyzing vast amounts of data from various sources, such as weather patterns, to forecast

floods and droughts(11). Additionally, AI has been used in vulnerability assessment, which is a crucial element in disaster mitigation. AI can evaluate the vulnerability of critical infrastructure, such as power grids, transportation systems, and communication networks. By identifying weak points, AI can strengthen infrastructure resilience and reduce vulnerability to disasters (12–14). Lastly, AI-powered Early Warning Systems (EWS) can provide timely alerts and notifications about threats. AI can detect trigger alerts, by continuously monitoring data from various sensors and sources. As a result, authorities can take proactive measures, such as evacuation or emergency response, to minimize the impact of a disaster (15–18)

During the disaster, AI has emerged as a powerful tool to enhance disaster response efforts. AI has been extensively applied to event mapping and damage assessment (8). Robots such as drones are widely used in event mapping to sense and act at a distance from the impacted areas. Drone mapping technology for disaster damage investigation is expected to be an alternative approach for first responders in disaster site investigations. (19). The generated data can provide dynamic information for planning search and rescue operations, staging and deploying resources and understanding short-term housing needs (19). Furthermore, AI can be effective in disaster rescue and relief; utilizing social media and mobile phone data often supports timely and effective decision-making. Social media platforms are powerful communication tools for individuals and local communities to seek help. It includes impeded information about time, location, and disaster-related information Fields (20).

In the aftermath of a disaster, AI can facilitate disaster recovery. The quick and accurate assessment of disaster impact is essential for recovery. AI methods offer a solution for impact assessment by utilizing aerial images, social media imagery data, and sensor

measurements to automate and streamline the assessment process (21). In addition, AI algorithms can generate models that help to develop post-event recovery plans by considering factors such as infrastructure, population, and resource availability. Furthermore, AI can optimize the allocation of resources during the recovery phase (22). AI algorithms can suggest efficient resource distribution strategies by analyzing data on available resources, demand, and geographical factors. This ensures that critical supplies, personnel, and equipment are deployed to the areas that need them the most, facilitating a faster recovery process (23).

Case Study: Utilizing AI In Flood Management In Saudi Arabia

The Kingdom of Saudi Arabia has a historical profile of natural disasters, such as drought, landslides, slope collapses, flash floods, and man-made disasters, such as terrorist attacks (24). Saudi Arabia's climate is characterized as dry overall. However, flash floods increasingly affect most Saudi cities (25).

In November 2009, the city of Jeddah experienced a significant rainfall event, receiving 90 mm of rain within four hours, which was twice its annual average (26). This resulted in flash flooding across various areas of Jeddah, with poorer neighborhoods in the southern part of the city being the most affected. Less than two years later, in January 2011, Jeddah faced another severe heavy rain event, with 111mm of rainfall (27). This heavy rain caused severe consequences, including injuries, fatalities, and significant damage to homes, vehicles, and other properties (28). The devastating floods in Jeddah have highlighted the need for advanced technologies and innovative approaches to enhance flood prevention, early warning systems, and response strategies. Therefore, the application of artificial intelligence is essential for flood management. The literature suggests that the application of AI in Saudi

Arabia, particularly in the context of flood management, is a relatively new and emerging field with promising opportunities for improvement.

In the mitigation phase, several studies have focused on flood susceptibility and prediction using Machine Learning (ML) and deep learning models (29–31). AI, particularly machine learning, has been successfully applied to predict hazards by analyzing large volumes of data obtained from past flood events. This approach has led to a better understanding of flood behaviors and has significantly improved the accuracy of flood predictions (32). As a result, it contributes to better preparedness, enhances resilience, minimizes damage, and saves lives.

During the preparedness phase, Alsumayt et al. (2023) researched the use of AI in Early Warning Systems (33). Their study introduced the Flood Detection Secure System (FDSS), which utilizes a drone application and blockchain technology to detect and manage floods in real time. By utilizing FDSS, the extent of flooded areas can be estimated, providing various authorities the ability to make informed decisions to address floods effectively.

During disaster response, satellite imagery and remote sensing technologies, combined with AI algorithms, have the potential to generate detailed flood maps. Elhag and Abdurahman (2020) discussed the use of advanced remote sensing techniques to assess flash floods in Tabuk City (34). The study utilized images from the European Space Agency's synthetic aperture radar (SAR) sensor to map and analyze a deadly flood crisis in Tabuk City in January 2019. The authors highlight the importance of incorporating flood risk considerations into future urban planning in Tabuk and similar regions. And conclude that advanced remote sensing techniques, such as SAR, can

contribute to effective flood mapping and provide valuable information for disaster management.

Challenges:

While AI holds significant importance and offers substantial benefits in disaster management, it faces various challenges that limit its potential to play a more significant role. According to Alruqi and Aksoy (2023), one of the biggest obstacles in AI is data availability and accessibility. The lack of available data can prevent the development of a robust AI model (35). Moreover, even if the required data are accessible, data incompleteness is a common issue in disaster-related data due to the dynamically changing environment of a disaster. In addition, one of the challenges is data quality and validity, which is crucial for building trustworthy AI models (8).

In the context of Saudi Arabia, there is a need for more policies and databases in the disaster management (25). Consequently, further research, development, and implementation efforts are still needed to apply AI in disaster management effectively.

CONCLUSION

In conclusion, AI has emerged as a powerful tool in disaster management, enabling more effective and efficient responses to crises. From early warning systems to event mapping, damage assessment, and communication, AI technologies have the potential to revolutionize the way disasters are managed. By utilizing the power of AI, governments, organizations, and communities can enhance their disaster preparedness, response, and recovery efforts, ultimately saving lives and mitigating the devastating impact of disasters. However, it is crucial to address the challenges including data accessibility, availability, and validity.

Overall, the integration of AI in disaster management holds great potential for improving response capabilities, reducing loss

of life and property, and enhancing the overall resilience of communities. Further research, technological advancements, and collaboration between stakeholders are essential to further harness AI's benefits in mitigating the impact of disasters and building more resilient societies.

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