



Role of Geographic Information Systems (GIS) in Disaster Management

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Abstract

Disasters—whether natural or human-induced—pose significant challenges to communities, infrastructure and ecosystems. Effective disaster management requires timely, accurate and actionable spatial information. Geographic Information Systems (GIS) have emerged as a critical technology for all phases of disaster risk management: mitigation, preparedness, response and recovery. This paper examines how GIS contributes to each phase of disaster management, the core functionalities of GIS in this domain, barriers and challenges, and future opportunities. Emphasis is placed on how GIS supports hazard mapping, vulnerability assessment, real-time situational awareness, evacuation planning, damage assessment and coordination of resources. The paper concludes that integrating GIS with other technologies, stakeholder participation and data-governance are key to enhancing disaster resilience.

Keywords: GIS · Geographic Information Systems · Disaster management · hazard mapping · vulnerability assessment · situational awareness · evacuation planning

1. Introduction

Disasters have become more frequent, intense and complex in the modern era due to urbanisation, climate change, population growth and ecosystem pressure. Whether earthquakes, floods, wildfires, hurricanes or man-made emergencies, the capacity to anticipate, respond and recover from such events depends heavily on spatial information and coordination.

Geographic Information Systems (GIS) are computer-based tools designed to capture, store,



manipulate, analyse, manage and visualise geographic or spatial data. At their core, GIS link data to a location—allowing decision-makers to see patterns, relationships and trends in ways that plain tabular data cannot. In disaster management, GIS offers capabilities that can transform how agencies prepare for, respond to and recover from disasters.

This paper discusses the role of GIS across the disaster management cycle, explores key applications and tools, outlines challenges, and suggests directions for future research and practice.

2. The Disaster Management Cycle and GIS

Disaster management is typically divided into four main phases: mitigation (or prevention), preparedness, response and recovery. GIS contributes to each phase in distinctive ways.

2.1 Mitigation / Prevention

Mitigation involves reducing or eliminating long-term risk to people and property from hazards and their effects. Here, GIS aids by:

- Hazard mapping: Using spatial data (topography, land-use, historical event locations) to map zones prone to earthquakes, landslides, floods, wildfires.
- Vulnerability and risk assessment: Overlaying hazard layers with demographic, infrastructure and environmental layers to identify vulnerable populations, critical infrastructure and exposure.
- Land-use planning and scenario modelling: GIS supports simulation of future development, identification of safe zones, and planning that avoids placing assets in high-risk zones.
- Resource inventory and asset management: Mapping lifelines (roads, bridges, pipelines, utilities) and assessing their risk and criticality.

By integrating spatial layers of hazards, exposure and vulnerability, GIS helps shift from reactive



to proactive disaster risk reduction.

2.2 Preparedness

Preparedness relates to building capabilities for effective response once a disaster strikes. GIS supports this by:

- Evacuation routing and shelter planning: Using network analysis to design optimal evacuation routes, locating safe shelters and staging areas.
- Training and simulation: Simulating disaster scenarios (flood inundation, wildfire spread, earthquake shaking) and visualising impacts to train decision-makers and responders.
- Early-warning systems and monitoring: GIS can integrate sensor networks, remote-sensing data and weather feeds to create dashboards and alerting systems.
- Resource pre-positioning: Mapping the location of assets (ambulances, fire-engines, medical supplies) and planning logistics for mobilisation.

2.3 Response

Once a disaster occurs, timely situational awareness is critical. GIS facilitates:

- Real-time mapping of the event: Integrating satellite imagery, UAV/drone imagery, sensor feeds and crowdsourced information to map affected areas, hazards in progress, blocked roads and casualties.
- Incident mapping and coordination: Creating single “common operating picture” maps for coordination across agencies—police, fire, medical, utilities—so decisions align on a spatial basis.
- Prioritisation of rescue & relief: GIS helps identify where the greatest needs are (densely populated, isolated, vulnerable), map access routes, plan distribution of aid, and guide field teams.
- Damage assessment initiation: Initial mapping of impacted zones, infrastructure-damage overlays, and estimation of affected population.



2.4 Recovery

In the longer term after the immediate response, GIS contributes to recovery and building back better:

- Damage and loss assessment: Mapping destruction, estimating rebuilding costs, mapping how infrastructure and lifelines must be restored, and tracking recovery progress.
- Recovery planning and land-use changes: Using spatial analysis to restore safer land-use patterns, relocate vulnerable communities, rebuild infrastructure with hazard mitigation in mind.
- Monitoring and reporting: GIS dashboards monitor recovery milestones, aid distribution, infrastructure restoration, and support transparency and accountability.
- Learning and feedback: Analysing spatial patterns of damage and response to improve future mitigation and preparedness.

3. Core Functionalities and Enabling Features of GIS in Disaster Management

To appreciate the capabilities of GIS in disaster management, it is useful to highlight key functionalities:

3.1 Multi-layer spatial data integration

GIS enables combination of multiple spatial layers—e.g., hazard zones, soil/terrain, land-cover, population density, infrastructure, bathymetry, weather data. This multi-layer overlay capability is the foundation for vulnerability and risk assessment.

3.2 Spatial analysis and modelling

GIS provides analytical tools: buffer analysis (e.g., proximity to fault lines or flood zones), overlay and intersection (to find vulnerable populations), network analysis (evacuation routes), terrain analysis (slope, aspect, landslide potential), interpolation and raster modelling, scenario



simulation (flood inundation modelling, wildfire spread).

3.3 Visualisation and decision support

Maps and interactive dashboards allow stakeholders to visualise risk, exposure and event progress. Clear visualisation improves sharing across disciplines and enhances communication to public, responders and policy-makers.

3.4 Real-time data integration and situational awareness

Modern GIS systems can ingest near real-time data (satellite imagery, UAVs, sensor networks, crowdsourced reports, social media) and update spatial representations of disaster unfolding in near real-time. This allows dynamic decision making and resource allocation.

3.5 Geographic database and spatial query

GIS maintains geodatabases of features (population, infrastructure, hazard history) and allows queries (“Which hospitals are within 10 km of the flood zone?”) and generates reports to support response decisions.

3.6 Resource and asset management

GIS supports inventory and management of resources (emergency equipment, shelters, fire-engines), helps with logistics, tracking movements, mapping supply chains and optimising deployment during emergencies.

4. Applications and Case Examples

To illustrate GIS in action, some typical applications are described (generalised rather than specific institutional cases):

4.1 Hazard and risk mapping



GIS is used to map flood-prone zones, seismic fault zones, landslide susceptible slopes, coastal surge zones. By combining terrain, hydrology, land-cover and historical hazard data, planners produce maps indicating high risk zones, which feed into zoning, building codes and mitigation investments.

4.2 Evacuation and sheltering

GIS tools analyse population distribution, road networks, slope and blockages to design evacuation routes and locate shelters. In an earthquake scenario, GIS may overlay built-environment vulnerabilities with population density to prioritise door-to-door search or resource mobilisation.

4.3 Real-time emergency coordination

During a disaster (e.g., flood or wildfire), GIS dashboards display live imagery, sensor feeds, damaged infrastructure, shelter occupancy, rescue team locations. This spatial display supports command and control, helps responders identify access routes and avoid blocked or dangerous areas.

4.4 Damage assessment and recovery planning

After a disaster, GIS is used to map damage extents—destroyed buildings, collapsed bridges, flooded zones—and overlay this with socio-economic data to determine priority of rebuilding, compensation, restoration of utilities and relocation decisions.

4.5 Public information and warning systems

GIS maps are used in public information portals to show evacuation zones, safe shelters, accessible hospitals, road closures, hazard zones. They empower citizens with spatial awareness and guide behaviour.

4.6 Integration with remote-sensing and mobile GIS



GIS often works in tandem with remote-sensing imagery (satellite or UAV) and mobile GIS apps (smartphones) for data capture, crowdsourced reporting (photos geolocated), and field operations.

5. Challenges and Limitations

While GIS offers strong benefits, several challenges must be acknowledged:

5.1 Data availability and quality

Spatial data may be missing, out of date or of low resolution in many regions—especially in developing countries. Without accurate input, GIS outputs may mislead. Abundant historical hazard data and detailed infrastructure maps are crucial but often lacking.

5.2 Real-time constraints and processing

Disasters unfold fast. Integrating live sensor, UAV or social media data, processing large volumes, and visualising in near real time demands compute capacity, bandwidth and system design. In many contexts, these are constrained.

5.3 Interoperability and standardisation

Different agencies may use different formats, coordinate systems, standards and software. Lack of interoperability hampers data sharing and coordination across jurisdictions. Also, standardisation of hazard classification, vulnerability metrics and mapping symbols is often weak.

5.4 Training, institutional capacity and culture

Effective GIS use requires trained personnel, institutional buy-in and coordination among stakeholders (emergency management, urban planning, utilities, health, etc.). Many agencies lack trained GIS staff or have siloed operations.



5.5 Legal, privacy and ethical concerns

Use of spatial data may raise privacy issues (e.g., mapping vulnerable populations, social media geolocation). Sharing data between agencies may be hampered by legal/administrative restrictions. Furthermore, ethical use of crowdsourced data and who is responsible in emergencies is complex.

5.6 Cost and maintenance

GIS systems, especially real-time dashboards with satellite/UAV feeds, sensors and large servers, can be expensive to establish and maintain. For resource-poor jurisdictions disaster-preparedness budgets may be limited. Ongoing maintenance and updating of spatial datasets is often neglected.

6. Future Directions and Innovations

The future of GIS in disaster management is tied to several emerging trends:

6.1 Integration with Big Data, AI and Machine Learning

Combining GIS with big data streams (social media, IoT sensors, drones) and applying machine learning offers opportunities for pattern recognition (e.g., before flood onset), predictive modelling of hazards, and automated damage detection.

6.2 Cloud GIS and Web GIS Dashboards

Cloud-based GIS services provide scalability and accessibility across agencies, supporting shared “common operating pictures” and real-time updates accessible from mobile devices or field tablets. Web GIS portals enable public information and participatory mapping.

6.3 Mobile GIS and Crowdsourcing

Smartphones and mobile GIS apps allow field personnel or the public to capture geolocated



photos, report damage or hazard observations, and feed them into GIS systems. This enriches the dataset and supports faster situational awareness.

6.4 Unmanned Aerial Vehicles (UAVs) and Real-Time Imagery

Drones/UAVs can collect high-resolution spatial data rapidly after a disaster and feed into GIS for near real-time mapping of damage, terrain changes and hazard flows. This enhances speed and accuracy of assessment.

6.5 Digital Twins and Urban Resilience Modelling

Developing digital twin models of cities—linked to GIS layers, live sensors and simulation engines—can support dynamic modelling of disaster scenarios, testing “what-if” simulations, resource logistics and infrastructure resilience planning.

6.6 Participatory GIS and Community-Driven Mapping

Including local communities via participatory mapping, volunteer geographic information (VGI) and crowdsourced spatial data fosters local ownership, improves data coverage and ensures local knowledge is incorporated into risk assessments and response plans.

7. Recommendations for Practice

For agencies and practitioners seeking to maximise GIS value in disaster management, the following recommendations are offered:

- 1. Develop and maintain comprehensive geodatabases:** Agencies should invest in updated spatial data for hazards, buildings, infrastructure, population, utilities and historically reported events.
- 2. Adopt interoperable GIS standards and promote data sharing:** Use common coordinate systems, metadata standards and establish inter-agency data sharing agreements to enable multi-stakeholder collaboration.



3. **Build capacity and train personnel:** Provide training in GIS for emergency managers, integrate GIS into standard operating procedures (SOPs) and conduct regular drills utilising GIS platforms.
4. **Integrate GIS into decision-making workflows:** Ensure GIS outputs are embedded in command-and-control systems for real-time operations and decision support—not just as nice-to-have tools.
5. **Prioritise real-time situational awareness systems:** Develop live dashboards, link sensor networks, UAV feeds, social media reporting and mobile GIS apps for rapid event monitoring.
6. **Promote community-based mapping and public awareness:** Use maps for public information (evacuation zones, shelters), encourage citizen reporting of hazards/damage and involve stakeholders in scenario planning.
7. **Ensure sustainability and update of systems:** Allocate resources for keeping spatial datasets current, review system performance after events, update tools and adapt to changing risks (climate, urban growth).
8. **Leverage emerging technologies:** Consider incorporating AI/ML for hazard prediction, drones for rapid mapping, cloud GIS for scalability and digital twin models for infrastructure resilience.

8. Conclusion

Geographic Information Systems (GIS) have become indispensable tools in the field of disaster management. From hazard mapping and risk assessment to real-time response coordination and post-disaster recovery planning, GIS provides spatial intelligence that improves situational awareness, supports informed decision-making, and enhances resilience. Although challenges such as data gaps, interoperability, capacity and costs remain, the future holds promise through technological advancements, greater integration and participatory approaches.

For disaster-prone regions, investing in GIS infrastructure, training, institutional coordination and community engagement is no longer optional—it is central to effective, proactive and



resilient disaster management. As disasters grow in frequency and complexity, the role of GIS will only become more critical in safeguarding lives, assets and ecosystems.

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