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The Role of Unmanned Aerial Vehicles in Diverse Stages of Disaster Management: A Narrative Review

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Review Article

Abstract

INTRODUCTION: The unpredictable magnitude and scope of disasters make it particularly challenging to respond effectively and provide timely assistance to affected populations. In many situations, geographical location, regional topography, and adverse weather conditions, especially in the early stages, hinder rapid access to disaster-affected areas. In recent years, Unmanned Aerial Vehicles (UAVs), commonly known as drones, have emerged as an innovative technology that offers rapid data collection, real-time surveillance, and access to remote areas, thereby enhancing situational awareness and decision-making during disasters.

METHODS: This study employed a narrative review methodology to synthesize existing research on the application of UAVs across the pre-disaster, during and post-disaster phases of disaster management. A comprehensive search of relevant databases yielded a total of 1,986 articles. After removing duplicate records and screening titles, abstracts, and full texts based on predefined inclusion criteria, nine articles were selected for final analysis and review.

FINDINGS: The findings were categorized into four main phases of disaster management: prevention and mitigation, preparedness, response, and recovery. The reviewed studies demonstrated that UAVs play a significant role in improving situational awareness, damage assessment, Search and Rescue (SAR) operations, infrastructure monitoring, and recovery planning. Despite certain technical, regulatory, and operational challenges, the overall evidence highlights the substantial potential of UAVs to enhance disaster management effectiveness across all phases.

CONCLUSION: According to the results of this review, systematic planning for the integration of UAV technology across various stages of disaster management is essential. Although challenges remain, these can be addressed through the adoption of advanced technologies such as deep learning algorithms, as well as improved equipment, software, and analytical tools for data collection and processing. Such advancements can significantly enhance the cost-effectiveness and operational value of UAVs, supporting more efficient disaster response, mitigation, and recovery strategies.

Keywords: Unmanned aerial vehicles; Disaster management; Preparedness; Response; Recovery; Mitigation.

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Introduction

In recent decades, many countries have suffered substantial casualties and economic losses due to the increasing frequency of disasters, posing significant challenges for both developed and developing nations. The unpredictability of disaster magnitude and scope complicates timely and effective responses to affected populations (1). According to the Center for Research on the Epidemiology of Disasters (CRED), 7,348 disasters were recorded worldwide between 2000 and 2019, representing an increase compared to the 1980–1999 period (2). When disasters occur, rapid and effective response is essential to assist affected populations, minimize casualties, and reduce economic impacts (3).

In certain situations, factors such as geographical location, terrain, and weather conditions can make timely access to affected

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populations during the early days of a disaster nearly impossible (4). Additionally, designing effective emergency management plans is often hindered by limited information on human casualties and damage to critical infrastructure. Communication challenges frequently impede visual assessment of losses, making it difficult to determine their extent (5,6). To enhance disaster management efficiency, it has been suggested that new methods and technologies are needed, integrating telecommunications, remote sensing, and spatial–temporal databases (7). One such innovative technology is the use of UAVs, which support visual assessments and all phases of disaster management. The deployment of UAVs in disaster operations, known as Aerial Disaster Management (ADM), is increasingly being adopted in many countries.

A remotely piloted aircraft, commonly called a drone, is an unmanned vehicle that operates without a pilot on board. Originally, the term "drone" referred specifically to military aircraft, but today it encompasses any aircraft that can be controlled remotely by a ground operator or operate autonomously without human intervention (8). Drones were initially designed as simple vehicles, but as their missions grew more complex, their design and functionality evolved accordingly. The type, size, power, and operating conditions of a drone significantly influence its operational capabilities (9). UAVs are commonly classified into eight types: fixed-wing, swept-wing, rotary-wing, tilt-rotor, ducted fan, helicopter, ornithopter, and unconventional (10). Although many studies have examined the use of drones in disasters, they typically focus on a single type of disaster and only on the response phase. This study adopts an all-hazards approach, analyzing drone applications across all phases of disaster management and for a wide range of disaster types. The aim is to explore and describe the role of UAVs in disaster management, highlighting their effectiveness in enhancing disaster response, mitigation, and overall management strategies.

Methods

The This research employs a narrative review methodology to comprehensively synthesize existing studies focused on the utilization of UAVs in disaster management. The objective is to thoroughly evaluate and categorize the diverse roles and functions that UAVs serve throughout the various stages of disaster management, which encompass the pre-disaster phase—where planning and risk assessment occur—during the disaster phase, characterized by real-time data collection and damage assessment, and the post-disaster phase, involving recovery efforts and damage evaluation. Through this detailed analysis, the study aims to highlight the effectiveness and impact of UAVs in enhancing disaster response and mitigation strategies.

Search Strategy

Comprehensive searches were conducted in multiple academic databases, including Scopus, Web of Science, and Google Scholar, for the period between 18 August 2010 and 31 August 2025. The following keywords and phrases were used to guide the search: "Unmanned Aerial Vehicles," "Drones," "Disaster Management," "Emergency Response," "Aerial Surveillance," and "Crisis Management."

Inclusion Criteria

- Articles published in English between 2010 and the present.
- Studies specifically addressing the use of UAVs in disaster management.

Exclusion Criteria

- Articles not focused on disaster management applications.
- Non-peer-reviewed literature, such as conference proceedings.

Data Extraction and Screening

First, the researcher screened the titles of all retrieved articles. Studies that met the inclusion criteria and were relevant to the research question were selected. Next, the abstracts of the selected articles were reviewed. Articles that fully aligned with the research objectives and inclusion criteria were then chosen for full-text assessment. Relevant data were extracted from the included studies, with a focus on UAV applications, advantages, limitations, and reported case studies. Finally, the extracted data were analyzed to identify key insights into UAV operations across the different stages of disaster management.

Table 1. Search strategy

PIO	#1 AND #2 AND #3	Strategy
P	UAVs OR Drones OR aerial drones OR Unmanned Aerial Systems	#1
I	Disaster OR Event OR Crisis OR Hazard OR Phenomena OR Catastrophe OR Risk OR Danger OR Incident OR Accident OR Emergency	#2
O	"Disaster Management" OR "Emergency Response" OR "Aerial Surveillance" OR "Crisis Management" OR Response OR Recovery OR mitigation OR prevention OR preparedness	#3

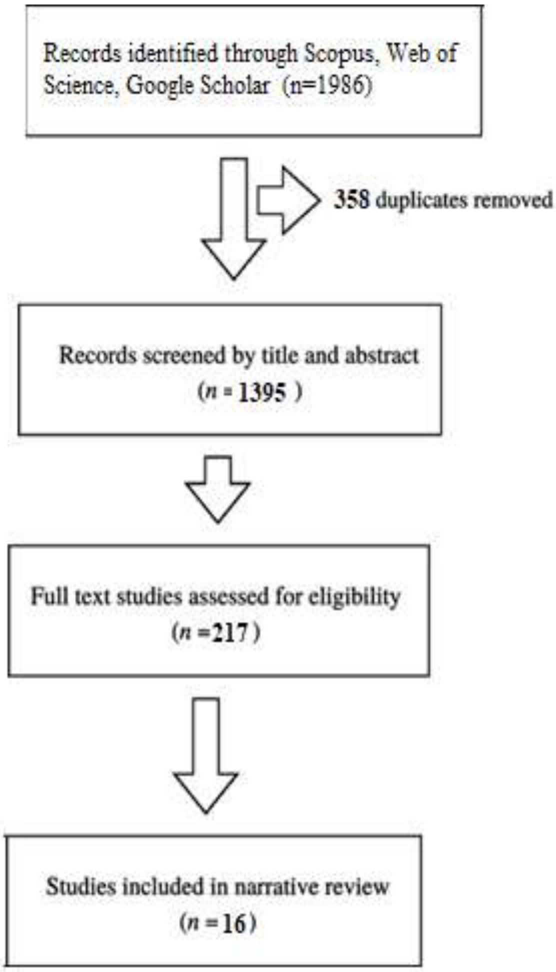

Figure 1. Flow diagram of the article selection process

Findings

A total of 1,986 articles were retrieved from the database search. After removing duplicates and screening titles, abstracts, and full texts, 16 studies were included in the final review. The findings indicate that drones are applicable across all three phases of disaster management—pre-disaster, during disaster, and post-disaster—with the most frequent use observed in the post-disaster response phase. Drones have been effectively employed in a wide range of disasters, including floods, landslides, rockfalls, wildfires, storms, tsunamis, volcanic eruptions, earthquakes, and hazardous material spills (5–15). The article selection process is illustrated in Figure 1.

The main applications of drones in disaster management include monitoring, forecasting and early warning, disaster information integration and sharing, situational awareness, logistics and evacuation support, damage and loss assessment, communication system establishment, SAR operations, area surveillance and media dissemination, traffic and crowd management, emergency medical and health support, and infrastructure reconstruction (5–8 and 11–15). These applications are particularly critical in situations where access to disaster areas is limited due to impassable routes, delayed response times, or risks to rescue personnel. The use of drones across different stages of disaster management is outlined below.

Prevention and Mitigation

In the prevention and mitigation phase, drones primarily perform two key functions: the first is environmental monitoring, through which potential disasters are predicted by detecting early indicators or changes in geological and environmental conditions; and the second function is a warning, involving the dissemination of alerts and implementation of measures to reduce potential impacts. Overall, drone applications in this phase focus on structural and environmental monitoring, research, and early warning systems for disaster prediction (5).

Kamilaris et al. (2018) applied deep learning techniques to enhance drone-based disaster prediction. Using a dataset of 544 images depicting various disaster scenarios—including collapsed buildings, earthquakes, floods, fires, tsunamis, and non-disaster scenes—the study demonstrated that camera-equipped drones could predict disasters with high accuracy (16). Similarly, Sherstjuk et al. (2018) developed a tactical forest fire detection and monitoring system based on remote sensing, drones, and image processing (17). Feng et al. (2015) proposed a drone-based flood management approach that captures high-resolution imagery to identify inundated areas and applies data preprocessing, texture analysis, image classification, and accuracy assessment to precisely map flooded regions (18).

Preparedness

Training of operational forces and the public is a key component of disaster preparedness. Drones provide an effective tool for training operational forces, particularly in Mass Casualty Incident (MCI) scenarios (19). Fernandez-Pacheco et al. conducted a simulation study comparing participants' perceived competencies before and after an MCI exercise. The results showed that drone use was easier and more cost-effective in MCIs occurring in open areas with a large number of casualties. Moreover, participants reported improved self-perceived performance at both individual and team levels following the MCI simulation (20).

Response

The primary application of drones occurs in the disaster response phase, where rapid access to timely information is critical for reducing damage and loss of life. The findings of this study indicate that drones are highly effective in supporting four key response activities: warning and awareness, mapping and damage assessment, SAR operations, and relief delivery.

Warning and Awareness

Early Warning Systems (EWS) have become an important tool in disaster management, driven by advances in telecommunications and sensor technologies. These systems aim to reduce casualties and minimize economic losses by using networks of environmental sensors and communication systems to transmit data to control centers.

One important application of UAVs within EWS is the assessment of air pollution and monitoring of land surface changes (21–22), which support the prediction and early warning of hazards such as landslides, rockfalls, and hazardous leaks (23–24). In addition, UAVs can disseminate disaster alerts to accelerate response and recovery efforts, particularly in situations where public communication networks and critical lifelines are disrupted (25).

Mapping and Damage Assessment

Drones can rapidly survey disaster-affected areas, providing high-resolution imagery and data to assess damage and prioritize relief efforts. For example, Tatham employed drones during the initial assessment of the 2005 earthquake in Pakistan (25). Remote sensing-based damage assessments are essential for enabling swift relief operations. Drones play a key role in collecting and sharing diverse information to support decision-making and integration of insights. However, their effectiveness is often constrained by limited operational range (14, 26).

Search and Rescue (SAR)

The efficiency of drones in disaster relief has demonstrated their ability to perform tasks that were previously difficult or impossible for humans (15). Advances in drone technology—such as autonomous flight, high-precision sensors, and machine learning algorithms—enable rapid collection of large volumes of data, including images, videos, and audio, which can greatly assist operational teams in locating casualties and conducting faster disaster assessments (15). For instance, drones facilitated rescue operations in the Bieszczady Mountains in Poland (27).

The primary goal of SAR operations is to quickly locate and recover individuals while performing necessary interventions within a limited timeframe (28–29). This is particularly critical for locating survivors after building collapses, where any delay can reduce survival chances. Searching large areas for missing persons also poses challenges, especially when resources are limited (30).

Drones help address these issues by accelerating rescue operations while minimizing risks to rescuers. Van Tilburg reported the first documented case of drone use in a canyon ravine to confirm casualties on steep terrain, showing how drones can provide imagery of areas otherwise inaccessible to ground teams (31).

The use of drones will help to overcome all these challenges. On the other hand, the use of drones significantly speeds up the rescue process without endangering rescuers. Van Tilburg provided the first case report on the use of drones, in which drones were used in a canyon ravine to confirm death on steep terrain. According to this report, drones assisted ground search efforts by obtaining images of areas that were difficult or impossible to search (31). The study conducted by Nielsen et al. found that SAR teams are able to operate more effectively in hard-to-reach areas (32). They proposed a new method that utilizes a group of drones instead of just one. This approach not only cuts costs and saves time but also enhances the quality of SAR operations when searching for missing persons over large areas (33).

Relief and Transportation

Logistics is one of the most challenging aspects of disaster management, as roads and streets may be blocked or destroyed during or after major disasters, hindering access to victims and critical medical services. In such cases, drones can deliver essential supplies—such as food, medicine, and communication devices—directly to affected areas (22).

Studies have shown that drones can reach disaster sites and injured individuals faster than emergency teams in simulated scenarios with short distances and favorable weather conditions (34). In addition, drones can assess patients' conditions before ambulances arrive and deliver medical supplies, including equipment, blood samples, insulin, and emergency food, with payloads of up to 17 kg. These findings indicate that drones represent one of the most promising strategies for disaster mitigation and emergency intervention (35, 36).

Recovery

During the disaster recovery phase, drones play a vital role in mapping and monitoring reconstruction efforts. Networks of drones enhance inspection processes, improving both efficiency and accuracy. They can generate detailed maps of affected areas, which are essential for planning recovery activities and tracking changes over time. Furthermore, drones' data collection and reporting capabilities streamline recovery operations. Advanced imaging technologies, including 3D modeling and virtual representations of disaster zones, support the development of reconstruction plans. These maps enable government agencies to prioritize infrastructure restoration and recovery missions (5). Table 2 summarizes the primary applications of drones in disaster management, along with their advantages and challenges.

Table 2. Applications, advantages and challenges of using drones in disaster management

Applications	Advantages	Challenges
Forecasting, Monitoring and Early Warning Systems	- Providing up-to-date information about the disaster - Predicting the disasters through environmental monitoring - Conducting information analysis	- Energy consumption - Reliable data transfer - Accurate estimation skills - High bandwidth for high-quality video transmission
Emergency Communications	- Facilitating wireless communication - Restoring damaged communication infrastructure - Remotely activating wireless connectivity - Improving contact between rescue teams and victims.	- Power efficiency standards. - Drone positioning - Flight pattern optimization for greater coverage
SAR	- Finding and rescuing the injured. - Rapid observation and analysis	- High safety standards, - Coordination with SAR operations forces
Data Collection and Remote Sensing	- Data collection from multiple sources - Connection of different data systems	- Need for an energy-efficient system, - Need for effective route planning, - Integration with other systems
Disaster Logistics	- Providing relief aid such as food, medicine, and mobile devices to disaster victims in affected areas.	- Selecting optimal locations for relief centers

Discussion and Conclusion

The activities of drones can vary significantly depending on the type and severity of the disaster, the characteristics of the affected area, and the stage of disaster management. Drone applications in disaster management are commonly classified into three categories: strategic, operational, and tactical (37).

Drones provide first responders with timely, high-quality imagery more quickly than satellite or GPS data and are often more suitable than fixed-wing aircraft or helicopters in severe weather conditions (8). In debris removal and SAR, specialized teams can optimize their efforts based on the measured remaining access space (38–39). Moreover, drones offer flexibility in resources and timing; for instance, during erosion and flood assessments, they can generate accurate and continuous 2D and 3D data while minimizing on-site time (40–41).

An important consideration in drone deployment is their use in hazardous disaster situations where sending personnel poses risks to human life. For example, drones can support fire management by providing real-time aerial information on the location of hot spots, enabling fire managers to minimize damage (42–44). Similarly, in incidents involving hazardous materials (HAZMAT), such as radioactive leaks, drones offer a practical and effective means for observation, monitoring, and assessing the extent of contamination (45).

Although drones are highly useful for disaster mapping and assessment, they face limitations in collecting low-altitude imagery, and image matching at low altitudes is often unreliable (25). A major challenge is the lack of a centralized system for allocating, consolidating, and sharing humanitarian drone data among relief agencies or NGOs, which complicates obtaining flight permissions during disasters (46). In contrast, helicopter operations—despite limited access to remote areas—are approved more quickly and require fewer permits than drones (8). Additionally, using drones for building surveys and collapse risk analysis presents challenges, including high camera quality requirements, image blurring due to vehicle movement, and GPS signal issues (15).

While UAVs offer significant advantages in SAR operations, their implementation faces challenges such as legal restrictions, adverse weather conditions, and limitations in local community capacity (47). Detecting individuals at high altitudes using imagery alone can be difficult; this challenge has been addressed by equipping UAVs with microphones to detect human voices and using deep learning algorithms to identify people in images (48). Another key application of drones is documenting disasters and emergency response activities, which provides valuable insights for improving future disaster management. Deployed within minutes of an event, drones can record the progression of disasters and the effectiveness of response efforts, offering data useful for research, education, and analysis of disaster behavior, victim responses, response capacity, and infrastructure performance (5).

It should be noted that this approach considers potential limitations, including propagation bias and the variability of drone applications across different regions and disaster types. This study reviews the use of UAVs in disaster management, emphasizing their functions, potential, and innovations across different stages of disaster management worldwide. The findings indicate that, despite certain challenges, drones offer significant benefits in enhancing disaster response and recovery efforts.

The findings of this study underscore the importance of strategic planning for the implementation of UAV technology across all stages of disaster management, despite challenges that can be mitigated. Policymakers should recognize the transformative potential of drones in enhancing operational efficiency and cost-effectiveness, particularly in situations where traditional teams face logistical or hazardous constraints. Prioritizing the development and integration of drone technology can improve damage assessment, enabling faster and more accurate results than conventional methods. Additionally, investment in infrastructure, training, and advanced analytical tools, such as deep learning algorithms, is essential to maximize the benefits of UAVs. This strategic approach can address existing challenges while strengthening disaster management practices, ultimately saving lives and resources.

In conclusion, future studies should aim to address gaps to advance the understanding, deployment, and effectiveness of UAVs in disaster management.

Compliance with Ethical Guidelines

All ethical principles have been considered in this article, and participants were informed of the purpose of the research and its implementation steps.

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Author's Contributions

This article is based on Hamid Karimi Kivi's idea, who was responsible for conducting the research, collecting, and analyzing the data and methodology and correspondence and editing the final manuscript submitted to the journal also Elham Zamani, was responsible for the design and supervision.

Conflict of Interests

The authors declare no conflict of interest.

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