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Technologies Enabling Situational Awareness and Assessment During Disaster Response: A Literature Analysis from 2014 – 2024

Dr. Abdulkadir Jeilani Mohamud

Lecturer, faculty of computer science & IT, Mogadishu University, Mogadishu, Somalia

Email*:* a.jeilani@mu.edu.so

Ayub Abdi Ibrahim

Dean, faculty of computer science & IT, Mogadishu University, Mogadishu, Somalia

Email: Eng.ayub@mu.edu.so

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Abstract

The growing complexity and frequency of natural disasters necessitate advanced technologies to enhance situational awareness and conduct rapid needs assessments, ensuring timely and efficient disaster response. This study provides a comprehensive literature analysis of technologies enabling situational awareness and rapid needs assessment

during disaster response over ten years (2014–2024). The research aims to (1) determine which technologies enhance situational awareness during natural disasters and their impact on improving emergency response times, (2) identify the most effective technologies used for rapid needs assessment in disaster response and recovery efforts, and (3) uncover research gaps while predicting future technological trends in disaster management. Through a systematic review of over 50 peer-reviewed articles, reports, and case studies, key technologies such as Geographic Information Systems (GIS), drones, Internet of Things (IoT) sensors, mobile data collection platforms, and artificial intelligence (AI) were found to be pivotal in improving situational awareness and conducting rapid needs assessments. This study also identifies significant research gaps, such as greater integration between technologies and improved platform interoperability. Based on the findings, future trends will include advancements in AI-driven predictive models, blockchain for resource tracking, and augmented reality for situational visualization. These insights contribute to the understanding of how emerging technologies can be leveraged to improve disaster response efficiency, ultimately reducing loss of life and property.

Keywords: *Disaster Response Technology, Situational Awareness, Rapid Needs Assessment, Drones, AI, IoT in Disaster Management*

1. **Introduction**

A major disaster refers to any natural catastrophe, such as a hurricane, tornado, storm, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snowstorm, drought, epidemic, or outbreak. It also includes any fire, flood, or explosion, regardless of the cause, occurring anywhere in the world that causes damage severe enough to require disaster assistance. This assistance is necessary to supplement the efforts and resources of states, local governments, and disaster relief organizations in addressing the resulting damage, loss, hardship, or suffering(Bazan, 2005).A total of 313 major natural disasters (excluding epidemic diseases) occurred worldwide in 2020, affecting 123 countries and regions. Among all these disasters, 193 were caused by floods, with the highest frequency, accounting for 61.66% of the total; 69 caused by storms (typhoons, hurricanes), accounting for 22.04%; 19 caused by landslides, accounting for 6.07%; 14 by earthquakes, accounting for 4.47%; 7 by droughts, accounting for 2.24%; 6 by forest and grassland fires, accounting for 1.92%; 3 by volcanic eruptions, accounting for 0.96%; 2 by extreme temperatures, accounting for 0.64% (UNDRR, 2020). From 2014 to 2024, increased number disaster occurrence around the world the International Federation of Red Cross and Red Crescent Societies reported 378 disasters were recorded – not including disease outbreaks – which is higher than the 20-year average of 337 disasters per year. Many countries had to respond to hazards like hurricanes and floods while also dealing with COVID-19(International Federation of Red Cross & Red Crescent Societies, 2023).

Situational awareness (SA) refers “the ability to identify, process, and comprehend the critical information about an incident”(Paulison, 2008). Situational awareness refers to the ability of responders to

understand the current state of the environment, which is essential for making informed decisions. Rapid Needs Assessment (RNA) is a process used in disaster and emergency response to quickly gather essential information about the needs of affected populations. These two issues need to study comprehensively. Technologies are Machinery, equipment, or software developed from the application of scientific knowledge.

Technologies such as satellite imagery, drones, mobile communication networks, and Geographic Information Systems (GIS) facilitate the collection, processing, and analysis of real-time data. These technologies enable response teams to identify affected areas, assess the extent of damage, and allocate resources effectively, improving the overall efficiency of disaster response efforts(Cutter et al., 2013; Forrest & Milliken, 2019). Similarly, GIS tools play a pivotal role in mapping affected areas, offering spatial analysis that helps identify critical infrastructure damage, population displacement, and access routes(De Longueville et al., 2009). For instance, Unmanned Aerial Vehicles (UAVs) or drones offer high-resolution imagery and live video streams, providing accurate and up-to-date information, even in areas that are difficult to access by ground teams. This capability enhances the situational awareness of emergency managers, allowing them to visualize disaster zones, monitor the safety of responders, and prioritize resource allocation (Goodchild & Glennon, 2010). Social media platforms, equipped with algorithms for data filtering and geolocation, further contribute by offering real-time data on disaster impacts, thus assisting in both situational awareness and needs assessment(Yates & Paquette, 2011). Social media platforms serve as vital channels for situational awareness, with machine learning techniques effectively classifying disaster-related tweets. This method aids in real-time information dissemination and public engagement during crises (Thar, 2024). Android-based applications streamline rapid health assessments during

disasters, allowing for quick identification of victims' needs. A study demonstrated high usability and reliability of such applications, significantly reducing assessment time(Hidayati et al., 2023). Standardizing information streams across various sensor platforms enhances distributed situational awareness. This approach allows for dynamic querying and co-registration of sensor data, improving the overall perception of the disaster context(Scully et al., 2024). The use of mobile devices and social media for rapid needs assessment. Mobile applications allow affected populations to report their status, request assistance, and provide location-specific information, which can be analyzed and incorporated into decision-making processes(Meier, 2015; Mulder et al., 2016). Imran et al. (2014)presented AIDR (Artificial Intelligence for Disaster Response), a platform designed to perform automatic classification of crisis-related microblog communications. AIDR enables humans and machines to work together to apply human intelligence to large-scale data at high speed. The objective of AIDR is to classify messages that people post during disasters into a set of user-defined categories of information (e.g., "needs", "damage", etc.) For this purpose, the system continuously ingests data from Twitter, processes it (i.e., using machine learning classification techniques) and leverages human-participation (through crowdsourcing) in real-time. AIDR has been successfully tested to classify informative vs. non-informative tweets posted during the 2013 Pakistan Earthquake.

This study aims to investigate how emerging technologies can be more effectively integrated and adapted to resource-limited environments to provide better situational awareness and more accurate needs assessments during disasters." These three objectives set this study:

1. Determining technologies enable situational awareness during natural disasters, and how do they improve emergency response times?

2. Detecting the most effective technologies used for rapid needs assessment during disaster response and recovery efforts?
3. Identifying research gaps and predicting the future trends of technologies enables awareness and rapid assessment during disaster response.

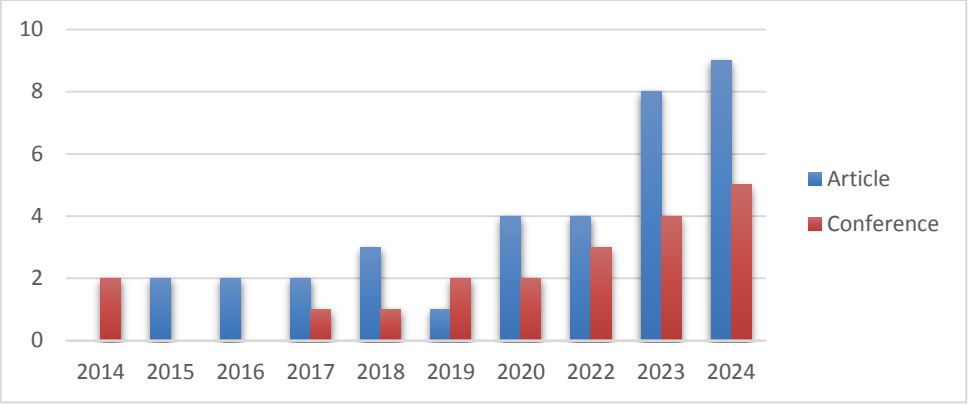

Fig. 1. *Number of Technology enabling assessment and awareness on disaster response.*

The table features research focused on disaster management, artificial intelligence, social media, big data, drones, and humanitarian responses.

Several entries highlight the use of technology to support disaster situations, such as wearable location trackers, AI-based tools for disaster awareness, drones, and data fusion techniques. For example, **Praveen P.** in 2024, discusses wearable technology to track locations during disasters. Similarly, **Thar** explores detecting disaster-related tweets using ensemble learning. The use of **drones** for natural disaster response is another focus, seen in works like **Casella et al.** in 2016, and **Imran et al.** in 2017.

There is a strong emphasis on **big data** and **AI** integration in disaster management systems. **Imran et al.** (2017) and **Ling M** (2023) delve into data-driven disaster management leveraging artificial intelligence and analytics. Another notable contribution includes studies on social media's role in disaster awareness, such as **Ma et al.** (2023) and **Paal et al.** (2023). These technologies offer significant potential for improving the speed, accuracy, and efficiency of disaster response efforts. For example, AI-powered algorithms can analyze large volumes of data from social media, satellite imagery, and other sources to identify potential hazards, track the spread of disasters, and assess damage. IoT devices can be deployed to monitor environmental conditions, infrastructure, and the safety of people in disaster-affected areas.

Additionally, several papers address humanitarian responses and disaster relief planning, like **Seitzinger & Kalra** (2023), who examine emerging technology in healthcare emergency planning, and **Hayes & Stephen** (2015), which cover digital humanitarianism. Research involving **crowdsourcing tools**, particularly for disaster awareness and resource management, is also discussed by **Mulder et al.** (2022).

Table1. Bibliometric overview of the selected papers.

No	Authors	Titles	Year	Type	Published
1	Praveen, P	Wearable Location Tracker During Disaster using AI and IoT	2024	Conference	3rd International Conference
2	Sopha et al.	Adopters and non-adopters of drones in humanitarian operations: Empirical evidence from a developing country	2024	Article	Progress in Disaster Science
3	Thar	Detection of Disaster Situational Awareness Tweets Using Ensemble Learning	2024	Conference	IEEE International Conference on Computer Applications
4	QGIS	QGIS Geographic Information System. Open-Source Geospatial Foundation Project.	2020	Conference	Qgisorg

No	Authors	Titles	Year	Type	Published
5	Meier, Patrick	Digital humanitarians: How big data is changing the face of humanitarian response	2015	Article	Digital Humanitarians
6	Hayes,& Stephen	Distributed morality, privacy, and social media in natural disaster response	2018	Article	Technology in Society
7	Wisor, Scott	Aid on the Edge of Chaos: Rethinking International Cooperation in a Complex World. By Ben Ramalingam.	2018	Article	Global Governance: A Review of Multilateralism and International Organizations
8	Imran et al	Enabling Rapid Disaster Response Using Artificial Intelligence and Social Media	2017	Conference	
9	Casella et al.	Drones as tools for monitoring beach topography changes in the Ligurian Sea (NW Mediterranean)	2016	Article	Geo-Marine Letters
10	UNDRR	Global Natural Disaster Assessment Report 2019	2020	Article	UN Annual Report
11	Aksit et al.	Data Fusion Analysis aData Fusion Analysis and Synthesis Framework for Improving Disaster Situation Awarenessnd Synthesis Framework for Improving Disaster Situation Awareness	2023	Article	Drones
12	Seitzinger Patrick & Kalra	The Role of Emerging Technology in Healthcare Emergency Planning and Response	2023	Conference	
13	Pandey et al.	Automated aerial assessment for seamless adaptive adhoc restoration in partially collapsed network	2024	Article	Computer Communications
14	Imran et al	AI for Disaster Rapid Damage Assessment from Microblogs	2022	Conference	Conference on Artificial Intelligence,
15	Merkle et al.	Supporting Disaster Relief Through Remote Sensing and AI	2023	Conference	International Conference

No	Authors	Titles	Year	Type	Published
16	Imran et al.	AIDR: Artificial intelligence for disaster response	2014	Conference	23rd International Conference
17	Grimaz et al.	Customizable IT tool for on-field assessments to support disaster management	2023	Article	Scientific Reports
18	Pal, et al.	Social media Driven Big Data Analysis for Disaster Situation Awareness: A Tutorial	2023	Article	EEE Transactions on Big Data
19	Forrest et al.	Building Resilience to Disaster: From Advice to Action	2019	Article	European Review
20	Ling, M Thomas, R J	Data-Driven Disaster Management: Leveraging Big Data Analytics for Preparedness, Response, and Recovery	2022	Article	Journal of Business Intelligence and
21	Mulder, etl al.	Questioning Big Data: Crowdsourcing crisis data towards an inclusive humanitarian response	2016	Article	Big Data and Society
22	Wens et al.	Education , financial aid , and awareness can reduce smallholder farmers ' vulnerability to drought under climate change	2022	Conference	
23	Poblet et al.	Crowdsourcing tools for disaster management: A review of platforms and methods	2014	Conference	Lecture Notes in Computer Science
24	Barve et al.	Situational awareness for all: From sensing to collaboration using real-time communication in cities affected by climate change	2022	Article	Handbook on Climate Change and Disasters
25	Ma et al.	Appraising Situational Awareness in Social Media Data for Wildfire Response	2023	Conference	Resilient World - Selected Papers from ASCE Inspire 2023
26	Soto-Vergel et al.	Recent technological advances, challenges, and future trends for rapid and accurate real-world applications of survivor detection	2023	Article	International Journal of Disaster Risk Reduction

No	Authors	Titles	Year	Type	Published
27	Khan et al.	Multi-hazard disaster studies: Monitoring, detection, recovery, and management, based on emerging technologies and optimal techniques	2020	Article	International Journal of Disaster Risk Reduction
28	Haworth, Billy Bruce, Eleanor	A Review of Volunteered Geographic Information for Disaster Management	2015	Article	Geography Compass
29	Gorelick et al.	Google Earth Engine: Planetary-scale geospatial analysis for everyone	2017	Article	Remote Sensing of Environment
30	Omwoma et al.	Technological tools for sustainable development in developing countries: The example of Africa, a review	2017	Article	Sustainable Chemistry and Pharmacy
31	Kato, N Guo, S	Guest Editor's Introduction: Special Section on Emerging Technologies for Disaster Management	2020	Conference	IEEE Transactions on Emerging Topics in Computing
32	Scully et al.	Enabling cross-platform sensor co-registration for distributed situational awareness	2024	Article	
33	Nunavath, V Goodwin, M	The Use of Artificial Intelligence in Disaster Management - A Systematic Literature Review	2019	Conference	2019 International Conference on ICT
34	Deria et al.	Evaluating implications of flood vulnerability factors with respect to income levels for building long-term disaster resilience of low-income communities	2020	Article	International Journal of Disaster Risk Reduction
35	Hakimifar et al.	Evaluation of field visit planning heuristics during rapid needs assessment in an uncertain post-disaster environment	2022	Article	Annals of Operations Research
36	Varghese et al.	Next generation cloud computing: New trends and research directions	2018	Article	Future Generation Computer Systems
37	Allison et al.	Towards Distributed Learning to Support Situational Awareness for Robotic Team Augmented Humanitarian Disaster Response	2024	Conference	2024 IEEE 14th Annual Computing and Communication

No	Authors	Titles	Year	Type	Published
38	Kedia et al.	Technologies Enabling Situational Awareness During Disaster Response: A Systematic Review	2022	Article	Disaster Medicine and Public Health Preparedness
39	Sowmya et al.	Creating a Resilient Solution: Innovating an Emergency Response Drone for Natural Disasters	2024	Article	2024 10th International Conference on Communication
40	Shah et al.	The Rising Role of Big Data Analytics and IoT in Disaster Management: Recent Advances, Taxonomy and Prospects	2023	Article	IEEE Access
41	Wisor, Scott	Aid on the Edge of Chaos: Rethinking International Cooperation in a Complex World. By Ben Ramalingam. Oxford: Oxford University Press, 2013.	2018	Conference	A Review of Multilateralism and International Organizations
42	Hidayati et al.	Android-based Mobile Rapid Health Assessment in the Disaster Emergency Response Phase	2023	Article	Babali Nursing Research
43	Ouaissa et al.	AI and Iot integration for natural disaster management: A comprehensive review and future directions	2024	Article	AI and IoT for Proactive Disaster Management
44	Harika et al.	Harnessing The Power of Artificial Intelligence for Disaster Response and Crisis Management	2024	Conference	2024 International Conference on Communication
45	Haldorai et al.	Climate Resilience Via Smart Technologies Over Natural Disaster BT - Artificial Intelligence for Sustainable Development	2024	Article	
46	Helander, Martin	Disaster Response and Recovery	2020	Article	Introduction to Homeland Security
47	Singh, et al.	Disaster response and recovery role of cloud- enhanced robotics	2024	Article	Shaping the Future of Automation
48	Ersoz et al.	Utilizing digital technologies for rapid damage assessment and reconnaissance: the February 6, 2023 Kahramanmaraş-Türkiye earthquakes (Mw 7.7 and Mw 7.6)	2024	Article	Bulletin of Earthquake Engineering

No	Authors	Titles	Year	Type	Published
49	Tan et al.	Research on Rapid Assessment Technology of Earthquake Disaster Loss Based on GIS	2019	Conference	2019 IEEE 2nd International Conference on Computer
50	Huang et al.	Application of Remote Sensing and GIS in Drought and Flood Assessment and Monitoring	2023	Article	Water (Switzerland)
51	Kim et al.	Disaster assessment using computer vision and satellite imagery: Applications in detecting water-related building damages	2022	Conference	
52	Banerjee et al.	Assessment using Deep Transfer Learning and GAN-based Data Augmentation	2023	Conference	ACM International Conference Proceeding Series
53	Bláhová et al.	Enhanced drought impact monitoring: integrating automated search, translations, and text analysis into online media report scraping	2024	Conference	
54	Chen et al.	AI-Empowered Multimodal Hierarchical Graph-Based Learning for Situation Awareness on Enhancing Disaster Responses	2024	Article	Future Internet

2. Literature Review

Since the commencement of technologies enabling situational awareness and rapid needs assessment, various researchers have published studies grounded in the analysis and systematic review of related literature. The literature identifies three types of analyses: situational awareness. Technologies enabling situational awareness during disaster (Aksit et al., 2023; Barve et al., 2022; Chen et al., 2024; Grimaz et al., 2023; Imran et al., 2017; Kedia et al., 2022; Khan et al., 2020; Pal et al., 2023; Scully et al., 2024; Seitzinger & Kalra, 2023; Sowmya et al., 2024; Thar, 2024; Wens et al., 2022). Technologies enabling rapid needs assessment during disaster(Casella et al., 2016;

Drusch et al., 2012; Gorelick et al., 2017; Grimaz et al., 2023; Hakimifar et al., 2022; Hartung et al., 2010; Hidayati et al., 2023; Imran et al., 2017; Merkle et al., 2023; Pandey et al., 2024; Poblet et al., 2014; Seitzinger & Kalra, 2023; Soto-Vergel et al., 2023; Webster & Watson, 2002; Wens et al., 2022) and other types of technologies used disaster response and recovery(Haldorai et al., 2024; Harika et al., 2024; Helander, 2020; Hidayati et al., 2023; Ouaissa et al., 2024; Poblet et al., 2014; Shah et al., 2019; Singh et al., 2024; Soto-Vergel et al., 2023). These three categories discussed as follows:

2.1 Technologies Enabling Situational Awareness During Disaster.

These studies analyze technologies that provide real-time information to improve situational awareness during disasters. These tools allow emergency responders to monitor and assess the evolving disaster landscape, making timely decision. Various innovative approaches leverage data from social media, robotics, and big data analytics to improve decision-making and coordination among responders. Technologies were categorized based on the technology type and purpose. The technologies such as communication, data analysis, data management, identification, mapping, robotics, sensor and user interface. Technology types varied, with the most common types in articles being data analysis (52%) and sensor technologies (42%), while the most common types were communications (90%) and user interface technologies (55%) Communications and user interface technologies were significantly more likely to be mentioned, while data analysis technologies were significantly more likely to be mentioned in articles(Kedia et al., 2022).

The use of multimodal systems, such as the proposed multimodal hierarchical graph-based situational awareness (MHGSA) system for disaster response, allows for the extraction of visual and audio features

from diverse sources, enhancing disaster event classification(Chen et al., 2024). This approach enables a more comprehensive understanding of the situation by fusing complex data types. Social media platforms serve as critical channels for situational awareness. Techniques like ensemble learning classify disaster-related tweets, improving the detection of relevant information amidst high-dimensional data(Thar, 2024). Robots equipped with advanced sensing technologies can support first responders by providing real-time situational insights. Distributed learning frameworks enable these robots to collaborate effectively, enhancing human decision-making in hazardous environments (Allison et al., 2024). Big data analytics significantly improves disaster preparedness and response by enhancing situational awareness and resource allocation. The analysis of diverse data sources leads to better decision-making and community engagement (Ling & Thomas, 2022). Integrating community-generated data through platforms like RiskMap fosters real-time coordination between citizens and authorities, ensuring a more effective response to disasters (Barve et al., 2022).

Table 2 Technological Enabling Situational Awareness During Disaster and Recovery Effort

Technology	Description
Multimodal Data Integration	The integration of multimodal data sources, such as social media and audio-visual inputs, enhances SA. The proposed multimodal hierarchical graph-based system effectively classifies disaster events by fusing visual and audio features, improving the recognition of complex scenarios (Seng et al., 2024).
Machine Learning Applications	Ensemble learning techniques have been employed to classify situational awareness tweets, demonstrating the effectiveness of machine learning in processing high-dimensional data from social media. This approach aids in identifying critical information during disasters (Thar, 2024).

Technology	Description
Robotic Assistance	Robots equipped with advanced sensing capabilities can collaborate to gather real-time data, thereby supporting first responders. This distributed learning framework enhances human decision-making by providing timely and relevant information (Allison et al., 2024).
Big Data Utilization	Big data analytics significantly improves disaster preparedness and response by enhancing situational awareness and community engagement. The analysis of diverse data sources allows for better resource allocation and decision-making (Pisal & Jadhav, 2024).
Community-Centric Approaches	Integrating community-generated data through platforms like RiskMap fosters real-time coordination between citizens and authorities, ensuring a more effective response to disasters ("Situational awareness for all: from sensing to collaboration using real-time communication in cities affected by climate change", 2022).
Geospatial Information Systems (GIS):	Used for mapping disaster zones and tracking events (Aksit et al., 2023; Barve et al., 2022; Chen et al., 2024).
Unmanned Aerial Vehicles (Drones):	Used for aerial imagery and situational assessment (Imran et al., 2017; Pal et al., 2023).
IoT-based Sensors:	Deployed for real-time environmental data gathering (Grimaz et al., 2023; Kedia et al., 2022).
Social Media Analytics	Platforms like Twitter and Facebook analyzed for real-time situational updates (Khan et al., 2020; Sowmya et al., 2024).

The benefits of these technologies are: Improved decision-making, faster information dissemination, and enhanced communication between agencies (Seitzinger & Kalra, 2023; Scully et al., 2024).

2.2 Technologies Enabling Rapid Needs Assessment During Disaster.

These studies examine tools used to quickly assess damage and resource needs in the immediate aftermath of a disaster. They allow for the prioritization of aid distribution and identification of critical areas. As table 2 shows

Table 3. Technologies Enabling Rapid Needs Assessment During Disaster.

Technology	Description
Satellite Imagery:	Employed for wide-area damage assessments and to identify critical infrastructure impacts (Casella et al., 2016; Drusch et al., 2012; Gorelick et al., 2017).
Mobile Data Collection Platforms	Tools like KoBo Toolbox and Open Data Kit (ODK) allow fieldworkers to collect real-time data during assessments (Hartung et al., 2010; Webster & Watson, 2002; Wens et al., 2022).
Machine Learning Algorithms	Automated analysis of collected data to predict future resource needs and guide recovery efforts (Hakimifar et al., 2022; Hidayati et al., 2023).
Crowd-Sourced Data	Platforms that gather information from citizens, enhancing assessment efforts by providing localized insights (Pandey et al., 2024).

The advantages of these technologies are: Rapid assessment of needs, improved accuracy in damage reports, and better resource allocation during disaster recovery (Merkle et al., 2023; Seitzinger & Kalra, 2023).

2.3 Other Technologies Used for Disaster Response and Recovery.

This section highlights additional technologies that contribute to overall disaster response and recovery, complementing situational awareness and needs assessment. In Somalia's context of recurring droughts and floods, affordable and scalable technologies are needed for rapid assessment. Mobile-based data collection tools, such as Open Data Kit (ODK), are highly effective for gathering real-time data in areas with poor internet connectivity (Hartung et al., 2010). Satellite imagery from free platforms like Google Earth Engine, NASA, and Sentinel satellites can provide crucial large-scale data on environmental conditions, enabling quick assessment of floods or droughts (Drusch et al., 2012; Gorelick et al., 2017). Coupled with GIS tools like QGIS, these technologies allow for efficient mapping and analysis of the affected areas (QGIS Development Team, 2020). Technologies such as Geographic Information Systems (GIS), drones, and mobile applications have significantly enhanced data collection in disaster zones (Kedia et al., 2022). These tools enable rapid mapping and assessment of affected areas, facilitating timely responses. In regions with limited internet, SMS and USSD systems enable communities to report conditions via mobile networks (Wisor, 2018). Drones, while requiring a higher upfront cost, offer precise data collection in remote or dangerous areas, making them an invaluable tool for disaster assessment (Casella et al., 2016). Cloud-based platforms like Google Cloud or Amazon Web Services (AWS) support data integration and analysis in real-time, enhancing decision-making capabilities during emergencies (Varghese & Buyya, 2018). Cloud-enhanced robotics (CER) allows robots to utilize vast computational resources, improving operational efficiency and decision-making during disasters. This technology facilitates real-time data analysis and better coordination among response teams, leading to more effective crisis management (Singh et al., 2024). AI and IoT technologies

enable early detection of disasters and facilitate communication between emergency responders, significantly improving response times (Ouaissa et al., 2024). AI systems can analyze large datasets quickly, aiding in resource allocation and emergency communication, which is crucial in the first 48 hours post-disaster (Harika et al., 2024). GIS and Integrated Decision Support Systems (IDSS) enhance disaster preparedness and recovery by providing critical data for decision-making. These technologies support proactive measures, helping communities better prepare for and respond to natural disasters (Haldorai et al., 2024). As table 3.

Table 4. Other Technologies Used for Disaster Response and Recovery

No	Type of technology	Definition	Type of disaster
1	Data Analytics and Machine Learning	Machine learning and data analytics techniques can be incorporated into flood disaster management systems to improve flood forecasting, risk assessment, and response planning. These techniques can analyze large amounts of historical and real-time data, such as rainfall patterns, river levels, and meteorological conditions, to identify patterns, trends, and potential flood events. Machine learning algorithms can acquire knowledge from historical data to improve the accuracy of flood forecasting and facilitate proactive decision making. Techniques used to analyze data to predict outcomes and optimize responses.	Natural disasters (earthquakes, floods)
2	Model-Driven Engineering	The model-driven approach or Model-Driven Engineering (MDE) is a systematic method that employs models to design, analyze, and simulate complex systems, including flood disaster management systems. Models that depict many components of the flood management procedure,	Natural disasters (earthquakes, floods)

No	Type of technology	Definition	Type of disaster
		such as flood forecasting, risk assessment, and emergency response planning, can be created using MDE. A methodology for software development that focuses on creating models to represent systems.	
3	Google Earth Engine	Google Earth Engine is a cloud-based platform developed by Google that provides a powerful and scalable environment for analyzing and processing geospatial data from satellite imagery and other Earth observation sources. It was launched in 2010, and is primarily used for conducting large-scale geospatial analysis, monitoring environmental changes, and supporting scientific research related to Earth sciences. Platform for processing and analyzing geospatial data on a large scale.	Environmental monitoring
4	Big Data Analysis and Cloud Computing	This analysis method provides adaptable and effective approaches for handling and processing the substantial amounts of data linked to floods. Cloud-based platforms can store and process data from a variety of sources, including sensor networks, satellite imagery, and historical records. By utilizing historical data, these technologies can assist in enhancing flood forecasts and planning for resiliency can process large volumes of data in a distributed environment for insights and decision-making.	All disaster types
5	Sensors Network and Internet of Things	Both sensor networks and IoT have the capability of real-time data collecting as well as monitoring for flood disaster management systems. By deploying sensors in flood prone areas, such as riverbanks or municipal drainage systems, continuous data can be acquired on flood levels, the extent of rainfall, and infrastructural states. IoT and sensor networks facilitate the early detection of flood events, aid in the evaluation of	Natural disasters (floods, fires)

No	Type of technology	Definition	Type of disaster
		flood impact, and provide vital data for decision-making. The data from these networks can be combined with data from other systems such as GIS to track and manage floods more completely.	
6	Management Information System	When the information has multiple use and application, it is called as database information. Applications of MIS in Disaster Management includes, to establish a Decision Support Systems and Disaster Information Network. It is used for hazard mapping and vulnerability assessment. It can be a very vital component in disaster preparedness plan.	All disaster types
7	Database Management System (DBMS)	is a computer-based system that is used to store, manipulate and retrieve data. In any DBMS, there are three types of data models used to store and retrieve (recover) data namely hierarchical, network and relational models. Examples of Microsoft Access, Microsoft SQL, Oracle, My SQL, Open Office Base, IBM DB2. Application of DBMS include: It is the base for other systems like MIS, DSS, GIS etc and can be used for creating Disaster Information Software. It can be used for setting up Disaster Information Network. It is essential to send out warning to all people in a vulnerable region. It can provide information on disaster professionals in a particular nation/region. It can be useful for proper accounting of calamity funds in a particular area.	All disaster types
9	Remote Sensing (e.g., satellites, drones)	Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. Uses of satellite or drone technology to collect data from remote locations.	Natural disasters (earthquakes, floods)
10	Decision Support System	Decision Support System can be defined as an integration of computer hardware, software and	All disaster types

No	Type of technology	Definition	Type of disaster
		methodology that is designed to complement the cognitive thinking of human beings in their decision making.	
11	Mobile applications (e.g., apps for data collection, communication)	Applications designed for mobile devices to facilitate communication and data collection.	All disaster types
12	Social media and crowdsourcing platforms	Platforms that allow users to share information and gather data during emergencies. Use platforms like Twitter, Facebook, and Instagram to raise awareness about flood and drought preparedness. Use **ATLAS.ti** for data analysis. Use platforms like OpenStreetMap to gather real-time data on affected areas, road conditions, and resources. Conduct surveys to assess community needs and impacts through platforms like Google Forms.	All disaster types
13	**Blockchain**	Used for tracking aid distribution and ensuring transparency in resource management (Ouaissa et al., 2024; Shah et al., 2019).	All disaster types
14	Artificial Intelligence (AI)	Applied to optimize logistics, predict disaster spread, and enhance coordination between agencies (Haldorai et al., 2024; Helander, 2020).	All disaster types
15	**Cloud Computing:**	Enables scalable data storage and sharing, ensuring that multiple agencies can access real-time data (Harika et al., 2024; Singh et al., 2024).	All disaster types
16	**Augmented Reality (AR)**	Used in training simulations and real-time visualization of disaster scenarios (Hidayati et al., 2023; Soto-Vergel et al., 2023).	All disaster types

The benefits of these technologies are: These technologies enhance collaboration, improve transparency, and optimize post-disaster recovery processes (Soto-Vergel et al., 2023; Haldorai et al., 2024).

2.4 The efficacy, challenges of these technology in developing countries

While technologies like drones and satellites have proven effective, their adoption in developing countries is often hindered by inadequate infrastructure. Many regions lack stable internet access, electricity, and the technical capacity required to operate and maintain advanced equipment(Sopha et al., 2024). Furthermore, the training required to effectively use these technologies is often inaccessible to local disaster responders(Omwoma et al., 2017). The costs associated with procuring and maintaining technology such as drones and satellite systems are another significant barrier in developing countries. Many governments and organizations struggle to secure funding for these innovations (Wens et al., 2022) Moreover, ongoing operational costs, including training, maintenance, and software updates, further limit the long-term sustainability of such innovations in these regions(Deria et al., 2020). In developing countries, data privacy and security are also major concerns, particularly when using crowdsourced data and satellite images. Weak regulatory frameworks often result in poor data management practices, which can expose sensitive information and compromise the security of affected populations(Hayes & Kelly, 2018). Another critical limitation is the lack of trained personnel capable of effectively using these technologies. Advanced technological solutions require specialized knowledge in areas like data interpretation, drone operation, and satellite image analysis, which is often lacking in developing countries (Ahmed & Saleem, 2017). Without proper training and expertise, the effectiveness of these tools is severely compromised (Kamau, 2018).

Table 5. Challenges for technology

No	Challenges	Description
1	Technical limitations (e.g. software or hardware issue)	This challenge encompasses issues related to software and hardware, such as system incompatibilities, limited processing power, or outdated technology that can restrict effective data collection and analysis in disaster scenarios.
2	Data accuracy and reliability issues	This refers to the potential for errors in data collection, which can arise from various sources, including human error, sensor malfunctions, or unreliable data sources. Accurate and reliable data is crucial for making informed decisions during emergencies.
3	Integration with existing systems	This challenge highlights the difficulties in merging new technological solutions with current systems and processes. Effective integration is essential for ensuring that new technologies complement rather than disrupt existing workflows.
3	High costs of technology	The financial implications of acquiring, maintaining, and upgrading technology can present significant barriers, especially for organizations with limited budgets. This challenge can impact the scalability and sustainability of technological solutions in disaster management.
4	Lack of training or expertise	The effectiveness of technological innovations often depends on the users' skills and knowledge. Insufficient training or expertise among personnel can hinder the successful implementation and utilization of new technologies in disaster response efforts.
5	Difficulties in data interpretation	Even when data is accurately collected, interpreting it can be challenging. This includes understanding complex data sets and deriving actionable insights, which are critical for effective decision-making during disaster assessments.

3. Research Methodology

The literature analysis process involves three key stages: first, the researcher collects a comprehensive set of relevant articles from credible sources that align with the research topic. Next, these articles are organized and classified into an appropriate framework, such as by themes, methodologies, or theoretical perspectives. Finally, the researcher evaluates the articles, synthesizing key findings and trends to draw meaningful insights that address the research objectives(Jourdan et al., 2005). The researchers collected from the databases Google Scholar, Scopus, IEEE Xplore, Sage, Wiley, IGI global, speaciall, all the articles published in the top eight journals during 2014 to 2024 were first reviewed and coded. In the second stage, a two-dimensional framework encompassing technology enabling situational assessment and rapid needs assessment during disaster in developing countries was created in order to classify the research papers, and each paper was then categorized with regard to the type of technology in and challenges. Finally, the analysis addressed practices such as comparing, connecting, and explaining the trends and results(Levy & Ellis, 2006). In the final step, the researcher evaluates the articles, identifies gaps in the existing research literature, and predicts future trends based on the findings and emerging patterns(Webster & Watson, 2002). Based on these three stages, the methodological framework of this research is illustrated in Figure 2

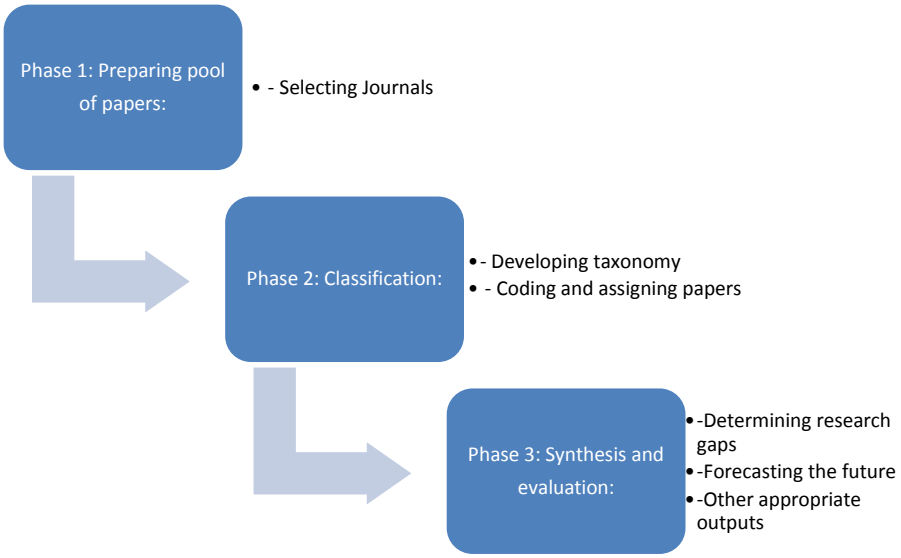

Figure 2. Research Methodology

(adopted from Jourdan et al., (2005))

3.1 Journal Selection

To create a pool of papers, the top and valid journals in the field of disaster management were primarily selected; These journals offer a comprehensive perspective on disaster management, technological innovations, and public health. The **International Journal of Disaster Risk Reduction** and **Natural Hazards** provide foundational insights into risk mitigation strategies and the science of natural disasters, setting the stage for understanding the context in which these technologies are applied. **Disaster Medicine and Public Health Preparedness** focuses on health challenges and how technology improves medical response in disaster zones, while **Natural Hazards and Earth System Sciences** explores innovations for monitoring and assessing natural disasters. **Geomatics, Natural Hazards and Risk** highlights the use of geospatial

technologies like GIS and remote sensing for rapid data collection, which is crucial for needs assessment. **Earthquake Spectra** and **Journal of Flood Risk Management** offer specific insights into rapid assessment technologies for earthquake and flood scenarios. Lastly, **Progress in Disaster Science** provides a multidisciplinary approach, offering a broad view of technological advancements and future trends in disaster science. These journals together provide a rich foundation for analyzing the efficacy, challenges, and future directions of technological innovations in disaster needs assessment.

3.2 Classification

The researcher developed a classification framework of disaster management research based on several criteria. A majority of the studies using the literature analysis have focused on a combination of factors such as research topic, research model, research methodology, paradigmatic research approach, authors, and universities. In the previous section, some of the most important studies which have addressed these dimensions were mentioned. The present study focused on technological enabling situational awareness during disaster and rapid needs assessment and challenges implementation in developing countries, which are explained in the following sections. The table provides a comparison of H4-index and H4-median values for various journals in the field of disaster risk and hazard management. The **International Journal of Disaster Risk Reduction** has the highest H4-index (88) and H4-median (107), indicating strong academic influence. **Natural Hazards** follows with an H4-index of 63 and a median of 83, while **Disaster Medicine and Public Health Preparedness** has an H4-index of 53 and a median of 76. **Natural Hazards and Earth System Sciences** and **Geomatics, Natural Hazards and Risk** have similar metrics, with H4-indexes of 53 and 47, and medians of 74 and 68, respectively.

Earthquake Spectra and **Journal of Flood Risk Management** both have an H4-index of 45, with medians of 68 and 62. **Progress in Disaster Science** has the lowest H4-index (43) but maintains a median of 69, demonstrating a consistent impact across all journals.

Table 6. Top Journals in disaster management

Journal	H4- Index	H4- Median
International Journal of Disaster Risk Reduction	88	107
Natural Hazards	63	83
Disaster Medicine and Public Health Preparedness	53	76
Natural Hazards and Earth System Sciences	53	74
Geomatics, Natural Hazards and Risk	47	68
Earthquake Spectra	45	68
Journal of Flood Risk Management	45	62
Progress in Disaster Science	43	69

Results

In this section, the results are presented based on the technology enabling situational awareness and rapid need assessment of the concerned articles, for which the main thematic points and methodology as well as the major trends are discussed separately.

Technology Enabling Situational Awareness During Disaster Response:

Situational awareness (SA) is crucial for effective disaster response, enabling rapid decision-making and resource allocation. Technologies can significantly enhance SA by addressing challenges such as unreliable

communications, time-intensive data analysis, and lack of interoperable sensor networks (Kedia et al., 2020). Innovative systems combining UAVs, expert systems, and dispersion models can provide a common operational picture for responders and commanders (Mohsin et al., 2016). The RESCUE project focuses on developing next-generation SA technologies, emphasizing the extraction, management, and analysis of situational information (Ashish et al., 2008). DistressNet, an ad hoc wireless architecture, supports disaster response through collaborative sensing, topology-aware routing, and resource localization (George et al., 2010). These technologies aim to improve information accuracy, timeliness, and delivery, ultimately enhancing decision-making in disaster scenarios. Bridging the gap between research efforts and operational needs remains a priority for advancing SA in disaster response (Kedia et al., 2020). As the table shows

Table 7. Technology Enabling Situational Awareness During Disaster Response

Technology	Description
Multimodal Data Utilization	The MHGSA system utilizes social media data, combining visual and audio features to classify disaster events effectively, enhancing situational awareness through a hierarchical graph-based approach (Seng et al., 2024). Ensemble learning techniques have been employed to classify situational awareness tweets, improving the detection of relevant information during disasters (Thar, 2024).
Distributed Learning and Robotics	Heterogeneous robotic teams are being developed to assist first responders by providing real-time situational awareness, thus improving decision-making in hazardous environments (Allison et al., 2024).

Technology	Description
	A hypergraph-based methodology allows for the representation of distributed situational awareness, facilitating collaboration among multiple agencies during disaster response (Gao et al., 2024).
Community-Centric Approaches	Platforms like RiskMap demonstrate the potential of integrating community-generated data with government protocols, enhancing real-time communication and situational awareness during disasters(Barve et al., 2022)
Enhancing Situational Awareness	A systematic review identified that emerging technologies can significantly improve situational awareness, addressing challenges like unreliable communications and data analysis delays(Kedia et al., 2020).

Technology enabling rapid needs assessment during disaster

Rapid needs assessment during disasters is crucial for effective response, and various technologies have been developed to aid this process. Social media platforms, coupled with artificial intelligence, can provide real-time information on urgent needs and situational awareness(Imran et al., 2017). Machine learning platforms can automatically categorize textual messages and process imagery data, enhancing disaster response efforts. Existing methods primarily use structured questionnaires and data from medical registries to assess health needs and status. Emerging technologies can improve situational awareness by addressing challenges such as unreliable communications, time-intensive data analysis, and lack of interoperable sensor networks (Kedia et al., 2020). To bridge the gap between research and operational needs, priority should be given to developing technologies that enable quicker, more accurate decision-making during disaster response operations.

Table 8. Technology Enabling Rapid Needs Assessment During Disaster

Technology	Description
Android-based Rapid Health Assessment (RHA):	This application facilitates quick health assessments, allowing responders to identify the needs of disaster victims efficiently. It demonstrated high usability, with 84.3% of users finding it easy to operate (Hidayati et al., 2023).
Digital Technologies for Damage Assessment	The SiteEye Disaster Plugin was instrumental in managing over 28,000 images post the 2023 Türkiye earthquakes, improving accuracy in damage classification and assessment(Ersoz et al., 2024). GIS technology facilitates rapid assessment of earthquake disaster losses, providing automated calculations and spatial analysis to support decision-making(Tan et al., 2019).
Customizable IT Tools and Automated Systems	The SPRINT-Engine tool allows for quick customization in the field, enabling real-time data collection and analysis, which is essential for effective disaster management (Grimaz et al., 2023). Automated Aerial Assessment: This technique identifies network blackouts and establishes alternative communication routes, enhancing connectivity and response times in disaster-affected regions (Pandey & Nandi, 2024).
Remote Sensing and Drones	Utilizing drones combined with deep learning, this approach enables rapid surveys of affected areas, automating the extraction of critical information from aerial data. This method significantly reduces the time required for situation assessments (Merkle et al., 2023). Remote sensing and GIS techniques are pivotal for monitoring hydrological hazards, providing innovative models for assessing floods and droughts(Huang et al., 2023)

Technology	Description
Machine Learning and Damage Assessment	Deep learning models utilizing pre- and post-disaster satellite imagery can accurately identify affected areas, achieving up to 85.9% accuracy in detecting building damages(Kim et al., 2022). Generative adversarial networks (GANs) enhance damage assessment by generating synthetic images to improve model training, achieving a test accuracy of 88.81%(Banerjee et al., 2023).
Automated Drought Impact Monitoring	Integrating AI tools into drought impact monitoring systems allows for the rapid processing of online reports, significantly improving the efficiency of data collection and analysis(Bláhová et al., 2024)

While these technologies offer substantial benefits, challenges remain, such as the need for trained personnel and the chaotic nature of post-disaster environments, which can hinder effective implementation (Hakimifar et al., 2021).

Discussion and Conclusion

Emerging Technologies for enhancing situational awareness (SA) during 2014 – 2024

Emerging technologies such as IoT, AI, ML, and big data analytics significantly enhance situational awareness (SA) during disaster scenarios by improving data collection, processing, and interpretation. These technologies facilitate real-time insights, enabling more effective disaster response. AI systems utilize multimodal approaches to fuse data from various sources, such as social media, sensors, and audio-visual inputs, enhancing the understanding of disaster events(Chen et al., 2024). For instance, a multimodal hierarchical graph-based system effectively classifies disaster events by integrating visual and audio features,

improving event recognition (Seng et al., 2024). The combination of Artificial Intelligence (AI) and the Internet of Things (IoT) has improved the capabilities of location trackers, especially in disaster management. IoT-enabled wearable devices collect real-time data on individuals' movements and environmental conditions, while AI algorithms process this data to distinguish between normal and emergency situations (Praveen & Kumar, 2024). This capability allows for timely interventions and better resource allocation during disasters. Advanced data fusion techniques combine information from diverse sources, such as UAVs and sensors, to provide a comprehensive view of disaster impacts(Aksit et al., 2023). This approach ensures that emergency control centers can make informed decisions quickly. These technologies enable rapid collection, processing, and sharing of actionable information from various sources, including social media, sensors, and satellites (Kedia et al., 2020; Shah et al., 2019). AI and ML techniques, such as SVM, CNN, and NLP, are being applied to analyze and classify large volumes of disaster-related data for improved prediction and response(Nunavath & Goodwin, 2019). IoT and WSN facilitate real-time monitoring and detection of disaster scenarios, while remote sensing and satellite imagery provide valuable insights for disaster management(Khan et al., 2020). Big data analytics plays a crucial role in processing and visualizing vast amounts of data for accurate and timely decision-making (Shah et al., 2019). However, challenges remain in bridging the gap between research efforts and operational needs of response agencies(Kedia et al., 2022).

Emerging Technologies for Rapid Needs Assessment During 2014 – 2024

Effective technologies for rapid needs assessment during disaster response and recovery efforts leverage advancements in mobile applications, remote sensing, and automated systems. These technologies

enhance the speed and accuracy of assessments, enabling timely interventions. Emerging technologies are increasingly important for rapid needs assessment during disaster response. Social media platforms and artificial intelligence can be leveraged to collect and analyze real-time data, enhancing situational awareness and enabling quicker decision-making (Imran, 2017; Kedia et al., 2020). Android-based applications have been created to conduct rapid health assessments, allowing for quick identification of victims' needs. These applications have demonstrated high validity and usability, with 84.3% of users finding them easy to operate (Hidayati et al., 2023). The SPRINT-Engine is an IT tool designed for on-field assessments, enabling rapid customization to meet specific disaster management needs. It automates data collection and enhances information exchange across disaster management phases(Grimaz et al., 2023). AI systems utilize social media data for real-time damage assessments, significantly reducing response times. These systems have shown effectiveness in identifying unique damage reports, thus aiding formal response organization(Imran et al., 2022). Despite advancements, challenges such as data validity, ethical concerns, unreliable communications, time-intensive data analysis, and lack of interoperable sensor networks and the need for collaborative frameworks remain. Effective disaster planning requires integrating diverse perspectives and utilizing the best available tools(Kedia et al., 2022; Seitzinger & Kalra, 2023). To address these issues, emerging technologies such as crowdsourcing and dynamic mapping have been applied in recent disasters (Kato & Guo, 2020). While progress has been made, there remain open challenges in fully exploiting the potential of these technologies for disaster management. Bridging the gap between research efforts and operational needs of response agencies should be prioritized to improve disaster response efficiency (Kedia et al., 2020).

Research gaps and future technologies trends in disaster

The third objective of this paper was to identify research gaps and predict the future trends in technologies used disaster management.

Between 2014 and 2024, the landscape of disaster management technologies has evolved significantly, but critical gaps remain. In terms of **technologies enabling situational awareness**, key challenges include limited interoperability between various systems used by emergency responders and agencies. The integration of multiple data sources, such as drones, IoT sensors, and satellite imagery, is often hindered by a lack of standardized protocols. Additionally, data overload remains a major issue, where the influx of real-time information becomes difficult to process and prioritize, especially in resource-limited settings. Despite the advancements in predictive modeling and AI, the accuracy of disaster forecasting and situational awareness tools in extreme or complex scenarios continues to be an area of concern. There is also a notable gap in the accessibility of these technologies in developing regions, where infrastructure and technological adoption lag, thus limiting the overall effectiveness of situational assessment.

Similarly, for **technologies enabling rapid needs assessment**, gaps persist in scalability and speed of deployment. While tools like mobile data collection platforms and satellite imagery have proven effective, their ability to cover wide geographical areas in real-time is still constrained, particularly in the aftermath of large-scale disasters. There is also a significant gap in data validation, where ground-level data collection is often delayed or inconsistent, leading to inaccurate assessments. Furthermore, the integration of crowd-sourced data into formal needs assessment frameworks remains underexplored, despite its potential to provide localized and timely information. The limited use of automation in needs assessment workflows also suggests that there is

room for improvement in utilizing AI and machine learning to enhance decision-making during disaster recovery efforts.

Looking forward, **future technology trends** in disaster management are expected to focus on improving connectivity and interoperability through the deployment of 5G networks, enabling more efficient communication between different systems. Blockchain technology is likely to gain traction for tracking resources and ensuring transparency in aid distribution, while AI-driven predictive models are anticipated to become more accurate and integrated into real-time response systems. The use of augmented reality (AR) and virtual reality (VR) for disaster training and real-time situational visualization is also expected to rise, providing first responders with enhanced tools for decision-making. The use of big data analytics in disaster management has grown significantly. By analyzing vast amounts of data from various sources—such as satellite imagery, social media, and IoT devices—disaster management teams can identify trends, predict risks, and make data-driven decisions. Additionally, advances in smart wearables and edge computing could play a crucial role in improving on-the-ground situational awareness and rapid needs assessment, especially in remote or disaster-affected areas with limited infrastructure. Research will likely focus on improving the scalability and accessibility of these technologies, ensuring they can be rapidly deployed and adopted across different regions and disaster scenarios.

In conclusion, this literature analysis highlights the critical role that technologies have played in enhancing situational awareness and enabling rapid needs assessment during disaster response from 2014 to 2024. Significant advancements have been made in the use of geospatial information systems, drones, IoT sensors, mobile data platforms, and artificial intelligence, all contributing to faster and more efficient disaster

management. However, gaps remain in the areas of system interoperability, data overload, scalability, and accessibility, particularly in resource-constrained settings. These challenges hinder the full potential of these technologies in improving response times and accurately assessing needs in the aftermath of disasters.

Future trends indicate promising developments, including the adoption of 5G networks, blockchain for transparent resource management, and AI-driven predictive models for more accurate situational awareness. Additionally, augmented reality, virtual reality, and wearable technologies are poised to further enhance disaster response capabilities. To fully realize these advancements, research must continue to focus on bridging the gaps in system integration, data validation, and the scalability of technologies. By addressing these gaps, the disaster management field can leverage emerging technologies to reduce response times, improve the accuracy of needs assessments, and ultimately save lives and resources during future disasters.

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