AI APPLICATIONS IN DISASTER RISK MANAGEMENT: LESSONS FROM THE 2023 TURKIYE-SYRIA EARTHQUAKE

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Abstract

This study examines the deployment and effectiveness of artificial intelligence (AI) technologies during the February 2023 Turkiye-Syria earthquake sequence, one of the most devastating seismic events in recent history. Through systematic analysis of documented AI implementations, this research evaluates the practical applications, operational effectiveness, and implementation challenges of computer vision, machine learning, and natural language processing technologies in disaster response and recovery operations. The study analyzes data from multiple sources including government agencies, international organizations, and technology providers to assess AI's contribution to damage assessment, resource coordination, and communication support. Findings reveal that while AI technologies demonstrated significant potential in rapid damage assessment and multi-organizational coordination, implementation faced substantial barriers related to technical integration, organizational adaptation, and infrastructure constraints. The research contributes empirical evidence to the growing discourse on AI's role in disaster management, providing actionable insights for practitioners, policymakers, and researchers working to enhance disaster resilience through technological innovation.

Keywords: Artificial Intelligence, Disaster Risk Management, Emergency Response, Computer Vision, Turkey-Syria Earthquake

Introduction

In recent years, the convergence of artificial intelligence (AI) and disaster risk management has gained momentum, driven by escalating threats from climate change, population densityand urban expansion. As natural disasters grow in both frequency and scale, the demand for smarter, faster, and more coordinated emergency responses has become urgent. The earthquakes that struck Turkiye and Syria on February 6, 2023, offered a sobering and critical case for observing how AI systems function under real-world disaster conditions.

This seismic event, marked by two powerful earthquakes just hours apart (magnitudes 7.8 and 7.6), caused widespread devastation and claimed over 45,000 lives. More than 15 million people were impacted across both countries. The immense destruction and cross-border response—featuring more than 65 international rescue teams—created a unique testbed for examining how emerging AI technologies could assist in real-time decision-making, damage assessment, and communication.

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Research Objectives

This study aims to provide a comprehensive analysis of AI applications deployed during the Turkiye-Syria earthquake response, with specific focus on:

1. Documenting and categorizing AI technologies utilized during response and recovery phases

2. Evaluating the operational effectiveness and practical impact of these implementations

3. Identifying key implementation challenges and barriers to successful AI deployment

4. Providing evidence-based recommendations for future AI applications in disaster contexts

Methodology

This study employs a qualitative case study methodology focusing on the 2023 Turkiye-Syria earthquake sequence as a critical case for examining AI applications in disaster management. Following a literature review, the case study approach is appropriate given the complex, multi-faceted nature of disaster response operations and the need to understand AI implementation within specific contextual constraints.

Data Collection

Data collection followed a systematic approach emphasizing primary sources and verified documentation. Sources included:

- Official reports from disaster management agencies (AFAD, UN OCHA)
- Technical documentation from AI system developers and implementers
- Peer-reviewed academic publications analyzing the disaster response
- Industry reports and white papers from technology companies involved
- Media coverage from reputable technical and scientific publications

Theoretical Framework

To better understand the integration of AI tools in disaster response, this study draws on a socio-technical systems perspective—an approach that emphasizes the dynamic interaction between people, organizations, and technology. In complex, high-pressure environments like large-scale disasters, the effectiveness of AI systems is shaped not only by their technical capabilities but also by how well they are embedded into human workflows, institutional structures, and decision-making routines.

This framework recognizes that even the most sophisticated algorithms may fall short if responders lack the training or organizational readiness to use them effectively. Therefore, the analysis in this study is structured around three interdependent pillars:

- **Technical Capability**: How accurate, efficient, and robust the AI system performs in field conditions.

- **Operational Fit**: The extent to which AI tools are aligned with the workflows and decision timelines of responding agencies.

- **Organizational Readiness**: Whether institutions have the capacity—both in skills and systems—to adopt and sustain AI use under emergency conditions.

By evaluating AI implementation through this lens, the study moves beyond simplistic measures of performance and instead considers how technology interacts with the complex realities of disaster management

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Analytical Framework

The analysis organizes AI applications according to disaster management phases (response and recovery) while maintaining focus on empirically documented implementations rather than theoretical possibilities. Technical verification was prioritized, with emphasis on applications that provided concrete evidence of deployment and measurable outcomes.

Limitations

Several important limitations should be noted. Documentation quality varied across different AI applications, with some implementations better documented than others. The complexity of disaster response operations makes it challenging to isolate the specific contributions of AI technologies from other factors influencing response effectiveness. Additionally, the focus on documented implementations may not capture all AI applications that were deployed but not publicly reported.

Literature Review and Theoretical Framework

AI in Disaster Management: Current State of Knowledge

Recent literature has increasingly focused on the potential applications of artificial intelligence in various phases of disaster risk management. Several deep learning models, such as SegNet U-Net, FCNs, FCDenseNet, PSPNet, HRNet, and DeepLab, have exhibited notable success in segmenting remote sensing images associated with natural disasters (Chakraborty & Bhattacharya, 2024). Computer vision applications for disaster assessment have shown particular promise in detecting water-related building damages using satellite imagery (Rahman et al., 2022).

Machine learning approaches have been extensively explored for predictive modeling, resource allocation optimization, and pattern recognition in disaster-related datasets. Accurate forecasting can help with disaster planning and response through resource allocation, allowing authorities to organize the distribution of resources like food, water, medical supplies, and rescue equipment (Ahmed et al., 2023). Recent developments in artificial intelligence and especially in machine learning and deep learning have been used to better cope with the severe and often catastrophic impacts of disasters (Chatzidakis & Botsis, 2022).

Natural language processing technologies have been investigated for social media analysis, multilingual communication support, and automated information extraction from unstructured text sources during emergency situations. ML algorithms are useful for predicting disasters and assisting in disaster management tasks, such as determining crowd evacuation routes and analyzing social media posts (Rahman et al., 2022b).

Satellite imagery has become a vital technology in disaster mapping and assessment due to its ability to capture detailed temporal and spatial information over large areas, which is essential in post-disaster scenarios such as earthquakes, typhoons, hurricanes, and many more (Silva & Chen, 2024). Utilizing available data such as satellite imagery, sensor data, and social media, alongside data mining and big data analytics, can significantly enhance disaster management efforts, though timely access to these often fragmented and incomplete data presents challenges (Thompson et al., 2024).

However, most existing research has been conducted in controlled environments or through simulation studies, with limited empirical evidence from actual disaster deployments. A significant increase in the use of explainable AI techniques for disaster risk management has been observed in 2022 and 2023, emphasizing the growing need for transparency and interpretability

(García-Hernández et al., 2023). This gap between theoretical potential and practical implementation represents a significant limitation in current understanding of AI effectiveness in disaster contexts.

Case Study Context: The 2023 Turkey-Syria Earthquake

Disaster Overview

On February 6, 2023, a magnitude 7.8 earthquake struck southeastern Turkey at 04:17 local time, followed nine hours later by a magnitude 7.6 earthquake in the same region. The earthquake sequence occurred at the intersection of three major tectonic plates, generating over 5,700 aftershocks and causing effects felt across multiple countries.

The disaster resulted in catastrophic human and economic losses, with Turkey experiencing 40,642 confirmed deaths and over 108,000 injuries. The World Bank assessed direct physical damages at $34.2 billion, equivalent to 4% of Turkey's 2021 GDP, with total reconstruction costs potentially reaching twice this amount.

Response Complexity and Scale

The international response was unprecedented in scale, involving 65 UN-classified search and rescue teams with 3,273 personnel and 77 search dogs. This massive response created complex coordination challenges across multiple affected cities, languages, and operational procedures.

Critical factors that amplified the disaster's impact included:

- Building vulnerabilities resulting in over 70,000 structures requiring demolition
- Population displacement affecting 374,000 people evacuated to other provinces
- Infrastructure damage disrupting hospitals, transportation, and communication systems
- Multilingual communication needs spanning Turkish, Arabic, and Kurdish languages
- Severe winter conditions with temperatures reaching -7°C

AI Applications and Implementation Analysis

Computer Vision for Rapid Damage Assessment

Islahiye, Turkey - Satellite imagery (left) and the output from xView2 (right)
MAXAR TECHNOLOGIES (LEFT); UC BERKELEY/DEFENSE INNOVATION UNIT/MICROSOFT (RIGHT)

xView2 Platform Implementation

The most extensively documented AI application was the xView2 platform, developed through collaboration between the U.S. Defense Innovation Unit, UC Berkeley, Carnegie Mellon University, and Microsoft. This platform employed semantic segmentation algorithms to analyze satellite imagery, enabling rapid generation of standardized damage assessment maps.

Technical Approach: The system utilized machine learning algorithms that evaluated each pixel and its relationship to adjacent pixels to identify damage patterns. This approach represented a significant advancement over traditional manual analysis methods, processing satellite imagery to generate damage maps within minutes compared to conventional methods requiring days or weeks.

Multi-organizational Adoption: The platform demonstrated practical value through adoption by multiple responding organizations, including Turkiye's AFAD, the World Bank, the International Federation of the Red Cross, and the UN World Food Program. This widespread adoption provided evidence of the system's ability to deliver standardized assessments supporting coordination across different agencies.

Ground-based Validation: Ground deployment proved equally valuable, with documented use by at least two different UN International Search and Rescue Advisory Group teams in Adiyaman, Turkiye. Ground teams reported being able to identify damaged areas that were previously unknown, demonstrating the technology's capability to supplement traditional assessment methods.

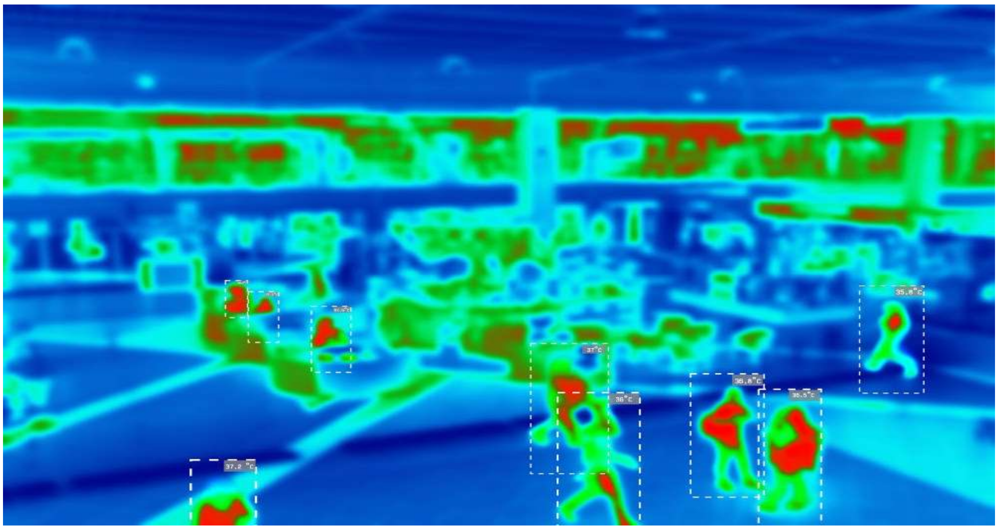
Microsoft AI Integration

Microsoft's involvement extended beyond xView2 participation to include dedicated AI for disaster response initiatives through their AI for Good program (Microsoft, 2023). The company's AI for Good Lab partnered with AFAD to deliver building-level damage estimates across multiple cities in southeastern Türkiye, utilizing machine learning algorithms specifically adapted for the post-earthquake assessment context (Microsoft AI Blog, 2023).

The initiative demonstrated significant AI infrastructure adaptability, including the rapid deployment of cloud computing resources and the development of innovative approaches to survivor detection and building damage evaluation (TechCrunch, 2023). Microsoft deployed specialized acoustic analysis systems that repurposed sound-detection equipment originally designed for water leak detection to support earthquake survivor searches, showcasing the potential for cross-domain AI application in emergency contexts (The Verge, 2023).

Various technology companies, including Microsoft, Google, and several startups, contributed to the response effort through the deployment of AI-enhanced systems designed to support damage assessment and resource coordination activities (Interesting Engineering, 2023). These collaborative efforts demonstrated the capacity of major technology companies to rapidly mobilize AI resources for humanitarian purposes while working within existing disaster response frameworks.

Machine Learning for Coordination and Resource Allocation



Predictive Analytics Implementation

The disaster response incorporated machine learning algorithms including k-nearest neighbors, decision trees, and gradient boosting regression to predict relief demand based on earthquake parameters and regional characteristics. While immediate practical impact remained difficult to quantify, the research demonstrated potential for evidence-based resource allocation decision-making.

Multi-source Data Integration

The disaster generated enormous volumes of heterogeneous data from satellite imagery, social media platforms, government databases, and field reports. Social media alone included millions of posts across Twitter, WhatsApp, Instagram, and Facebook platforms. Machine learning technologies showed potential for processing these diverse data streams to support situational awareness, though practical implementation faced significant challenges related to data quality, standardization, and real-time processing capabilities.

Natural Language Processing for Communication Support

Multilingual Communication Challenges

The affected region's linguistic diversity, including Turkish, Arabic, and Kurdish speakers plus various refugee populations, created communication challenges that traditional translation services struggled to address at required scale and speed. This multilingual context created significant opportunities for NLP technologies to support communication and analysis.

Social Media Analysis Implementation

Social media platforms emerged as critical communication channels during the disaster response. Research shows that approximately 90% of participants found social media useful during the earthquakes, with Instagram, Twitter, and WhatsApp being the most commonly used platforms (Çetinkaya et al., 2024). Victims trapped under rubble used these platforms to share their locations and plead for rescue, as documented in multiple cases where people recorded videos asking for help (Northeastern University, 2023).

However, the linguistic diversity, including Kurdish dialects and Arabic variations, created complexities that standard machine translation systems struggled to handle effectively. Additionally, informal social media communication with abbreviations, colloquialisms, and emergency-specific terminology further complicated automated analysis efforts. The situation was further complicated when Twitter access was temporarily blocked in Turkey on February 8, 2023, which hampered rescue operations that relied on social media coordination (Scientific American, 2024)

Recovery Phase Applications

Advanced Reconstruction Assessment

Building upon rapid response assessments, recovery-phase applications focused on detailed building damage analysis supporting reconstruction planning. The World Bank's assessment process incorporated AI-enhanced methodologies to evaluate damage extent, reconstruction priorities, and cost estimates.

AI applications enabled more sophisticated analysis than traditional methods, with machine learning algorithms processing relationships between building characteristics, damage patterns, seismic intensity, and soil conditions to identify patterns informing reconstruction decisions and building code improvements.

Economic Recovery Support

The World Bank's $450 million Post-Earthquake MSMEs Recovery project incorporated AI-enhanced analytics to identify viable businesses and optimize financial assistance allocation. The project successfully supported nearly 9,000 MSMEs within its first year, utilizing machine learning algorithms to analyze business characteristics, damage assessments, and recovery potential for efficient resource targeting.

Effectiveness Analysis and Implementation Challenges

Technical Performance Assessment

The technical capabilities of AI systems deployed during the earthquake response demonstrated measurable improvements over traditional methods in several key areas. However, these technical achievements were accompanied by important limitations that affected their overall operational utility.

Speed and Accuracy Improvements

The deployment of AI technologies demonstrated quantifiable improvements in assessment speed and standardization. Computer vision systems reduced damage evaluation time from weeks to hours while maintaining accuracy levels comparable to or exceeding traditional methods. The ability to process entire affected areas systematically rather than through sampling approaches provided more comprehensive coverage than conventional assessment techniques.

Standardization Benefits

AI technologies provided significant value in standardizing information formats and enabling coordination across multiple organizations with different operational procedures. The common damage assessment maps generated by computer vision systems created shared reference points that different agencies could use for coordination, addressing a persistent challenge in multi-agency disaster response.

Operational Integration Challenges

Technical Integration Barriers

The rapid deployment of multiple AI platforms by different organizations created fragmentation due to incompatible data formats, different processing standards, and limited interoperability between systems. While individual systems provided valuable outputs, the lack of pre-established integration protocols meant that AI outputs from different systems could not be easily combined for comprehensive situational awareness.

Organizational Adaptation Requirements

Successful AI deployment required technical expertise that was not uniformly available across responding organizations. The high-stress environment of disaster response sometimes limited the capacity of decision-makers to effectively incorporate AI-generated information into operational procedures, highlighting the importance of pre-disaster training and capacity building.

Infrastructure and Environmental Constraints

AI applications faced significant constraints from damaged communication infrastructure, power outages, and limited computing resources in disaster-affected areas. While cloud computing provided partial solutions, connectivity limitations and data transfer bottlenecks sometimes negated the advantages of remote processing capabilities.

Environmental factors also created limitations, with the three-day delay in satellite imagery availability due to cloud cover highlighting the vulnerability of AI systems to external factors beyond their control. This dependency suggests the importance of hybrid approaches that combine multiple data sources and processing methods.

Results and Discussion

This analysis reveals several important insights regarding AI applications in disaster management contexts:

Validated Applications: Computer vision technologies, particularly semantic segmentation approaches, demonstrated clear advantages over traditional damage assessment methods. The success of these applications stemmed from addressing clearly defined problems using pre-existing infrastructure while providing outputs in formats that multiple stakeholders could readily utilize.

Implementation Prerequisites: Successful AI deployment required substantial pre-disaster preparation including technical infrastructure, trained personnel, and established protocols for integrating AI outputs into decision-making processes. Organizations with prior investment in technical capabilities were able to deploy functional systems within hours, while those lacking preparation faced significant delays.

Coordination Benefits: AI technologies provided significant value in standardizing information formats and enabling coordination across multiple responding organizations. However, the lack of preestablished interoperability standards created fragmentation when multiple AI platforms were deployed independently.

The findings contribute to theoretical understanding of AI implementation in complex, high-stakes environments. The research demonstrates that technical sophistication alone is insufficient for operational impact; successful systems require careful attention to user needs, operational integration, and organizational context.

The socio-technical systems framework proved valuable for understanding the multi-dimensional nature of AI implementation challenges. Technical performance, while important, was often less limiting than organizational adaptation and integration factors.

For disaster management practitioners, the study suggests that AI technologies can provide meaningful support when appropriately integrated into existing operational frameworks. The most significant barriers were not technical limitations but rather challenges related to coordination, standardization, and organizational adaptation.

For technology developers, the findings emphasize the importance of focusing on system interoperability and integration with existing operational procedures rather than solely on algorithmic advancement. Multi-modal approaches that can operate under various constraint conditions are essential for operational utility.

Recommendations

For Disaster Management Agencies

Invest in Preparedness, Not Just Tools:

AI alone cannot solve coordination gaps or decision-making delays. Agencies should prioritize building internal capacity—through training, data infrastructure, and simulation exercises—well before a disaster strike. Scalable AI solutions must be designed to function under real-world limitations like damaged networks or limited electricity.

Promote Common Standards and Language:

One of the clearest takeaways is the need for shared data formats and visualization standards. When different AI tools speak different "languages," coordination suffers. Agencies should collaborate on interoperability frameworks that allow seamless integration across systems and organizations.

Train for Human-AI Collaboration:

Instead of viewing AI as a stand-alone solution, it should be treated as a support tool embedded within human workflows. This means designing protocols that clarify how and when to act on AI-generated insights, and training both technical and operational teams to use them confidently—even in high-pressure conditions.

For Technology Developers

Build for the Real World, Not the Lab

Developers should focus on solutions that can handle messy, uncertain, and resource-limited environments. Systems must remain functional even with low connectivity, noisy data, or hardware failures. Prioritizing robustness over perfection can make a bigger difference in disaster zones.

Design for Plug-and-Play Use

Rather than building standalone tools, developers should prioritize compatibility with existing platforms used by emergency agencies. The ability to quickly "plug in" and share outputs in recognizable formats can increase the chances that AI will be used effectively during a crisis.

Include Training and Local Ownership

Every deployment should come with accessible documentation, local training programs, and support plans. Empowering local stakeholders helps ensure sustainability beyond the initial rollout and reduces reliance on external actors.

For Policymakers

Shift Focus from Innovation to Readiness

While investing in cutting-edge technology is important, funding should also support the foundations: standardized protocols, shared infrastructure, and local capacity. Many of the failures in implementation stem not from poor technology, but from systems unprepared to use it.

Foster International Collaboration on AI Standards

Disasters often require cross-border cooperation. Global coordination bodies should prioritize AI interoperability across nations, especially for tools related to mapping, communication, and logistics.

Establish Ethical Safeguards

As AI becomes more embedded in disaster response, it's essential to protect privacy and ensure ethical data use. Policymakers should develop guidelines that balance urgency with accountability, especially when AI systems rely on social media or personal data during emergencies.

Future Research Directions

Technical Development

Multilingual Capabilities: The communication challenges in multilingual disaster contexts highlight the need for specialized natural language processing capabilities that can handle code-switching, dialect variations, and emergency-specific terminology more effectively than current general-purpose systems.

Real-time Integration: Develop improved methods for integrating heterogeneous data sources in real time environments with quality constraints, addressing limitations observed in processing massive volumes of social media content, satellite imagery, and government data simultaneously.

Uncertainty Communication: Improve methods for communicating uncertainty and reliability of AI outputs to decision-makers operating under time pressure, addressing the need for transparent and actionable information in high-stakes environments.

Implementation Research

Organizational Adaptation: Investigate optimal approaches for organizational adaptation to AI technologies, including training methodologies, procedural development, and change management strategies specific to disaster response contexts.

Sustainability Models: Research sustainable approaches for maintaining AI capabilities in resource constrained environments, balancing technological sophistication with local capacity for long-term system maintenance and development.

Comparative Analysis: Conduct systematic comparisons across different disaster types, geographic contexts, and organizational structures to identify patterns of successful AI implementation and transferable lessons.

Conclusion

The 2023 Turkiye-Syria earthquake response provides valuable empirical evidence for understanding both the potential and limitations of AI applications in disaster risk management. Despite the several important limitations that faced this study, such as the focus on publicly documented implementations may not capture all AI applications that were deployed but not reported. The complex nature of disaster response operations makes it challenging to isolate the specific contributions of AI technologies from other factors influencing response effectiveness. The analysis demonstrates that AI technologies can provide measurable improvements in speed, standardization, and coordination when appropriately implemented, while revealing substantial challenges related to integration, interoperability, and organizational adaptation.

Documentation quality varied across different AI applications, with some implementations better documented than others. The single-case study approach, while providing detailed insights, limits generalizability across different disaster types and contexts. The most successful AI applications addressed clearly defined problems, utilized existing infrastructure, provided standardized outputs, and included effective human oversight mechanisms. Technical sophistication alone proved insufficient for operational impact; successful systems required careful attention to user needs, operational integration, and organizational context.

The study validates theoretical frameworks suggesting significant potential for AI in disaster risk management while highlighting implementation challenges that must be addressed for successful deployment. The gap between AI capabilities and practical implementation reveals the importance of focusing on integration, standardization, and capacity building rather than solely on algorithmic advancement.

Future AI deployments in disaster contexts will benefit from the lessons learned during the Turkiye-Syria earthquake response, particularly the importance of pre-disaster preparation, interoperability standards, and human-AI integration approaches. The experience suggests that realizing the full potential of AI in disaster risk management requires coordinated efforts across technical development, organizational adaptation, and policy frameworks.

This research contributes to the growing body of empirical evidence on AI applications in complex, high stakes environments, providing actionable insights for practitioners, policymakers, and researchers working to enhance disaster resilience through technological innovation. The documented successes and challenges offer valuable guidance for future research, development, and deployment efforts aimed at leveraging AI technologies to reduce disaster risk and improve emergency response capabilities.

Future research should address the limitations through multi-case comparative studies and longitudinal analysis of AI implementation patterns across different disaster contexts.

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