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REVIEW

Review: Alternative data collection and analysis methods for disaster reconnaissance

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In recent years, the field of earthquake engineering has undergone a significant transformation in how post-disaster damage is assessed, documented, and analysed. This shift has been driven by the increasing availability of digital tools, remote sensing technologies, and data science methodologies, alongside a growing recognition of the limitations of traditional field-based reconnaissance. The devastating Türkiye earthquake sequence of February 2023, which caused widespread destruction across multiple provinces (Aktas et al. 2024), has further underscored the urgency of developing scalable, adaptable, less-resource-intensive and context-sensitive approaches to post-earthquake assessment. The sheer scale of the event meant it was desirable for local and international agencies to coordinate their efforts, to minimise replication of efforts, valuable resources and above all, alleviate the burden on local academics and authorities.

This evolution in practice has been shaped by a series of pioneering efforts. The UK's Earthquake Engineering Field Investigation Team (EEFIT) was motivated to derive a strategy for hybrid reconnaissance missions during the Covid-19 lockdown and has since further refined its methods collaboration with remotely sensed and locally engaged studies. The hybrid reconnaissance missions to the 22 March 2020 Zagreb earthquake (So et al. 2020), 30 October 2020 Aegean Sea earthquake and tsunami (Aktas et al. 2021 & 2022) and the 14 August 2021 Haiti earthquake (Whitworth et al. 2022) demonstrated the effectiveness of combining in-person fieldwork with remote data collection and digital analysis. These

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missions set a precedent for future hybrid approaches, showing how interdisciplinary collaboration and technological integration can enhance the depth and breadth of post-disaster insights.

These developments were previously discussed in Aktas and So (2022), where we posed the question: *Is a hybrid approach the way forward?* The contributions in this special issue of *Bulletin of Earthquake Engineering* offer a compelling answer. They showcase a range of innovative methodologies that reflect the growing convergence of engineering expertise, digital technologies, and data-driven analysis in the pursuit of more effective earthquake damage assessment.

1 This special issue

This special issue responds to a set of critical questions raised in the call for papers:

- How can digital technologies and remote sensing improve the speed and accuracy of post-earthquake assessments?
- What role can remote techniques, machine learning and AI play in damage prediction and vulnerability analysis?
- How can hybrid approaches be operationalised in diverse and challenging contexts?
- What are the limitations and ethical considerations of data-driven methods in disaster settings?

Several papers directly address these questions by exploring the potential of digital tools and remote sensing for rapid and scalable damage assessment. Ersoz et al. (2024) demonstrate the use of digital technologies, including mobile applications and cloud-based platforms, for real-time data collection and damage mapping in the immediate aftermath of the Kahramanmaraş earthquakes. Their work exemplifies how digital workflows can enhance situational awareness and coordination during emergency response across multiple key stakeholders of disaster risk resilience and response.

Macchiarulo et al. (2024) and Bektaş and Kegyes-Brassai (2024) push the boundaries of automation by integrating machine learning with satellite imagery and rapid visual screening methods. Macchiarulo et al. (2024) employ very high-resolution SAR data and convolutional neural networks to detect building-level damage, while Bektaş and Kegyes-Brassai (2024) develop a supervised learning model trained on post-Gorkha earthquake data to assess seismic vulnerability. These studies highlight the growing role of airborne-based sensor techniques, machine learning and AI in post-disaster contexts, offering scalable solutions that can be deployed even in data-scarce environments.

The use of point cloud data for forensic analysis, as presented by Yang et al. (2025), exemplifies the depth of insight achievable through high-resolution spatial data. Their study not only reconstructs failure mechanisms in masonry structures but also contributes an open-access dataset for the research community (GitHub repository), promoting transparency and reproducibility - an essential consideration in the ethical use of digital data.

Kijewski-Correa et al. (2024) propose a hybrid model for performance assessment in challenging environments, such as post-earthquake Haiti, where access and security constraints limit traditional fieldwork. Their multi-phase approach, combining rapid remote assessments with targeted in-person evaluations, demonstrates how hybrid frameworks can be operationalised to balance coverage, depth, and safety.

The Kahramanmaraş earthquake sequence also serves as a focal point for several contributions that delve into predictive modelling and decision-making. Silahtar et al. (2025) introduce a multi-criteria decision-making (MCDM) model that incorporates soil conditions, ground motion characteristics, and source-path parameters to evaluate building damage. This approach reflects a shift toward probabilistic frameworks that can support prioritisation and resource allocation during response and recovery. Senkaya et al. (2024) apply clustering algorithms to local site parameters to predict damage patterns, offering a data-driven alternative to traditional vulnerability assessments. Their work underscores the potential of unsupervised learning techniques to uncover latent patterns in seismic response, especially in regions with limited structural inventories.

Expanding the geographic scope, Kulariya et al. (2024) present a rapid visual screening methodology tailored to reinforced concrete buildings in hilly regions of India. Their study addresses the unique vulnerabilities posed by topography and construction typologies, reinforcing the need for context-aware solutions that can be adapted to diverse seismic settings.

Together, these papers illustrate the breadth of innovation in post-disaster damage assessment. They respond to the call for hybrid and data-driven approaches not only by showcasing technical advancements but also by engaging with broader questions of scalability and operational feasibility. This collection affirms that the future of disaster reconnaissance lies in the thoughtful integration of engineering judgment, digital technologies, and data science. More streamlined and hybrid methods ensure a wider and targeted coverage, and mutual and shared learnings to both host nations and in-field international teams.

2 Future research directions

The contributions in this issue point to several pressing areas for future research:

- *Standardisation of hybrid methodologies*: As hybrid missions become more common, there is a need to develop standardised protocols for integrating field observations with remote sensing and digital data.
- *Scalability and automation*: Machine learning and AI offer promising tools for rapid assessment, but further work is needed to ensure their reliability across diverse building typologies and geographies.
- *Longitudinal impact studies*: Earthquake effects evolve over time and geographies; return missions and longitudinal studies like the EEFIT Türkiye mission are essential for understanding recovery trajectories and informing policy.
- *Community and stakeholder engagement*: Future research should explore how data-driven assessments can be translated into actionable insights for local authorities, engineers, and affected communities.
- *Interoperability of data platforms*: As more data is collected from diverse sources, ensuring interoperability and accessibility across platforms will be key to maximizing its utility.

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Declarations

Conflict of interest The authors have not disclosed any competing interests.

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