

Advancements in Surveying and GIS for Disaster Resilience: Protecting Public Health in Vulnerable Regions

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ABSTRACT

Disasters pose significant threats to public health, particularly in vulnerable regions with geographic risks and socio-economic challenges. This paper explores advancements in surveying and Geographic Information Systems (GIS) that enhance disaster resilience. By leveraging high-resolution remote sensing, LiDAR, real-time GIS platforms, and predictive modeling, these technologies support disaster preparedness, response, and recovery efforts. Their applications in risk assessment, emergency healthcare access, disease prevention, and resilient infrastructure underscore their role in protecting public health. However, challenges such as data accuracy, technological barriers, and privacy concerns must be addressed. This paper highlights case studies demonstrating the transformative impact of surveying and GIS on disaster resilience and public health protection. Future directions include AI integration, enhanced data sharing mechanisms, and cross-disciplinary research to optimize GIS applications in disaster resilience.

Abbreviations: MCDA: Multi-Criteria Decision Analysis; GIS: Geographic Information Systems; RS: Remote Sensing; IWR: Integrated Water Resources; LiDAR: Light Detection and Ranging

Introduction

Disasters, both natural and human-induced, significantly disrupt public health, especially in regions with pre-existing vulnerabilities. The increasing frequency and severity of disasters, driven by climate change and urban expansion, disproportionately impact vulnerable regions, disrupting public health through disease, injury, and infrastructure failure (IPCC [1]). Coastal zones, seismic areas, and underserved communities face elevated risks due to limited resources and outdated tools (Cutter, et al. [2]). Surveying and GIS technologies have emerged as essential tools for enhancing disaster resilience by providing real-time data, predictive modeling, and spatial analysis to bolster disaster resilience (Goodchild [3]). GIS also supports long-term urban planning and climate adaptation, as governments rely on these tools for policymaking (UN-Habitat [4]). This paper examines how these advancements safeguard public health by enhancing preparedness, response, and recovery, using verified global examples and addressing implementation challenges through risk assessment,

emergency response, and disease control. Moreover, the role of GIS in disaster management extends beyond immediate response to long-term urban planning and policymaking. Governments and organizations increasingly rely on these technologies for climate adaptation strategies, making it crucial to examine their broader implications.

Technological Advancements in Surveying and GIS

Recent advancements in surveying and GIS have transformed disaster management. These technologies provide critical data to improve disaster preparedness, response, and recovery by delivering accurate, actionable data for disaster management.

High-Resolution Remote Sensing

Satellites and drones provide high-resolution imagery for real-time monitoring of disaster affected areas (Lillesand, et al. [5]). Landslides are present on all continents and play an important role in the evolution of landscapes. They also represent a serious hazard

in many areas of the world (Guzzetti, et al. [6]). This supports damage assessments and tracks changes like flood extents or wildfire spread (USGS [7]). Additionally, Hyperspectral imaging enhances detection of hazards such as oil spills post-disaster (Jensen [8]).

LiDAR and Photogrammetry

LiDAR (Light Detection and Ranging) creates precise 3D terrain models, which are vital for mapping flood risks and assessing seismic structural integrity (Carter, et al. [9]). Photogrammetry offers cost-effective alternatives, aiding disaster-prone areas (Westoby, et al. [10]). These tools are instrumental in mapping flood risks, predicting landslides, and evaluating earthquake-resistant structures. Recent studies highlight how LiDAR data integration with AI models enhances real-time landslide prediction accuracy. AI integration with LiDAR improves landslide prediction (Stephen, et al. [11]).

Real-Time GIS Platforms

Real-time GIS, linked with Internet of Things (IoT) sensors and mobile devices, produces dynamic disaster maps for coordination (Esri, 2021). Emergency responders utilize these platforms to coordinate efforts, track resources, and adapt to evolving disaster conditions. The integration of GIS with blockchain technology ensures secure and transparent data sharing across emergency response networks. Blockchain ensures secure data sharing across response networks (Reyna, et al. [12]).

Spatial Analysis and Predictive Modeling

Advanced GIS tools analyze spatial data to predict disaster impacts and optimize planning (Longley, et al. [13]). Predictive models identify vulnerable populations, assess potential disaster impacts, and determine strategic locations for emergency shelters and medical facilities. The increasing adoption of AI-powered GIS has led to significant improvements in hazard forecasting. AI enhances hazard forecasting accuracy, identifying vulnerable populations and shelter locations (Chen, et al. [12]).

Integration with Early Warning Systems

GIS enhances early warning systems by integrating hazard data with spatial analysis, improving evacuation planning and timely alerts, minimizing casualties and reducing health risks (UNDRR [14]). Advances in crowd-sourced GIS data collection have improved the accuracy and timeliness of disaster alerts, particularly in low-resource settings (Meier [15]). This enhances timely interventions, reducing disaster-related health risks.

Protecting Public Health Vulnerable Regions

Surveying and GIS address disaster-related public health risks. The ultimate goal of utilizing surveying and GIS technologies in disaster resilience is to protect public health. These tools enhance risk assessment, healthcare accessibility, disease control, and infrastructure resilience.

Risk Assessment and Vulnerability Mapping

GIS maps demographic data including age, income, and disability status with hazard zones to identify at-risk groups populations (Tate, et al. [16]). Authorities use this information to allocate resources effectively, reducing disaster-related morbidity and mortality rates. Multi-criteria decision analysis (MCDA) techniques enhance vulnerability mapping by integrating diverse datasets for resource allocation (Malczewski [17]).

Emergency Response and Healthcare Access

Real-time GIS optimizes ambulance routes, locates temporary medical sites, and coordinates relief efforts. (Russ [18]). These applications ensure timely medical assistance and continuity of healthcare services during disasters. Advanced Spatial analytics ensure timely supply distribution by facilitating the real-time distribution of medical supplies to critical zones (WHO [19]).

Disease Prevention and Control

Surveying tracks environmental factors, while GIS maps disease vectors such as water contamination and mosquito breeding sites, which contribute to disease outbreaks post-disaster (WHO [20]). GIS-driven epidemiological models are increasingly used to predict disease spread such as cholera mapping in flood zones (Hay, et al. [21]).

Resilient Infrastructure

LiDAR and GIS assess infrastructure vulnerabilities, ensuring health service continuity (Linda [22]). This aids long-term recovery planning.

Case Studies

1. **Bangladesh (Cyclone Preparedness):** LiDAR and satellite imagery improved floodplain mapping, while GIS optimized shelter placement, reducing cyclone mortality. Health facilities were prioritized using vulnerability data (Mallick, et al. [23]).
2. **California (Wildfires):** Drone surveys and GIS tracked the 2018 Camp Fire, enabling evacuations and air quality alerts (CAL FIRE [24]).
3. **Sub-Saharan Africa (Drought):** GIS integrated satellite data with health records to target food aid, combating malnutrition (FAO [25]).
4. **Saudi Arabia (Water Demand):** The use of new techniques such as Remote Sensing (RS) and Geographic Information Systems (GIS) are currently considered as powerful tools within Integrated Water Resources (IWR) planning and management. The main objective of the project was to provide a methodology for using such techniques for counting, representing, and classifying crops for estimation of the agriculture demand for water in KSA. A case study is provided to demonstrate this methodology based

on technical presentation of a project in KSA (Ebrahim [26]). This methodology supports drought resilience, mitigating water scarcity's impact on public health. These examples collectively demonstrate GIS's versatility across diverse hazard types and socioeconomic contexts and health challenges.

Challenges and Limitations

Despite their advantages, surveying and GIS technologies face challenges in disaster resilience efforts. For instance, integrating engineers' structural data with epidemiologists' disease models remains challenging due to differing data standards.

- **Data Accuracy and Accessibility:** Inaccurate or outdated data can undermine GIS reliability, particularly in remote or developing regions (UNDRR [27]).
- **Technological Barriers:** Advanced GIS tools require infrastructure and training, which may be limited in vulnerable areas (Tomaszewski [28]).
- **Interdisciplinary Collaboration:** Effective disaster management requires coordination across engineering, health, and policy sectors, which is often hindered by siloed expertise (NRC [29]).
- **Privacy Concerns:** The collection of geospatial data raises ethical issues related to surveillance and data consent (Elwood, et al. [30]).

Future Directions

AI enhances GIS predictive modeling (Anwar, et al. [31]), blockchain improves data sharing (Reyna, et al. [12]), and crowd-sourcing boosts real-time alerts (Meier [15]). Expanding training and platforms like OpenStreetMap could democratize GIS access will improve accessibility (UNDRR [14]). Interdisciplinary research will optimize resilience strategies.

Conclusion

Advancements in surveying and GIS technologies are revolutionizing disaster resilience by providing accurate, real-time data that enhances emergency preparedness and public health protection. These tools are instrumental in risk assessment, emergency response optimization, disease prevention, and the development of resilient infrastructure. As disasters become more frequent and severe due to climate change and urbanization, the integration of GIS with AI, blockchain, and real-time data analytics will further enhance its impact. Despite the promising potential of these technologies, challenges such as data accessibility, technological limitations, and ethical considerations must be addressed to maximize their effectiveness. Strengthening interdisciplinary collaboration among engineers, healthcare professionals, policymakers, and data scientists is crucial for advancing GIS applications in disaster resilience. Future research

should focus on improving the accuracy and interoperability of geospatial data, expanding training initiatives for emergency responders, and developing frameworks to balance data privacy with the need for effective disaster management. By leveraging these advancements, societies can build more resilient communities capable of mitigating disaster risks and ensuring public health protection in the face of evolving global challenges. Future research should focus on AI integration with GIS for improved predictive capabilities.

Additionally, strengthening interdisciplinary collaboration, enhancing data accessibility, and addressing ethical considerations will maximize the potential of these technologies in disaster resilience. By bridging civil engineering, geospatial science, and public health, these technologies pave the way for safer and more resilient communities. Ultimately, these advancements position GIS as a cornerstone of global disaster resilience in an increasingly volatile world.

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