

A Systematic Literature Review on Emergency Response Systems and their Impact on Infrastructure Resilience

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Abstract

The purpose of this study was to assess existing literature on the impact of emergency response systems on infrastructure resilience, identifying optimal methodologies and highlighting obstacles in emergency response that affect stability during emergencies. Thus, the research design was based on a systematic review of 30 peer-reviewed English-language articles published between 2015 and January 2025 to analyze global trends and expert opinions on emergency response infrastructure, identifying best practices and knowledge gaps. Articles addressing emergency response systems and impact issues were given extra consideration. The study's research limitations include bias toward developed countries and potential outdatedness due to rapid advancements in emergency response technologies. Key findings are based on examinations of existing scientific knowledge regarding the state of emergency response on infrastructure and its economic and socio-political impacts. The identified key infrastructure includes early warning, situational awareness, technology and infrastructure, response efficiency, resources and capabilities, strategic framework, community engagement, preparedness and knowledge, and institutional communication. The impacts include global economic consequences, human and property loss, infrastructure deficiencies, and displacement issues. The socio-political impact includes demographic and urban challenges, infrastructure gaps, vulnerability, and economic stability. The review emphasizes the importance of decision-makers prioritizing emergency preparedness and uniform agency procedures. It highlights the need for coordinated response plans, community involvement, and strengthening infrastructure against future crises, which are considered key practical implications.

Keywords: Emergency, Emergency response, Impact, Infrastructure resilience, Natural hazard.

1. Introduction

Emergency Response Systems (ERS) face challenges in disaster management and healthcare infrastructure, requiring urgent enhancement due to the growing population and increased vulnerability to natural and man-made disasters. Global disasters pose significant risks to human life and property, limiting sustainable growth and affecting economic and social development in communities (Zulu & Shi, 2023). Natural and manmade hazards significantly impact every livelihood, causing significant losses to housing infrastructure (Vinokurova, *et al.*, 2022). Building resilient infrastructure is crucial for socio-economic stability and community well-being.

Critical infrastructure underpins the functioning of contemporary societies, enabling access to essential services such as transportation, energy, food, and education (Sharma & Gardoni, 2018). The rapid growth of urban environments has led to a higher concentration of people in buildings and facilities, increasing the potential risks during emergencies such as fires or other

disasters (Matveev *et al.*, 2021). Effective disaster risk management (DRM) strategies are needed to address these vulnerabilities and ensure the safety of occupants. The increasing congestion of transportation systems poses safety risks, delays, and impeded emergency response times (Khalid *et al.*, 2021). Therefore, it is crucial to implement risk management and reduction strategies to mitigate these hazards.

Crowd management during evacuations is another critical concern. Human behaviour can shift rapidly from calm to panic in emergencies, leading to chaos and potential injuries (Yazdi & Zarei, 2024). Proper planning ensures safe and efficient evacuations, especially in crowded facilities. Fires remain a significant threat in public buildings, and many countries have established fire safety regulations to protect residents (Ahmed, 2024). The effectiveness of regulations varies, with high-profile incidents like the London Tower fire highlighting the need for robust emergency response infrastructures (Zuallkernan *et al.*, 2019). Ghana experiences frequent residential fire incidents, causing significant loss of life and financial

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damage, causing fear and panic among the population. Adopting preventative measures, awareness, response, and rehabilitation or reconstruction activities can enhance facility resident safety through a comprehensive DRM cycle (Zulu & Shi, 2023). Among the research tasks conducted by researchers is an illustration of nature-based solutions for a sustainable African built environment.

Research tasks conducted by researchers have illustrated nature-based solutions for an African-built environment on sustainable emergency response by Aghimien *et al.*, (2024). Assessing the social, economic, and environmental challenges of veld fires in South Africa by Adom *et al.*, (2025). Mallick (2025) investigated climate resilience and smart cities. However, previous studies have shown that research on emergency response is crucial for enhancing infrastructure resilience in sub-Saharan Africa, especially in response to recurring emergencies. This literature review aim to assess these systems and their impact on infrastructure resilience, providing insights that can inform future improvements in emergency management strategies across the region and beyond.

This study adopted the following research questions (RQ): RQ1: What is the impact of ERS on infrastructural resilience? and RQ2: What are the key challenges of ERS on infrastructural resilience?

2. Literature Review

2.1. Emergency response system

A coordinated framework created to successfully handle emergencies and disasters is an emergency response system (Wang *et al.*, 2022). A successful emergency response system is essential for reducing casualties, safeguarding property, and guaranteeing a speedy recovery (Dwarakanath *et al.*, 2021).

Risk knowledge and management is one of the systems that involves identifying hazards, and assessing vulnerability while utilising available resources and systems for the safety and well-being of people, and properties. Street security, traffic, and disaster have advanced monitoring technologies to detect, manage, and provide early warnings for disaster preparedness. Crime watch monitoring systems use surveillance cameras, community reporting apps, and data analytics to enhance public safety and emergency response in infrastructure (Damaševičius *et al.*, 2023). Data management, disaster risk analysis, community engagement, and religious institutions develop strategies by collecting, storing, and analysing disaster-related information and assessing impacts on infrastructure (Sutton *et al.*, 2024).

Forecasting for an emergency uses advanced tools to predict disaster events using meteorological, geological, and environmental data. Disaster risk

reduction (DRR) uses thorough data analysis to identify patterns, develop strategies, and mitigate risks in infrastructure (Basher, 2006). Assessing pre-disaster management measures improves resilience and risk management. Predicting disaster trends involves analysing historical data, adjusting DRR strategies, and implementing proactive measures. Social media platforms enable rapid dissemination of disaster information, enhancing public awareness and preparedness. Regular briefings, updates, and training sessions integrate pre-disaster information into DRR strategies (Sibiya, 2022). A comprehensive database improves accessibility and coordination. Platformizing early warning systems (EWS) delivers timely alerts. Religious and social institutions contribute to DRR through awareness campaigns and training (Sutton *et al.*, 2024).

Emergency preparedness using stakeholder cooperation, gender and social inclusion, effective communication, and community participation are crucial for DRR management. Transforming high-level policies into detailed procedures enhances preparedness and community resilience (Perera *et al.*, 2020). Investment in DRR is crucial for disaster resilience, funding infrastructure improvements, EWS, and community-based projects. Capacity building, educational curricula, and community engagement enhance DRR effectiveness (Cvetković *et al.*, 2021). Sutton *et al.*, (2024) suggest that religious and social institutions can enhance DRR initiatives. Assessing emergency response capabilities involves enhancing disaster prevention and mitigation capacity, involving human resources, science, technology, organization, and promoting effective management of facilities (Damaševičius *et al.*, 2023).

Disaster zones, damage assessment, and rehabilitation are crucial for disaster recovery. Germany's floods highlighted the need for cooperation, while risk assessment helps compare preventive measures and recovery costs. Assessing disaster damage aids in rebuilding plans and enhancing resilience through risk reduction, building standards, and infrastructure strengthening, requiring stakeholder collaboration for effective emergency response strategies (Cvetković *et al.*, 2021). Community engagement in emergency planning, investment in training, public education, and DRR incorporation in school curricula enhance preparedness, while effective communication is crucial for efficient response (Damaševičius *et al.*, 2023).

2.2. Current state of emergency response infrastructure

Early warning systems are effective globally but may not always lead to emergency responses, causing casualties and property loss. Emergency operations centres provide situational awareness, but their reach is limited (Perera *et al.*, 2020). US authorities prioritise technology over training for effective communication,

highlighting a communication gap with at-risk individuals. Disaster response involves authorities, agencies, and the public mobilising resources, such as transportation administration, immigration, and customs enforcement, for airport security measures (Gilmore & DuRant, 2021). Similar technology and strategies can be adopted to enhance infrastructure resilience to combat disaster in facilities. Information on potential event impacts is crucial for adaptive governance, but gaps exist in urban planning, particularly in master plans and social housing plans, exacerbated by resource scarcity (Travassos *et al.*, 2021). Municipalities play a crucial in adaptation planning. Emergency broadcasts raise awareness and guide evacuations. DRM planning involves government, private sector, and civil society, focusing on risk identification, reduction, preparedness, and financial protection (Bello *et al.*, 2021).

Integrating DRM policy tools with a country's framework aids resource allocation, but issues in the Flood Early Warning System (FEWS), including community participation, are crucial (Perera *et al.*, 2020). Social media platforms aid in crisis management, providing timely information to disaster victims for quick decision-making and lifesaving (Dwarakanath *et al.*, 2021). Cities integrate ERS into urban development strategies to enhance policy coherence. The World Meteorological Organization (WMO) started a forecasting program based on the impact on many to enhance user-friendly services for science, technology development, and natural hazards management (Merz *et al.*, 2020). Facilities management must adopt new technologies for hazard management and early warning programs to improve infrastructural resilience. Agencies prioritise environmental management and hazard forecasting, while smart city business models in developing countries prioritise economic capacity, technology readiness, and citizen participation (Myeong *et al.*, 2020). Not as much has been placed on the FEWS's three non-technical elements. Cooperation between interested parties, including local government, disaster management committees, and civil society organisations, is crucial for FEWS but is often hindered by barriers (Perera *et al.*, 2020).

2.3. Impact of emergency response infrastructure

2.3.1. Economic effects

From 2001 to 2018, more than half of water-related disasters were floods, which resulted in 94,000 fatalities and USD 504 billion in worldwide funds shortfalls (Perera *et al.*, 2020). Combining EWS with impact forecasts provides informed emergency measures and focuses on common targets (Merz *et al.*, 2020). Economic factors influence disaster likelihood and their effects on the economy. The smart city concept enhances sustainable development and improves local living standards (Myeong *et al.*, 2020).

Between 2001 and 2018, 2,309 disaster cases resulted in 510,204 deaths, 297 million affected persons, and \$437 billion in damage (Bello *et al.*, 2021). Insecure housing increases disaster impacts, including death, injury, and homelessness, while inadequate residential infrastructure can prolong or worsen health effects. From 2010 to 2019, global natural disasters caused an average annual economic loss of over USD 187 billion and displacement of an average of 24 million people annually. Disasters cause direct and indirect losses to communities, including physical destruction, environmental degradation, and human injuries. Developed nations have reduced losses, but developing nations like Ghana still face significant challenges (Mensah-Bonsu, 2022).

2.3.2. Socio-political effects

The socioeconomic impact is estimated using local thresholds influenced by hazard frequency, population density, and season (Merz *et al.*, 2020). The 2010 super floods in Pakistan severely damaged homes, infrastructure, medical facilities, and schools (Deen, 2015). Research on social and political institutions during emergencies is limited, with fragmentation influenced by socio-political landscape factors, and stronger political and administrative infrastructures are needed. Disasters can reintroduce vulnerable groups, highlighting the need for sustainable and resilient development policies to mitigate the consequences (Bello *et al.*, 2021). Impact forecasts assess how physical and socioeconomic factors affect critical infrastructure, buildings, fatalities, displaced individuals, monetary shortfalls, and supply chain disruptions. (Merz *et al.*, 2020). Pakistan's 2010 floods severely impacted 18 million people, causing widespread destruction and poverty. Government and international efforts provided short-term relief and interventions to restore livelihoods (Deen, 2015). Disaster risk events consistently impact sustainability, threatening community social and economic livelihoods due to the persistent threat of natural hazards (Tanesab, 2020). Migration from rural to urban areas reflects social and economic inequality, causing government pressure to build new facilities (Mensah-Bonsu, 2022).

2.4. Theories underpinning the study

To create resilient, flexible infrastructure emergency response systems, it is essential to apply systems and resilience concept that emphasize interconnectedness, feedback loops, and overall system behavior (Bonaretti and Piccoli 2018; Chen *et al.*, 2017). AI, Internet of Things, and GIS systems are integrated by system theory and resilience theory for real-time monitoring, emergency alert creation, and drone use for aerial surveillance and disaster assessment (Son *et al.*, 2020).

3. Research Methodology

This literature review evaluates the impact of ERS on infrastructure resilience by synthesising existing research knowledge, identifying best practices, and pinpointing knowledge gaps to guide future policy and practice. A comprehensive literature search was carried out across multiple academic databases, including Scopus, and Google Scholar, to gather relevant peer-reviewed articles, conference papers, and reports published between 2015 and 2025. The focus centred on studies related to ERS, infrastructure resilience, disaster management, and crisis response. The initial search yielded 150 articles, which were subsequently screened for relevance based on their titles, abstracts, and alignment with the study's focus on ERS and infrastructure resilience. Following this screening, 30 articles were chosen for detailed analysis using a qualitative thematic approach. The analysis sought to identify recurring themes and patterns regarding ERS and its effect on infrastructure resilience. The articles were filtered using specific keyword combinations such as "emergency response infrastructure," "challenges," "impact," "developing countries," "barriers," "limitations," and "constraints." Only studies examining ERS issues across various disaster scenarios were included, while those concentrating solely on developed countries or unrelated infrastructure issues were excluded. From the selected 30 articles, key data was extracted, including descriptions of the challenges, their causes, and their effects on emergency response. These findings were organised into thematic areas, encompassing socioeconomic inequality, infrastructure deficiencies, governance issues, resource shortages, and technological limitations.

4. Findings and Discussion

The literature review highlights early warning, technology, response efficiency, resources, strategic framework, community engagement, preparedness, and

institutional communication in assessing ERS's resilience for facilities. The impact of ERS on the resilience of infrastructure is illustrated in Figure 1. Ineffective EWS can delay disaster response due to poor communication, coverage, and technological constraints. Enhancing data integration and interagency communication can improve response effectiveness (Perera *et al.*, 2020; Kalogiannidis *et al.*, 2022). Modern technology, like geographic information systems, drones, and mobile applications, can enhance ERS by improving operational efficiency, reducing response times, and strengthening infrastructure resilience (Bello *et al.*, 2021; Merz *et al.*, 2020). Insufficient emergency response infrastructure, communication, and transportation networks hinder resource mobilisation and recovery efforts. Clear protocols, interagency collaboration, and training enhance readiness and resilience (Kalogiannidis *et al.*, 2022). The UN Office for DRR report highlights emergency response financial and human resource limitations, including outdated systems and inadequate funding, necessitating focused investments and collaborations (Bello *et al.*, 2021; Perera *et al.*, 2020).

The gap between disaster risk policies and their implementation is a major challenge, causing dispersed regional efforts and missed opportunities for resilience and recovery (Travassos *et al.*, 2021). Community involvement in emergency planning is crucial for resilience, but top-down approaches often lack ownership and understanding. Inclusiveness and gender perspectives can lead to more equitable outcomes (Perera *et al.*, 2020). Training and capacity-building programs are crucial for DRM, enhancing the preparedness and resilience of infrastructure (Binkley & Kemp 2022). Inadequate interagency communication hinders efforts and delays in information dissemination, affecting emergency management. Effective communication ensures stakeholders' collaboration during emergencies (Bello *et al.*, 2021; Perera *et al.*, 2020).

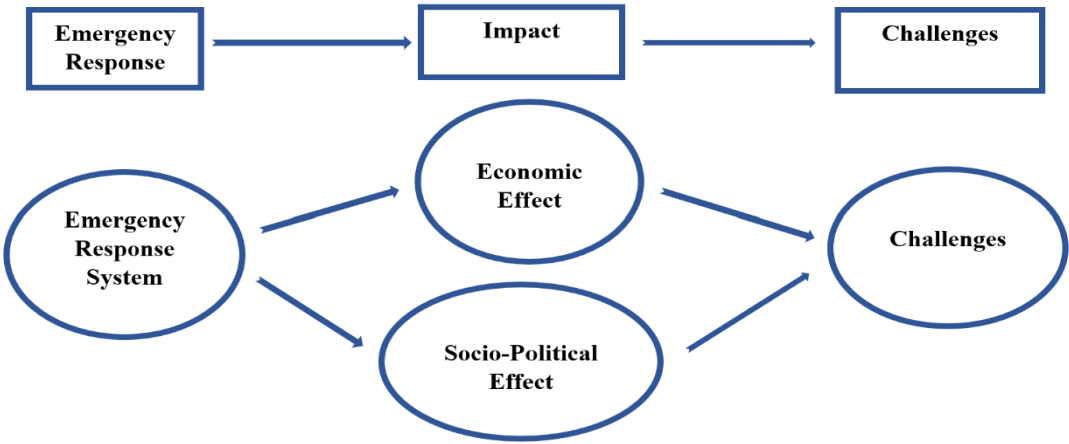


Figure 1: Conceptualised Emergency Response System. Author’s construct (2025)

4.1. *The economic impact of emergencies*

The occurrences of natural and manmade hazards have been a global issue. Very little work has been reported on the economic impact of emergencies, which can lead to emergency response infrastructural challenges, as shown in Figure 1. Emergencies cause major disruptions to economic activity, resulting in large losses for the world economy (Perera *et al.*, 2020). Both developed and developing economies are significantly impacted financially by disasters (Bello *et al.*, 2021; Deen, 2015). Research shows short-term asset damage and long-term economic downturns due to lower investment and productivity, with natural disasters costing developing countries up to 10% of GDP annually (Tanesab, 2020; Mensah-Bonsu, 2022). Emergencies significantly impact human life and property, with loss of life being the most tragic outcome (Bello *et al.*, 2021). Disasters can kill thousands of people, especially in places with a high population density and poor infrastructure (Deen, 2015; Tanesab 2020). According to a UN report, property loss from disasters often leads to increased poverty and unstable economies, particularly in low-income areas (Mensah-Bonsu, 2022).

Most residential and healthcare facilities lack resilience to crises, leading to disastrous failures (Deen, 2015; Tanesab, 2020). Studies show that inadequate residential and medical infrastructure increases risks for residents and vulnerable groups, leading to physical damage and increased mortality rates during emergencies (Bello *et al.*, 2021). The COVID-19 pandemic's inadequate healthcare infrastructure led to overburdened systems due to lack of adequate infrastructure. Emergencies often lead to displacement, causing people to leave their homes and resulting in temporary or permanent homelessness (Deen, 2015; Tanesab, 2020). Cities face severe vulnerability due to housing shortages and population density, leading to social dislocation (Merz *et al.*, 2020). There is a need for improved ERS that considers housing and assistance for communities caused by disasters.

4.2. *Socio-political impact of emergencies*

The trend in emergency response and its socio-political impact needs to be addressed in ERS, as shown in Figure 1. Emergencies exacerbate existing urban and demographic issues, particularly in areas with high population densities (Merz *et al.*, 2020; Deen, 2015). Rapid urbanisation in informal settlements increases vulnerability to disasters due to a lack of infrastructure, necessitating creative solutions for ERS (Tanesab, 2020; Mensah-Bonsu, 2022). Communities' ability to withstand emergencies is greatly impacted by social amenities (Deen, 2015; Merz *et al.*, 2020). Communities lacking sufficient access to social services, healthcare, and education are more vulnerable

to the impacts of natural disasters (Bello *et al.*, 2021; Tanesab, 2020). Insufficient social infrastructure can hinder emergency solutions (Mensah-Bonsu, 2022).

Emergencies frequently worsen societies' preexisting vulnerabilities and disparities (Merz *et al.*, 2020; Bello *et al.*, 2021). The literature highlights the disproportionate impact of disasters on marginalised groups, such as women, and the impoverished, who often lack the necessary tools and assistance (Deen, 2015; Tanesab, 2020). Children and women are especially at risk, with increased chances of exploitation and violence following disasters. Communities' economic stability is greatly impacted by emergencies (Merz *et al.*, 2020). Disasters often lead to low productivity, lower wages, and higher unemployment rates, making a recovery from economic instability challenging for communities (Bello *et al.*, 2021; Deen, 2015). Emergency-induced economic downturns often cause sluggish recovery, leading to ongoing social and economic issues, particularly in areas with weak economic infrastructure (Tanesab, 2020).

5. *Conclusion and Further Research*

ERS face challenges like ineffective early warning systems, outdated technology, funding, and poor community involvement, necessitating urgent reforms and unified national strategies for better response. Building emergency resilience requires community involvement, resource investment, and stakeholder training. Strengthening response systems, implementing reforms, and encouraging stakeholder cooperation can enhance disaster resilience. Emergencies significantly impact infrastructure resilience, causing economic losses, property damage, and displacement. Sociopolitical difficulties arise, particularly in urban areas, exacerbated by demographic pressures. To effectively prepare for future emergencies, a diversified strategy focusing on robust infrastructure, efficient early warning systems, and community involvement is crucial to fostering resilience and societal recovery.

This study contributes to the existing body of knowledge on ERS and raises awareness among emergency response stakeholders, facility users, and managers of their impact on infrastructure resilience. Future research should focus on understanding ERS and infrastructure resilience, integrating technology, focusing on community-centric approaches, conducting long-term studies, and evaluating policies for best practices and infrastructure impact assessment.

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