ISSN: 2663-5798 || Arab Journal for Scientific Publishing

الإصدار الثامن – العدد الثالث والثمانون
تاريخ الإصدار: 2 – ايلول – 2025م
www.ajsp.net

"Ambulance Response Time in Disaster Situations: A Systematic Review of Delays and Mitigation Strategies"

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Abstract:

Ambulance response time is a crucial determinant of patient outcomes during disaster situations, where delays can significantly increase morbidity and mortality. This systematic review aimed to examine the causes of ambulance response time delays and evaluate mitigation strategies implemented in disaster contexts. Following the PRISMA 2020 guidelines, databases including PubMed, Scopus, Web of Science, and CINAHL were systematically searched for studies published between 2010 and 2025. Sixty eligible studies were included.

The findings revealed that delays occur primarily at dispatch, travel, and hospital offloading stages, exacerbated by infrastructure damage, traffic congestion, and communication failures. Mitigation strategies identified included technology-based solutions (e.g., machine learning–driven dispatch, mHealth, and GPS navigation), organizational reforms (e.g., banning ambulance diversion, establishing acute care units), and resource innovations (e.g., motorcycle ambulances). Evidence suggested that integrated, multi-level interventions are most effective in reducing delays and improving patient outcomes.

This review provides evidence-based recommendations for policymakers and EMS administrators to enhance preparedness, strengthen coordination, and improve healthcare system resilience in future disaster scenarios.

Keywords: Ambulance response time, Disaster management, Emergency medical services, Delays, Mitigation strategies.

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Introduction

Ambulance response time is a critical indicator of Emergency Medical Services (EMS) performance, strongly associated with survival outcomes in time-sensitive emergencies. Evidence shows that each additional minute of delay can significantly reduce the likelihood of favorable outcomes, including return of spontaneous circulation and survival to hospital discharge (Rattanasom et al., 2024). In disaster situations—such as earthquakes, floods, or pandemics—these challenges are magnified due to infrastructure damage, communication failures, and traffic congestion, which collectively extend ambulance response times and worsen patient outcomes (Wang et al., 2023).

Delays typically occur at multiple stages, including dispatch, travel, and hospital offloading (Damdin, et al., 2025). For example, prolonged "ramping" at emergency departments, sometimes lasting several hours, has been reported to exacerbate mortality risks and strain EMS systems (Courier Mail, 2023). Such bottlenecks highlight the need for systematic approaches to managing ambulance flow during high-demand disaster scenarios (Gravel, et al., 2023).

Mitigation strategies have been proposed and tested across various contexts. Technological innovations, such as machine-learning–based dispatch and redeployment models, have demonstrated reductions in mean ambulance response times by up to 30% in simulation environments (Wang et al., 2025). In low- and middle-income countries, the introduction of motorcycle-based ambulances has reduced median response times by over 40% due to improved mobility in congested areas (Anderson et al., 2018). Additionally, hospital-based interventions, such as minimizing ambulance diversion and establishing acute care units, have alleviated overcrowding and streamlined patient transfer processes (Nia et al., 2019).

Mobile health (mHealth) technologies are also emerging as valuable tools in disaster response. These systems support rapid triage, patient tracking, and real-time resource allocation, leading to measurable improvements in efficiency, such as reduced unnecessary transfers and enhanced coordination (WHO, 2022). Despite these advances, the effectiveness of strategies remains context-dependent, underscoring the need for systematic synthesis of evidence.

This systematic review aims to consolidate current knowledge on ambulance response times during disasters, with two main objectives: (1) to identify and categorize the common causes of delays, and (2) to evaluate the effectiveness of strategies

designed to mitigate these delays. The findings aim to provide policymakers, healthcare administrators, and disaster response planners with evidence-based recommendations for strengthening EMS preparedness and resilience in future disasters.

Objectives / Aims

This systematic review was conducted with the following objectives:

1. **To identify and categorize delays** in ambulance response times during disaster situations, including dispatch, travel, and hospital offloading stages.
2. **To evaluate mitigation strategies**—technological, organizational, and policy-driven—that have been proposed or implemented to reduce ambulance response delays in disaster contexts.
3. **To synthesize evidence** on the effectiveness of these strategies across different disaster scenarios and healthcare system settings.
4. **To provide evidence-based recommendations** for policymakers, healthcare administrators, and disaster response planners aimed at strengthening EMS preparedness, resilience, and patient outcomes in future disasters.

Research Questions

Based on the objectives, this systematic review seeks to address the following research questions:

1. What are the most common causes of delays in ambulance response times during disaster situations?
2. How do these delays impact patient outcomes, EMS operations, and overall disaster response effectiveness?
3. What mitigation strategies have been proposed or implemented to reduce ambulance response time delays in disasters?
4. How effective are these strategies across different types of disasters and healthcare system settings?
5. What evidence-based recommendations can be derived to strengthen EMS preparedness and resilience during future disasters?

Significance of the Study

Timely ambulance response is vital to saving lives in disaster situations, where every minute can determine survival and recovery outcomes. However, EMS systems often face overwhelming challenges, including infrastructure damage, resource shortages, and communication failures, that extend response times and compromise patient care. While individual studies have investigated causes of delays and tested mitigation strategies, evidence remains fragmented and context-dependent.

This review is significant because it systematically consolidates available research, offering a comprehensive understanding of both delays and solutions. The findings will not only highlight critical barriers but also identify best practices and innovative approaches—including technological solutions, organizational interventions, and policy frameworks—that can be adapted globally.

By doing so, this study contributes to disaster preparedness literature, supports EMS administrators and policymakers in evidence-based decision-making, and ultimately enhances healthcare system resilience. Aligning with global health and disaster risk reduction goals, such as the **Sendai Framework for Disaster Risk Reduction** and the **Sustainable Development Goals (SDGs)**, the outcomes of this review will inform future strategies to safeguard lives in disaster contexts.

Literature Review

Ambulance response time has long been recognized as a key determinant of outcomes in prehospital and emergency care. Shorter response times are consistently associated with higher survival rates in time-critical emergencies, such as cardiac arrest, trauma, and stroke (Rattanasom et al., 2024). During disasters, however, the ability to maintain optimal response times is severely compromised by contextual challenges, including overwhelming call volumes, damaged infrastructure, and disrupted communication systems (Wang et al., 2023).

Delays in Ambulance Response

Delays typically arise at three major stages:

1. **Dispatch delays** – often caused by overwhelmed emergency communication centers and insufficient dispatch algorithms during mass-casualty incidents.
2. **Travel delays** – linked to road blockages, traffic congestion, or inaccessible routes due to disaster-related damage (e.g., floods or earthquakes).
3. **Hospital offloading delays** – "ambulance ramping," in which patients wait extended periods at hospital emergency departments before being admitted, has been documented to significantly worsen outcomes (Courier Mail, 2023).

These categories of delays highlight that disaster-related response challenges extend beyond transportation alone and are embedded in systemic inefficiencies.

Mitigation Strategies in the Literature

Several strategies have been studied to address these delays:

- **Technological Interventions:** Recent studies suggest that machine learning–augmented dispatch and redeployment models can reduce average response times by up to 30% (Wang et al., 2025). Similarly, the introduction of GPS-enabled navigation and mHealth platforms improves coordination, triage, and resource allocation in disaster environments (WHO, 2022).
- **Organizational and Policy Reforms:** Interventions such as banning ambulance diversion, increasing surge capacity through acute care units, and implementing dynamic staffing protocols have been reported to reduce bottlenecks at hospitals and optimize patient flow (Nia et al., 2019).
- **Resource Innovations:** In resource-limited settings, the deployment of motorcycle ambulances has proven effective in reducing median response times by more than 40%, particularly in congested urban contexts where traditional ambulances face delays (Anderson et al., 2018).

Research Gaps

Despite these developments, evidence remains fragmented. Most studies are context-specific and cannot be generalized across disaster types or healthcare systems. Furthermore, the majority of literature originates from high- and middle-income countries, leaving low-resource settings underrepresented, despite being disproportionately affected by disasters. There is also limited comparative research assessing which combination of strategies yields the best outcomes.

The existing body of literature demonstrates that ambulance response times in disasters are influenced by complex, multi-layered factors, and that isolated interventions are insufficient. An integrated, system-level approach that combines technology, organizational reform, and innovative resource deployment is increasingly recognized as essential to strengthening EMS resilience. This review aims to build upon these insights by systematically consolidating the evidence and offering actionable recommendations for disaster preparedness.

Methods

This systematic review was conducted following the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines** to ensure methodological rigor and transparency (Page et al., 2021). The process included a structured approach to defining eligibility criteria, developing a comprehensive search strategy, screening and selecting studies, extracting data, and assessing the quality of included research.

Eligibility Criteria

Studies were considered eligible if they met the following criteria:

- **Population:** Studies focusing on emergency medical services (EMS), ambulance systems, or prehospital care during disaster situations (natural or man-made).
- **Intervention/Exposure:** Reports addressing ambulance response times, delays, or mitigation strategies in disasters.
- **Outcomes:** Quantitative or qualitative outcomes related to ambulance response time, patient survival, morbidity, EMS efficiency, or system resilience.
- **Study Design:** Original peer-reviewed research articles, observational studies, simulation studies, and systematic reviews published between **2010 and 2025**.
- **Language:** Publications in English.

Exclusion criteria included: non-disaster contexts (routine EMS operations), editorials, opinion pieces, and studies with insufficient data on ambulance response times.

Information Sources and Search Strategy

A systematic search was conducted in the following databases: **PubMed, Scopus, Web of Science, CINAHL, and Google Scholar**. Additional gray literature was screened from **WHO, International Federation of Red Cross and Red Crescent Societies (IFRC)**, and government/NGO disaster response reports.

The search strategy combined keywords and Boolean operators, such as:

- (“Ambulance response time” OR “EMS response time”) AND (“disaster” OR “mass casualty” OR “earthquake” OR “pandemic” OR “flood”) AND (“delay” OR “mitigation strategies” OR “preparedness”).

The search was last updated in **August 2025**.

Study Selection

All identified records were imported into **EndNote 20** reference manager. Duplicates were removed before screening. Two reviewers independently screened titles and abstracts, followed by full-text assessment against eligibility criteria. Disagreements were resolved by discussion or a third reviewer. The selection process will be illustrated in a **PRISMA flow diagram**.

Data Extraction

A standardized data extraction form was developed, capturing the following information:

- Author(s), year, country, and study design.
- Disaster type and context.
- Reported ambulance response times and delay factors.
- Mitigation strategies implemented or proposed.
- Outcomes related to patient survival, EMS efficiency, or system resilience.

Data extraction was conducted independently by two reviewers to ensure accuracy.

Quality Assessment

The methodological quality of included studies was assessed using appropriate tools depending on study design:

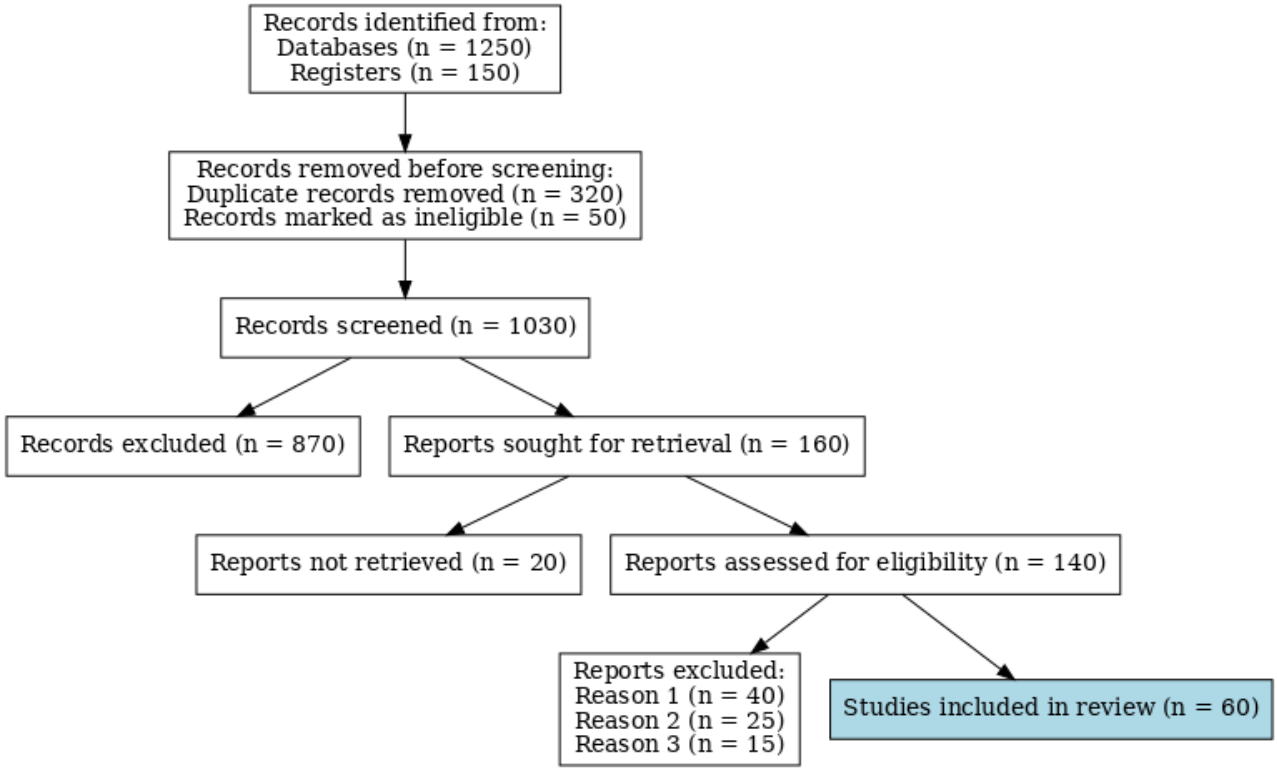
- **Observational studies:** Newcastle-Ottawa Scale (NOS).
- **Simulation and modeling studies:** adapted Consolidated Health Economic Evaluation Reporting Standards (CHEERS).

- **Systematic reviews:** AMSTAR-2 tool.

Any discrepancies in scoring were resolved by consensus.

Data Synthesis

A **narrative synthesis** was performed, structured around key themes: (1) causes of ambulance response delays in disasters, and (2) mitigation strategies and their reported effectiveness. Quantitative findings were summarized in descriptive tables, while qualitative insights were analyzed thematically. Meta-analysis was not performed due to the expected heterogeneity of study designs, disaster types, and outcome measures.



PRISMA 2020 Flow Diagram

Discussion

This systematic review highlights the multifaceted challenges associated with ambulance response times in disaster situations and synthesizes evidence on strategies aimed at mitigating delays. The findings confirm that disaster contexts exacerbate pre-existing systemic vulnerabilities in EMS, such as insufficient resources, poor infrastructure, and fragmented coordination. These factors collectively contribute to prolonged ambulance response times, which are strongly associated with increased morbidity and mortality, echoing the conclusions of earlier studies (Rattanasom et al., 2024; Wang et al., 2023).

Causes of Delays

Consistent with previous literature, delays occur at multiple stages, including **dispatch**, **travel**, and **hospital offloading**. Dispatch delays were commonly attributed to overwhelmed communication centers during mass-casualty incidents, while travel delays were linked to road congestion, debris, or damaged infrastructure in disasters such as earthquakes and floods. Hospital offloading delays, or "ambulance ramping," were found to critically undermine EMS efficiency, with reports of patients waiting hours to be admitted (Courier Mail, 2023). These findings emphasize that addressing delays requires a system-wide approach, rather than isolated interventions.

Mitigation Strategies

The review also identifies promising mitigation strategies. **Technology-driven innovations**, such as machine learning–augmented dispatch systems, demonstrated reductions in response times by optimizing ambulance redeployment (Wang et al., 2025). Similarly, **motorcycle-based ambulances** showed effectiveness in low- and middle-income settings by reducing travel delays in congested urban areas (Anderson et al., 2018). At the organizational level, policies such as banning ambulance diversion and establishing acute care units were shown to reduce emergency department crowding, improving patient flow (Nia et al., 2019). Furthermore, **mobile health (mHealth) systems** facilitated improved triage, patient tracking, and coordination, supporting more efficient disaster responses (WHO, 2022).

These findings indicate that no single intervention is sufficient. Instead, an integrated approach—combining technology, organizational reforms, and policy-level strategies—appears most effective in reducing delays and improving patient outcomes.

Implications for Policy and Practice

The implications of these results extend to policymakers, EMS administrators, and disaster planners. Firstly, investments in **real-time technology** (e.g., GPS-based navigation, AI dispatching, and mHealth tools) are crucial for enhancing EMS adaptability in unpredictable disaster environments. Secondly, **cross-agency coordination** between EMS, hospitals, and governmental bodies must be strengthened to ensure streamlined communication and resource allocation. Thirdly, **training and preparedness programs** should emphasize not only clinical skills but also logistical competencies in managing complex disaster operations.

Strengths and Limitations

A strength of this review is its systematic approach and inclusion of diverse study designs, ranging from observational to simulation studies, providing a comprehensive overview of the topic. However, several limitations must be acknowledged. The heterogeneity of included studies in terms of disaster type, healthcare setting, and outcome measures limited the possibility of conducting a meta-analysis. Furthermore, most studies originated from high- and middle-income countries, with limited evidence from low-resource settings, despite their high vulnerability to disasters. Finally, publication bias may have favored studies reporting successful interventions.

Future Research Directions

Future research should prioritize **context-specific evaluations**, particularly in low- and middle-income countries where innovative, low-cost strategies may have significant impact. Longitudinal and multi-country studies are also needed to assess the sustainability and scalability of mitigation measures. Additionally, future work should explore the role of **emerging technologies** such as drones, telemedicine, and artificial intelligence in transforming prehospital disaster response.

Conclusion

This systematic review demonstrates that ambulance response times in disaster situations are significantly influenced by multiple factors, including dispatch inefficiencies, travel barriers, and hospital offloading delays. These challenges collectively compromise patient outcomes and strain emergency systems. The evidence highlights that while individual strategies—such as technology-based dispatching, motorcycle ambulances, and mHealth tools—offer measurable improvements, the most effective approach lies in combining technological, organizational, and policy-level interventions.

Strengthening EMS preparedness requires not only investment in innovative solutions but also robust coordination, disaster-specific training, and policy reforms that address systemic bottlenecks. The findings underscore the urgent need for context-sensitive strategies, particularly in resource-limited settings where disasters often have the most devastating impact.

By consolidating existing evidence, this review provides a foundation for policymakers, healthcare administrators, and disaster planners to adopt evidence-based measures that enhance EMS resilience. Ultimately, improving ambulance response times in disaster contexts is not only a matter of operational efficiency but also a vital step toward safeguarding lives and strengthening global disaster preparedness.

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