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Title: Pre-hospital Patient Transport Strategies in Mass Casualty Incidents: A Scoping Review of Alternative and Complementary Approaches

Authors: Rahim Ali Sheikhi[1], Mohammad Heidari[2,*]

1. *Department of Disasters and Emergencies, Community-Oriented Nursing Midwifery Research Center, Shahrekord University of Medical Sciences, Shahrekord, Iran.*
2. *Department of Disasters and Emergencies, Community-Oriented Nursing Midwifery Research Center, Nursing and Midwifery School, Shahrekord University of Medical Sciences, Shahrekord, Iran.*

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Abstract

Background: Mass Casualty Incidents (MCIs) rapidly overwhelm conventional Emergency Medical Services (EMS) and hospital surge capacity, making pre-hospital transport from the scene to definitive care a critical determinant of patient outcomes. Tiered transport strategies that complement standard ground ambulances may improve throughput, equity of access, and survival when they are coordinated through a robust command-and-control system. The objective of this systematic scoping review is to identify, synthesize, and critically appraise the evidence regarding alternative and complementary patient transport strategies used during the pre-hospital management of MCIs.

Materials and Methods: A scoping review of pre-hospital patient transport strategy studies related to MCIs was conducted from database inception to November 2025 using MEDLINE (via PubMed), Embase, Scopus, Web of Science, and CINAHL. Search terms included "mass casualty incidents," "disaster," "pre-hospital," and "transport" or "evacuation." We charted data on incident type and setting, transport strategy, and reported process outcomes and patient outcomes for non-standard, optimized, or supplementary transport approaches, including centralized transport coordination, non-ambulance vehicles, rotorcraft, staged transport algorithms, and hospital response teams in clinically relevant qualitative and quantitative studies.

Results: Of 2,143 records identified, 8 studies were included. These covered real-world MCIs (industrial explosions, aviation and train crashes, terrorist attacks, nursing home fires, sudden-onset disasters) and large-scale simulations, and comprised one retrospective incident report, four observational or descriptive reports, one scenario evaluation, one systematic review, and one guideline/consensus paper. Centralized transport coordination and staged evacuation were associated with a reduction in PHT in the included studies, although the exact magnitude of the reduction was not consistently reported across studies. In complex MCIs, the combination of ground EMS, Helicopter Emergency Medical Services (HEMS), and multi-tier hospital-based response teams appeared feasible and potentially beneficial, although overall study quality was poor, heterogeneous, and highly context-specific.

Conclusion: Evidence on alternative and complementary pre-hospital transport strategies for MCIs is limited and heterogeneous, but it suggests that systems combining accurate scene triage, coordinated command-and-control, centralized dispatch and destination decision-making, and multi-tier transport modalities including ambulance buses for minor ambulant patients and HEMS for small numbers of critically injured patients can improve logistical performance. Future studies should employ standardized transport-related outcomes to clarify which combinations of control arrangements and transport resources provide the best balance of timeliness, safety, and equity in different health system settings.

Keywords: Mass casualty incidents, emergency medical services, pre-hospital, patient transport

Introduction

Mass Casualty Incidents (MCIs) are events in which the number of casualties and the demand for emergency medical care abruptly and disproportionately exceed the available capacity of Emergency Medical Services (EMS) and hospitals, causing a substantial mismatch between needs and resources [1-3]. MCIs include a wide range of scenarios such as multi-terrorist attacks, large fires, industrial explosions, transportation crashes, sudden-onset natural disasters, and similar high-impact events that generate multiple injured or ill patients within a short time frame [2,3,6-8]. These incidents can lead to increased mortality and morbidity, long-term disability, psychological and social consequences, disruption of routine healthcare, and significant strain on health systems and communities [1-3,9].

In the pre-hospital phase of MCIs, EMS has critical roles and responsibilities, including scene safety, rapid triage, initiation of life-saving interventions, and organization of patient movement from the scene to appropriate hospitals [1,2,4-6]. The way in which EMS performs these functions in mass casualty situations determines whether patients with time-sensitive conditions receive definitive care promptly and whether hospital surge capacity is used efficiently and equitably [2,3,6-8]. Therefore, pre-hospital EMS is a central component of MCI management and system resilience.

Existing evidence on pre-hospital MCI management shows that EMS systems face recurrent challenges when providing services during these events. Systematic and integrative reviews have described prolonged pre-hospital phases, disproportionate allocation of patients among hospitals, traffic congestion, shortages of transport resources, communication deficiencies, delays in recognizing the scale of the incident, and the absence of pre-established evacuation routes as common weaknesses in current practice [5,10]. At the same time, updated guidelines and Delphi-based consensus studies emphasize that when pre-incident planning, multi-agency coordination, and structured triage and life support are in place, EMS can mitigate some of these challenges and improve overall MCI response.

Within this broader pre-hospital context, patient transport has been identified as one of the most critical process domains in MCI response [1,10,12]. Transport logistics, including dispatch, loading, routing, and destination decisions, are closely linked to pre-hospital time (PHT), on-scene congestion, and the distribution of casualties across receiving hospitals [3,10]. Evidence from incident reports and reviews suggests that poorly coordinated transport flows can lead to delayed evacuation, overcrowding of some facilities, underutilization of others, and inequitable access to appropriate levels of care for different casualty groups, even when triage and life-support systems are relatively well organized [1,5,10]. Conversely, when transport decision-making is centralized and aligned with real-time information on patients, resources, and hospital capacity, pre-hospital performance and system resilience may improve.

To address transport-related challenges in MCIs, a variety of alternative and complementary patient transport strategies have been proposed and, in some cases, implemented [1-3,12,13]. Reported approaches include centralized or staged transport coordination cells that assume loading and destination decisions from individual field units, hub-and-spoke and corridor evacuation models, integration of HEMS as a designed adjunct to ground EMS, deployment of hospital-based Special Medical Response Teams (SMRTs) into the pre-hospital environment, and the intentional use of non-ambulance vehicles such as buses for evacuating large numbers of low-acuity or non-ambulatory patients [2,3,5,13]. Additionally, technology-assisted decision support tools, such as Unmanned Aerial Vehicles (UAVs) for remote scene size-up and Global Positioning System (GPS)-based patient tracking, have been explored to enhance situational awareness, optimize casualty collection points, and support dynamic transport routing during MCIs.

Despite this emerging repertoire of complementary transport strategies, the evidence base remains heterogeneous and fragmented [10,12,13]. Most available studies are observational reports, single-incident analyses, simulation exercises, or guideline-derived conceptual frameworks rather than robust comparative outcome studies [1-3,12,13]. They differ in event type, geographic and health system context, and outcome measures, with inconsistent reporting of transport-related indicators such as PHT, scene congestion, destination appropriateness, and equity of access [1-3,10,12,13]. As a result, there is limited synthesized knowledge specifically focused on alternative and complementary patient transport frameworks and models in the pre-hospital management of MCIs [2,5,10-12].

This fragmented and context-specific evidence landscape creates a significant knowledge gap for EMS planners, decision-makers, and frontline responders who seek to design multi-tiered transport systems that are both logistically efficient and clinically safe in MCIs. In particular, it is unclear which combinations of centralized control arrangements, transport modalities (e.g., ground ambulances, ambulance buses, HEMS, and technology-assisted tools provide the best balance of timeliness, safety, and equity in different health system settings [1-3,10,12,13]. There is also a need for more consistent use of standardized transport-related performance indicators and more detailed reporting of implementation conditions and constraints.

In light of these gaps, and given the breadth and heterogeneity of reported strategies, study designs, and outcomes, a scoping review approach is appropriate for mapping the existing literature on pre-hospital patient transport strategies in MCIs. Therefore, the objective of this scoping review is to systematically identify and categorize alternative and complementary pre-hospital patient transport strategies described in MCIs; to summarize their incident contexts, implementation features, and reported transport-related outcomes; and to highlight key knowledge gaps and priorities for future research and system planning in MCI patient transport [10-13].

Previous reviews have addressed general MCI management, pre-hospital challenges, triage systems, and performance indicators in disaster response. These reviews have examined broad response processes and overall system issues, but they have not specifically reviewed alternative and complementary pre-hospital patient transport strategies in MCIs. In particular, the literature has not been comprehensively mapped for centralized transport coordination, staged evacuation, HEMS integration, hospital-based response teams, non-ambulance vehicles, and technology-assisted transport approaches in pre-hospital MCI settings. The objective of this systematic scoping review is to identify, synthesize, and critically appraise the evidence regarding alternative and complementary patient transport strategies used during the pre-hospital management of MCIs.

Materials and Methods

Study design and framework

This scoping review was conducted according to the Population, Concept, and Context (PCC) framework. The population included patients involved in MCIs, the concept was alternative and complementary pre-hospital patient transport strategies, and the context was pre-hospital and initial interfacility transport settings. This scoping review was not prospectively registered in a public protocol registry, which is acknowledged as a methodological limitation.

Eligibility criteria

Inclusion criteria

We included original studies, incident reports, simulation studies, guideline papers, and relevant empirical or conceptual reports that described alternative or complementary pre-hospital transport strategies in MCIs. Studies were required to describe alternative or supplementary transport arrangements clearly. We included studies from all years with full texts in English, up to November 2025. Studies had to focus on the pre-hospital or initial inter-facility stage of an MCI (e.g., sudden-onset disaster, terrorist incident, transport collision, industrial explosion, etc.). Alternative or supplementary transport arrangements were defined as any transportation modality, coordination model, or support system used in addition to or instead of conventional ground ambulance evacuation during an MCI, including centralized coordination, staged transport, HEMS integration, non-ambulance vehicles, and technology-assisted transport support. Clear description and examination of alternative or supplementary transport arrangements, including but not limited to: I) Centralized or staged transport coordination or hub-and-spoke evacuation. II) HEMS integration into MCI transport systems. III) Hospital-based SMRTs whose deployed activities substantially alter the transport of patients from the scene to the hospital. IV) System-level changes that affect PHT, patient distribution among hospitals, or transport-related patient flow.

Exclusion criteria

Exclusion criteria were studies limited to in-hospital surge management without pre-hospital transport, pure triage algorithm studies without a transport component, commentaries, editorials, letters without transport data, conference abstracts or conference papers without full text, and duplicate records. The primary outcomes were transport time and mortality. Secondary outcomes included hospital distribution, resource utilization, scene clearance time, and system resilience.

Information sources and search strategy

Searches were run in November 2025 in the following databases: MEDLINE (PubMed), Embase, Scopus, Web of Science, and CINAHL. The search syntax was customized per database, but the primary search concepts remained the same: “mass casualty,” “pre-hospital,” and “transport/evacuation”. Grey literature was identified through targeted searches of organizational websites, guideline repositories, conference proceedings with available full text, reference lists of included studies, and backward citation tracking of relevant articles. To ensure comprehensive retrieval of transport-related literature, the search strategy included not only transport and evacuation terms but also related concepts such as casualty distribution, patient distribution, transport coordination, transport management, evacuation strategy, evacuation planning, transportation logistics, and surge transportation (Supplementary 1).

Quality Assessment

The methodological quality of the eight included studies was appraised using the Mixed Methods Appraisal Tool (MMAT). Two reviewers independently rated each study according to its design (quantitative non-randomized, qualitative, or mixed-methods), and disagreements were resolved by discussion. Overall, study quality was low to moderate, with most studies meeting fewer than half of the MMAT criteria for their respective designs. Common limitations included lack of representative sampling, incomplete outcome data, and absence of appropriate statistical analyses or consideration of confounders. No study met all MMAT criteria; the highest overall ratings were observed for the systematic review and the guideline/consensus document, whereas single-incident observational reports and the scenario evaluation showed the lowest ratings. Details of the MMAT quality ratings for each included study are provided in Supplementary ٢.

Data extraction

Data extraction was performed using a pre-piloted charting form developed by the review team based on the PCC framework and the research questions. For each included study, we systematically extracted bibliographic details (first author, publication year, country/region), incident characteristics (type of mass casualty incident, setting, and scale of the event), and study design (observational report, cohort study, simulation exercise, guideline/consensus document).

We also extracted transport-related variables, including the pre-hospital or early interfacility transport strategy (e.g., centralized transport coordination, staged evacuation, HEMS integration, hospital-based SMRTs, use of non-ambulance vehicles, technology-assisted decision support tools), the role and composition of EMS and hospital response teams, and any reported process indicators such as PHT, scene congestion, loading and dispatch patterns, destination decision-making, hospital distribution of casualties, and scene clearance time. When available, patient-level outcomes (mortality, survival of moderately and severely injured patients, and indicators of system resilience or equity of access) were also recorded.

Initial data extraction was conducted independently by two reviewers (RAS and MH), who screened full texts and completed the charting forms. Discrepancies in extracted variables or categorizations (e.g., transport strategy type or outcome classification) were resolved through discussion, and when consensus could not be reached, a third senior reviewer was consulted. The final dataset was checked for internal consistency and served as the basis for the descriptive tables and thematic synthesis presented in the results section.

Data synthesis

A meta-analysis was not achievable for the included studies, given the heterogeneity in study design, methodology, and outcome measures. Therefore, a narrative, thematic synthesis approach was used. Extracted data were organized into descriptive tables and then synthesized thematically across studies according to the type of mass casualty incident, transport strategy, implementation context, and reported process and clinical outcomes. Themes such as centralized transport coordination, staged evacuation, HEMS integration, hospital-based SMRTs, use of non-ambulance vehicles, and technology-assisted decision support were identified and refined through iterative comparison of findings across observational, simulation-based, incident report, and guideline evaluation studies.

Study selection and screening

Titles and abstracts of all records were screened by two independent reviewers, followed by full-text assessment of potentially eligible articles. Disagreements at either stage were resolved through discussion, and when consensus could not be reached, a third reviewer was consulted. The study selection process is summarized in the PRISMA flow diagram [14], showing the numbers of records identified, duplicates removed, records screened, full texts assessed for eligibility, and studies included in the final synthesis.

Results

2,143 records from databases; 721 duplicates removed. Screening: 1,422 titles/abstracts screened; 1,353 excluded. Eligibility: 69 full texts assessed; 61 excluded (20 not transport-focused, 16 not pre-hospital, 12 not MCI, 8 non-English, 5 conference abstracts without full text). Included: 8 studies in the final review (Figure 1 & Table ١).

Figure 1.

Table ١.

There were several distinct but overlapping themes related to alternative and complementary transport strategies during the pre-hospital management of MCIs across the eight included studies: centralized coordination and staged evacuation, integration of HEMS, deployment of transport-influencing hospital-based special response teams, and system-level PHT reduction and patient distribution optimization [1, 3, 12, 13, 15-18]. One of the most explicit transport-focused innovations is centralized patient transport described in an incident report from a university emergency center MCI, which analyzed a shift from decentralized, unit-driven transport decisions at the scene to a centralized coordination cell [17]. In this case, a central command node coordinated dispatch, loading, and destination selection for multiple ambulances and complementary vehicles to shorten transport time, relieve scene command from excessive coordination burdens, and avoid under-triage related to nonsystematic transport decisions. The system was under substantial pressure and operated with compressed timelines. However, the transported casualties suffered no trauma-related deaths [17]. Quantitative estimates of the reduction in delivery time, PHT, and patient distribution improvement were not consistently reported in the included studies. (Table ٢ & Figure 2)

Table ٢.

Figure 2.

Discussion

Principal Findings

This scoping review mapped the available evidence on alternative and complementary pre-hospital transport strategies in MCIs and showed that the literature is dominated by observational reports, simulation studies, and conceptual frameworks. The review identified several strategy categories, including centralized transport coordination, HEMS integration, hospital-based response teams, non-ambulance vehicles, and technology-assisted decision support. These findings suggest that coordinated transport planning and multi-tier evacuation strategies may improve pre-hospital performance in MCIs. The eight included studies showed that centralized transport coordination and staged evacuation were associated with reductions in PHT, decreased scene congestion, and improved patient distribution across hospitals.

Comparison with Existing Literature

Consistent with previous reviews, prior systematic and narrative reviews of MCI management have reported similar transport-related challenges and benefits of coordinated evacuation strategies. These external sources, which were not part of the eight studies included in the present scoping review, similarly highlight that poorly organized transport flows can lead to delays in evacuation, overcrowding of some facilities, and inequitable access to definitive care, whereas centralized transport coordination and multi-tier transport modalities may mitigate these challenges.

This research review examines alternative ways to manage pre-hospital transportation in MCIs, including central coordination and staged evacuation, HEMS integration, hospital-based SMRTs, transport in non-ambulance vehicles, and technology-based decision support tools [1-3,12,13,15-18,22,23]. Most included studies and reviews emphasize that effective mass casualty transport depends primarily on accurate on-scene triage and strong command-and-control systems with centralized dispatch and destination decisions, and only secondarily on the specific transport vehicles used. When these control systems are in place, various transport systems can be used to distribute patients safely and effectively according to their injury severity, time sensitivity, and the receiving hospital's capabilities.

The evidence on alternative and complementary transport strategies in the eight included studies and related reviews can be grouped into two categories.

First, strategies with process-level evidence, such as centralized transport coordination, staged evacuation, and HEMS integration, are associated with shorter pre-hospital times, reduced scene congestion, and more equitable patient distribution across hospitals in specific settings.

Second, strategies such as hospital-based SMRTs, structured use of non-ambulance vehicles, and technology-assisted decision support (e.g., UAVs and GPS-based tracking) are mainly supported by theoretical rationale, feasibility data, or simulation studies rather than robust comparative outcome studies.

Literature on MCI Management supports the role of transport logistics alongside triage and support of life systems [3, 12, 18]. In these systematic updated reviews and guidelines of MCI Management, transport in the pre-hospital framework pulls together movement and triage [3], focusing on the need for rapid, simultaneous evacuation and distribution of victims to prevent overcrowding and delay definitive care in the treatment of victims. The guidelines review high-quality comparative studies as sparse in the literature; however, existing observational studies and expert consensus support pre-established regional transport plans, flexible control groups that coordinate to the needs of the patient and the system, and to the hospitals, and structured multi-agency communication on the state of transport at hand and the hospital [3]. The same emphasis on transport was noted in the modified Delphi study of the MCI response to a sudden disaster, focusing consensus statements on integrated triage transport decision-making, the need for explicit guidelines to prioritize time-sensitive patients, and the systematic use of exercises and simulations to evaluate transport pathways [18]. The T1 NIGHTINGALE scoping review again emphasized transport coordination and argued that new decision support systems and other tools need to incorporate and track real-time data on patients, available resources, and intended destinations for the purpose of optimizing patient flow [12]. As a group, these works do not evaluate specific transport vehicles or algorithms, but rather, offer a conceptual and evidence-informed framework to which additional alternative or complementary strategies may be applied [3, 12, 18].

In addition to process-level coordination, several studies have proposed models that introduce a structural change to the traditional separation between hospital and pre-hospital care and, consequently, alter transport patterns. One such proposal is the institution of hospital-based SMRTs designed to provide pre-hospital trauma care during disasters and MCIs. In this design, trauma physician- and paramedic-staffed teams are pre-hospital-fielded by hospitals to perform advanced interventions that may alter important transport priorities, such as transporting an unstable patient without prior stabilization or using a remote, high-level trauma center. The SMRT design is aimed as a complementary alternative to conventional EMS where local pre-hospital EMS are overloaded or lack trauma medical personnel [16]. Although largely a conceptual framework supported by observational studies, the work illustrates a considerable redesign of EMS transport demand planning based on the hospital's location and the surplus of clinical resources and continuum of decision-making required at the pre-hospital injury site [16].

Another transport-oriented presentation is the novel emergency transportation model formulated based on post-disaster analysis of the 2015 Formosa Fun Color Dust Party explosion in Taiwan.

Although the EMS response in this acute-onset MCI predominantly involving burns and blast injuries was highly praised as a "golden model," the authors questioned whether the EMS transport plan could be improved further. They examined on-scene triage, apparent PHT, in-hospital time, and diversion rates, and analyzed cases in which transport assets were reassigned or staged elsewhere. The presented analysis indicated that outcomes are very good, but other transport strategies (e.g., early diversion of moderate cases to burn-capable hospitals having higher distance or staged loading to avoid congestion and load, work sharing more equally) could improve the adverse effect on surge capacity. This paper serves to highlight that even where what appear to be successful interventions have been made, the use of structured scenario analysis may reveal incremental benefits of different transport modalities in terms of equity of access for those requiring specialized services [13].

The incorporation of HEMS into MCI transport systems is another area of essential consideration. One of the earliest reports in the area discussed the integration of a HEMS into a mass casualty response system and illustrated the advantage of having rotorcraft in reaching areas that ground ambulances cannot access and in providing quick inter-facility transfers of critically ill patients [15]. The study explained the mobilization of HEMS, the integration of ground EMS into the command hierarchies, and the use of the helicopters to increase transport speed and to shift (reallocate) the patients to different facilities based on the hospitals' capabilities. The authors pointed out that certain integrations like this are contingent on having pre-incident arrangements, established communication, and protocols that outline the engagement to eliminate the potential for disorganized and dangerous systems [15]. The MCIs in the reports may date from an earlier period; however, the foundational ideas remain widely relevant today. [3, 18]. The integration of HEMS into pre-hospital MCI systems likewise has process-level support, particularly in scenarios where ground access is compromised or where rapid inter-facility transfer of critically ill patients is required. In line with current practice, HEMS evacuation in MCIs is realistically limited to a small number of critically injured patients, and its main value lies in selected time-critical transfers rather than in mass movement of casualties.

Several other studies that are also included in this research, which are primarily concerned with triage or scene management, also provide the basis for understanding the relationships between transport strategies and triage. The pilot studies of the SALT mass casualty triage system and the refinement of the data-driven triage system for low acuity victims demonstrate how accurate scene triage impacts the order of transport and the transport destination. For instance, a more refined triage of low-acuity victims may mitigate the unnecessary early evacuation of victims who are minimally injured and who would occupy the transport, thereby potentially allowing the transport for more critical victims and allowing other forms of transport to be used for the minor injuries [19, 20]. From the design of casualty collection and collection points in MCIs, there is evidence that the organization of victims for transport to be loaded into a transport unit is efficient and safe, and that a hub-and-spoke or corridor evacuation can be a better option than a direct and unstructured loading sequence from a dispersed position [21]. Even though these studies may not be transporting trial studies, they provide the basis for integrated triage transport for pre-hospital MCIs [19-21].

The evidence regarding technology-assisted transport optimization is somewhat limited but developing. Evaluating remote scene size-up with aerial UAVs and GPS patient tracking during simulated MCIs shows that real-time aerial characterizations within geofenced environments increase situational awareness about casualty locations, threats, and transport pathways. UAVs had video capabilities that could assist paramedics in determining the clusters of patients, the dangers, and the optimal access and egress pathways before actual frontline engagement. This could allow the strategic arrangement of ambulances and other vehicles in proximity to the casualty collection points. GPS tracking devices that patients could carry provided continuous situational awareness to staff throughout the patient transport from the scene to the hospital and enabled the real-time monitoring of transport flows. Even though the studies primarily highlighted the temporal and perceptual feasibility of remote tracking rather than actual patient outcomes, they indicate that the digital decision support tools could assist in bypassing ordinary transport strategies and enhance non-standard vehicles or multi-hub evacuation systems.

The quality and generalizability of the evidence are major concerns. Most studies were observational, single-incident reports without randomized comparisons of transport strategies, which is understandable given the ethical and practical challenges of conducting research during real MCIs [1, 3, 12, 13, 18]. Certain variables, such as the type of event, location, and the capabilities of the health system, and the presence of concurrent triage or resuscitation interventions, complicate the effort to assess the sole impact of transport methods on mortality or morbidity [1, 3, 18]. Moreover, the outcome measures are inconsistent, as some studies indicate a supposed PHT frame, while others concentrate on mortality within the hospital, secondary transfers, or the attitudes of the employees, making it more difficult to synthesize studies [1, 3, 12, 13, 18]. That said, the combined results from heterogeneous studies, such as the correlation of coordinated transport to lower PHT, reduced on-scene overcrowding, and reasonable death rates, give a moderate indication that these methods are effective and beneficial to implement the more fully developed and designed transport models [1, 3, 13, 17, 18].

Contextual factors and implementation challenges also affect the feasibility of alternative transport models [3, 12, 18]. Centralized control requires compatible and unified communication systems, command structures, and protocols across EMS, fire, police, and hospitals, which may be lacking in some regions [3, 18]. Factors such as weather, daylight, landing zones, cost, and HEMS integration may be less viable in a built-up city where ground transport is faster, and HEMS integration is less viable [3, 15]. The utilization of hospital-based SMRTs is also dependent on the presence of specialized personnel, which may not be maintainable in extended or multipoint events [16, 18]. The concerns regarding safety, liability, and tracking for non-ambulance vehicles (such as buses, trucks, and private cars) can be superseded by the rapid evacuation of minor casualties [1, 13]. Investment, training, and the avoidance of distracting technology during high-pressure situations are needed for the integration of existing workflows with promising tools like GPS trackers and UAVs [12, 22, 23].

These obstacles notwithstanding, EMS systems can incorporate alternative and complementary transport methods into their MCI pre-hospital plans. EMS systems can draw four valuable insights for the integration of complementary and alternative transport methods into pre-hospital MCI plans. *First*, pre-incident plans ought to specifically outline the transport coordination frameworks that institutionalize the roles of central transport officers or units, destination criteria, and backup plans for civil works failures [3, 17, 18]. *Second*, there should be sufficient latitude in the employment of varying transport modalities, including HEMS, public transit, and other vehicles; protocols must delineate criteria specifying when patients are appropriate for non-ambulance transport. [1, 3, 13, 15]. *Third*, transport systems should be incorporated into triage and casualty collection point designs so that spatial arrangements and prioritization work together to facilitate rapid and efficient loading and unloading [3, 19-21]. *Fourth,* ongoing multi-agency exercises, alongside high-fidelity simulation training, should factor in transport bottlenecks and other scenarios to test the overall plans' adaptability and to familiarize the teams with primary synthesis and other digital control technologies, including UAVs and GPS [12, 13, 18, 22, 23].

Finally, the research agenda includes the formulation of standardized MCI pre-hospital transport performance outcomes (e.g., time to definitive care, equity of outcomes, functional outcome metrics) and the establishment of transport process registers for real occurrences [1, 3, 12, 18]. Enhanced modelling and simulation, perhaps through the use of agent-based modelling or digital urban EMS system twins, may offer the possibility of ethically controlled environments for comparative analyses of transport strategies in simulated versions of real [12]. Concurrently, qualitative activities around the experiences of patients and responders may unveil obstacles and facilitators to the adoption of alternative transport strategies, and ensure the designed solutions are practical and sustainable [12, 16, 18]. Through this integrated, multi-faceted approach, the still very thin evidence base will be expanded to inform more precise recommendations about the use of alternative and ancillary transport in the pre-hospital MCI domain [1, 3, 12, 13, 16-18].

Implications for Practice

In this scoping review, evidence on alternative and complementary pre-hospital transport strategies in MCIs was limited and heterogeneous. Most included studies were observational, single-incident reports, simulation-based evaluations, or guideline-derived frameworks.

Within this sparse evidence base, the intentional use of non-ambulance vehicles (e.g., buses) to evacuate low-acuity or non-ambulatory patients has been described only in a few incident reports and integrative reviews (for example, in nursing-home fires) and has not been evaluated in robust comparative trials.

Strengths and Limitations

This scoping review has several strengths. It was conducted using a comprehensive search across multiple databases and followed a structured review process, which helped identify a diverse body of evidence on alternative and complementary pre-hospital transport strategies in MCIs. In addition, the inclusion of different study types, such as observational reports, simulation studies, and guideline papers, allowed a broad mapping of the available literature. However, several limitations should be acknowledged. The included studies were highly heterogeneous in terms of incident type, transport strategy, and outcome reporting, which limited direct comparison and prevented meta-analysis. Moreover, most of the evidence was based on single-incident reports, observational studies, or expert-based documents, and quantitative outcomes such as reductions in delivery time, PHT, and patient distribution were not consistently reported. Therefore, the findings should be interpreted as descriptive and context-specific rather than definitive or generalizable across all settings. Although the clinical efficacy and safety of some of these alternative methods still need to be validated, there is a shortage of comparative outcome studies, inconsistent performance indicators reported, and a majority of analyses that are lost to the plurality of incidents or confined to high-fidelity simulations. Consequently, there is a need for more studies to advance transport-related outcome metrics and frameworks, real-time data collection during MCIs, and ethically designed comparisons to assess what combinations of methods provide the best improvements in time, equity, and patient-centered outcomes in different EMS and health system settings.

Future Research

Future research on alternative and complementary pre-hospital transport strategies in MCIs should prioritize the development and validation of standardized transport-related performance indicators, such as time to definitive care, equity of outcomes across casualty groups, and functional recovery metrics, and embed these within multicenter registries and real-time data capture systems. Longitudinal studies and high-fidelity simulations are needed to compare different combinations of centralized command-and-control arrangements, transport modalities (including ambulance buses, HEMS, SMRTs, and non-ambulance vehicles), and technology-assisted tools under diverse urban and rural health system conditions. In parallel, mixed-methods research that integrates quantitative outcome analyses with qualitative inquiry into responder and patient experiences can identify organizational, legal, and cultural facilitators and barriers to adopting innovative transport frameworks and digital decision support platforms. Finally, collaborations between EMS agencies, hospitals, policymakers, and engineering and data science groups may enable the creation of agent-based models and "digital twins" of pre-hospital systems, providing ethically acceptable environments to test, refine, and scale optimized transport strategies before their deployment in real incidents.

Conclusions

This scoping review identified a heterogeneous and limited literature on alternative and complementary pre-hospital transport strategies in MCIs. The evidence base is broad in terms of strategy types but sparse in comparative outcomes, underscoring the need for future studies with standardized definitions, outcome measures, and implementation reporting.

While the evidence surrounding integrated and alternative pre-hospital transport strategies for MCIs is inconsistent and still developing, they do highlight several process-level advantages. In particular, integrated HEMS and pre-hospital aviation within transport frameworks, centralized transport coordination, and staged evacuation are linked to reduced PHT, less congestion at the scene, and a more even patient distribution at receiving hospitals. The findings suggest the need for spatially coordinated models to improve patient allocation, hospital distribution, and transport routing in MCIs [24, 25].

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Declaration of AI-Assisted Language Editing

During the preparation of this manuscript, the authors used the AI-based language model ChatGPT (https://www.chatgpt.com/) to assist with translation, academic writing refinement, and grammatical optimization. All AI-generated content was thoroughly reviewed, verified, and edited by the authors to ensure accuracy, clarity, and alignment with the study's scientific objectives. No AI tool was used for data extraction, data analysis, interpretation of study findings, or drawing scientific conclusions. The authors take full responsibility for the final content of the manuscript and affirm that the authors performed all intellectual contributions, critical thinking, and interpretation. In addition, Napkin AI (https://napkin.ai/) was used to design Figure 2, which visually summarizes the thematic synthesis of transport strategies identified in the included studies. The figure layout and visual elements were generated with Napkin AI based on content and categories defined by the authors.

Author contribution

RAS and MH designed the study. RAS and MH collected data. RAS and MH analyzed data. All authors contributed to the analysis and interpretation of data. RAS and MH drafted and revised the article in response to the comments from the other authors. All authors approved the final version.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Compliance with ethical guidelines

The study was conducted in accordance with the ethical standards as outlined in the 1964 Declaration of Helsinki and its subsequent amendments, or with comparable ethical standards. This research was approved by the Ethical Committee of the Medical Sciences University of Shahrekord (Ethics code: IR.SKUMS.NUMHE.REC.1404.010).

Conflict of interest

The authors declare no conflict of interest exists.

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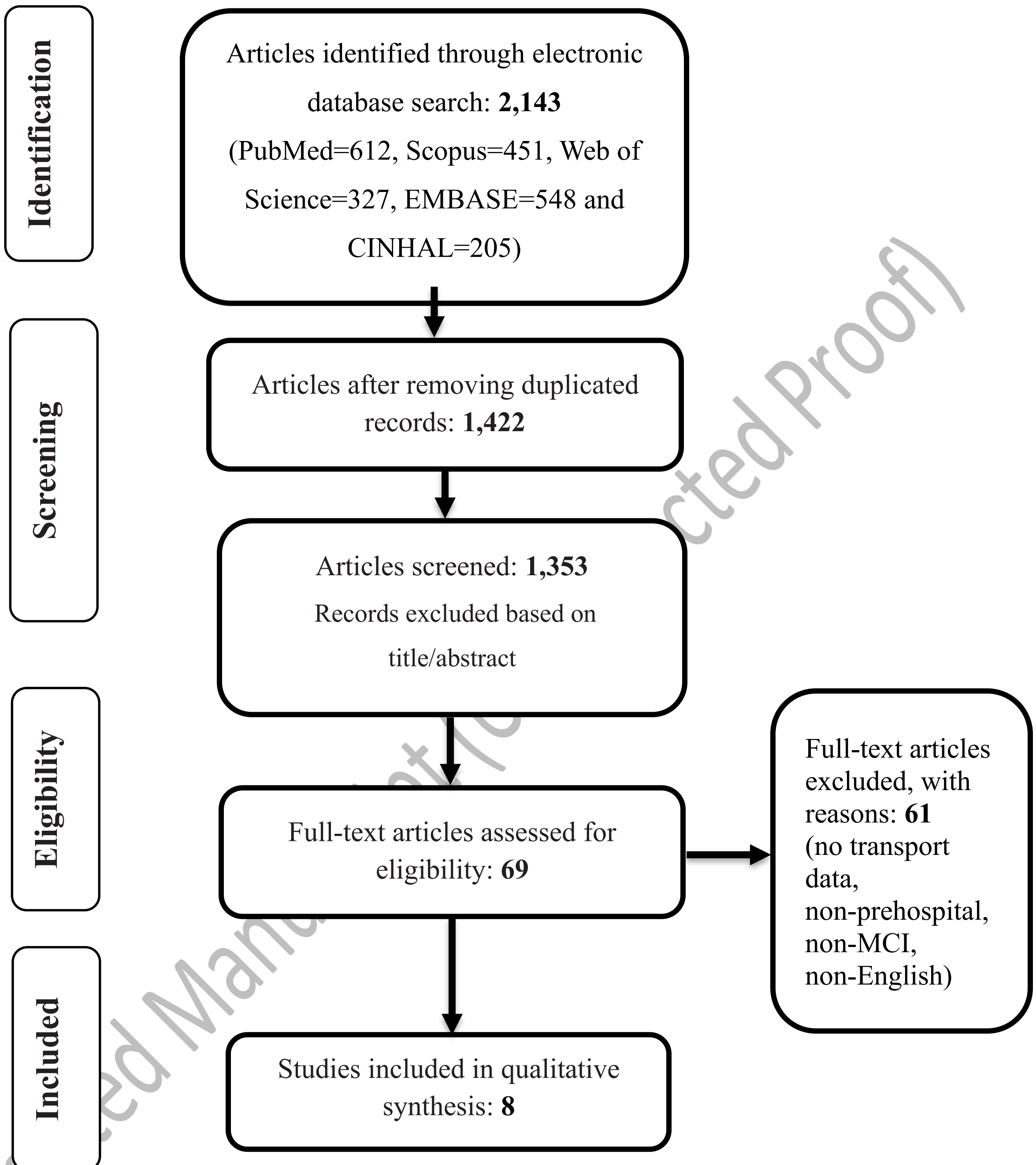

Figure 1. Review the selection process and results based on the PRISMA guidelines

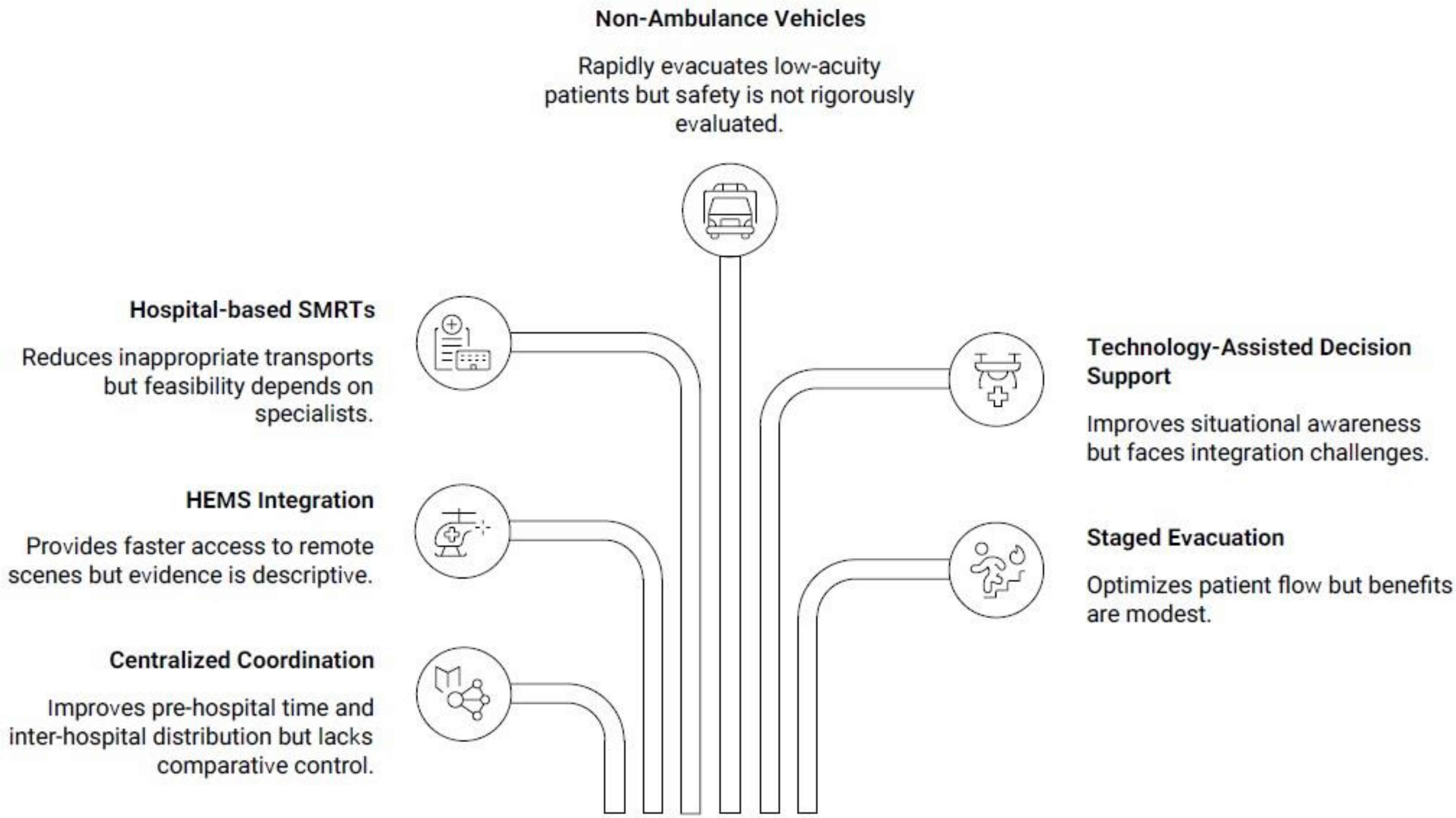

Figure 2. Transportation strategies in MCIs

Table 1. Characteristics of included studies

First author (year) (ref)	Title	Country/setting	Study design	MCI type / scenario	Alternative/complementary transport strategy	Key transport-related findings
Taniguchi H, et al. (2024) (17)	Optimizing mass casualty: centralizing patient transport	Japan, University Emergency Center	Retrospective incident report	Real-world MCI at the university emergency center	Centralized transport coordination cell; scene-to-hospital flows managed centrally	Shortened time to patient transport, reduced scene burden; no trauma-related deaths.
Cuthbertson H, et al. (2023) (8)	Sudden-onset disaster MCI response, Modified Delphi	International expert panel	Modified Delphi consensus	General sudden-onset MCI scenarios	Consensus on integrated triage-transport processes and multi-tier response models	Recommends coordinated transport prioritization and pre-defined pathways.
Suda AJ, et al. (2025) (3)	Management of mass casualty incidents: guideline update	Germany/Euro; guideline scope	Systematic review + guideline	Various MCIs (trauma, terror, disasters)	Evidence- and consensus-based recommendations on transport logistics and distribution	Emphasizes pre-defined regional transport plans and coordination cells.
Neeki M, et al. (2021) (16)	Prehospital trauma care in disasters, SMRTs	Germany; civilian MCIs	Conceptual paper with observational data	Disasters and civilian MCIs	Hospital-based Special Medical Response Teams deployed pre-hospital, altering transport priorities	Suggests earlier advanced care and more tailored destination decisions.
Lin M-W, et al, (2021) (13)	An innovative emergency transportation scenario	Taiwan; Formosa Fun Color Dust Party	Observational evaluation and scenario analysis	Real-world industrial/burn MCI	Alternative transportation scenarios (e.g. staged evacuation, adjusted diversion patterns)	Indicates potential benefits of adjusted transport to balance capacity and reduce congestion.

Jacobs LM, et al. (1991) (15)	The integration of a HEMS in a mass casualty response system	Europe: regional EMS system	Descriptive observational report	Multiple MCIs and major incidents	HEMS integrated as a complement to ground EMS for scene and inter-facility transport	Demonstrates feasibility and advantages for the reach and distribution of critical patients.
Alruqi F, et al. (2023) (1)	Factors associated with delayed pre-hospital times in trauma-related MCIs	International; multiple incidents	Systematic review	Trauma-related MCIs	Synthesizes factors that delay transport; discusses coordinated and alternative transport assets	Identifies congestion, asset limitations, and highlights the benefits of coordinated multi-tier transport.
Cuthbertson J, et al. (2023) (18)	Sudden-onset disaster MCI response, scoping review	EU Horizon 2020 consortium	Scoping review	Pre-hospital MCIs in Europe	Identifies transport as a key domain; recommends data-driven, tool-supported optimization	Supports the development of integrated decision-support for transport planning.

Table 2. Summary of alternative and complementary pre-hospital transport strategies

Transport Strategy	Incident Type/Context	Reported Outcomes (Process vs. Clinical)	Key Limitations of the Evidence
Centralized Transport Coordination	Industrial explosion; University hospital MCI drill [17]	**Process:** Shorter pre-hospital time, reduced scene congestion, and more balanced inter-hospital distribution. **Clinical:** No trauma-related deaths reported in one incident.	Single-incident observational report; lack of comparative control.
HEMS Integration	Mixed MCIs (terror, crashes) [15]; Guidelines & systematic reviews [3, 18]	**Process:** Faster access to remote/inaccessible scenes; facilitated inter-facility transfer. **Clinical:** Outcomes not independently measured.	Older report; evidence largely descriptive or based on expert consensus.
Hospital-based SMRTs	Conceptual framework for disasters & MCIs [16]	**Process:** Proposed reduction in inappropriate transports; advanced field decision-making. **Clinical:** No outcome studies available.	Theoretical model; feasibility depends on specialist availability and system integration.
Non-Ambulance Vehicles (e.g., Buses)	Nursing home fire; similar events [2, 5]	**Process:** Rapid evacuation of low-acuity patients, freeing EMS resources. **Clinical:** Safety and patient outcomes not rigorously evaluated.	Limited to few incident reports; no protocols or comparative trials.
Technology-Assisted Decision Support (UAVs, GPS)	Simulated MCIs [22, 23]	**Process:** Improved situational awareness, route planning, and patient tracking. **Clinical:** Feasibility studies only; no patient-centered outcomes.	Simulation-based integration challenges in real-world command systems.
Staged Evacuation & Multi-tier Models	Formosa Dust Explosion analysis [13]; Guideline updates [3]	**Process:** Potential to optimize patient flow and reduce surge at single hospitals. **Clinical:** Modest outcomes reported; incremental benefit suggested by scenario analysis.	Post-hoc analysis; it is hard to isolate the impact of transport from other response factors.