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Decision-Making in Natural Disaster Response: A Comprehensive Review of Strategies, Models, and Technological Advancements

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ABSTRACT

Natural disasters such as hurricanes and earthquakes cause extensive damage, requiring effective decision-making frameworks during emergency responses. Disaster management traditionally involves four phases: Mitigation, Preparation, Response, and Recovery. This study focuses on the Response phase, aiming to evaluate and categorise existing disaster response models to enhance decision-making and address challenges during this critical period. Employing bibliometric analysis and systematic content review of 86 scholarly works, the study identifies key patterns, research gaps, and challenges in disaster response. Bibliometric methods reveal global research trends and collaboration networks, while content analysis uncovers recurring themes in decision-making, resource allocation, and communication. The findings highlight a shift towards technology-driven frameworks, including IoT, remote sensing, augmented reality, and blockchain, which aid real-time decisions and resource management. However, limitations remain in developing adaptive decision-support systems and fostering multi-stakeholder collaboration. Furthermore, low international co-authorship—especially among researchers from disaster-prone regions—indicates scope for enhanced global cooperation. The study recommends greater adoption of emerging technologies and strengthened international partnerships to improve disaster response effectiveness. Its systematic classification of response models offers a practical tool for advancing evidence-based decision-making and capacity building in emergency management.

1. Introduction

Although nature can inspire awe, it also poses significant risks to human well-being through various natural disasters. These events are a recurrent cause of widespread destruction and loss. Between 2000 and 2019, over 7,300 major disasters were recorded, affecting approximately 4.2 billion individuals, resulting in around 1.23 million deaths, and inflicting economic damages

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estimated at $2.97 trillion [65]. Disasters stemming from phenomena such as flooding and extreme wind events have not only become more frequent but also more severe, exacerbated by urban development and climate change. For instance, the 2010 earthquake in Haiti led to over 200,000 fatalities and incurred financial losses between $7.2 billion and $13.9 billion [10].

Similarly, the 2017 Atlantic hurricane season, among the most financially devastating, caused cumulative damages nearing $217 billion through hurricanes Harvey, Irma, and Maria [54]. These figures underscore the urgent necessity for effective disaster management frameworks, particularly within the response phase, which critically influences both survival and recovery outcomes for affected populations. To mitigate the impact of such large-scale disruptions, natural disaster management practices are implemented, commonly structured into four stages: Mitigation, Preparation, Response, and Recovery [6]. Mitigation and preparation occur in anticipation of potential events and involve forecasting risks and designing strategies to minimise damage. These efforts also lay the groundwork for response and recovery planning. The Response phase, central to this investigation, initiates at the onset of a disaster and continues into the immediate aftermath, giving way to recovery operations. Collectively, these four interconnected phases form an integrated approach aimed at ensuring cities are prepared and capable of functioning effectively during emergencies [18; 59].

Although some regions are more susceptible to natural disasters, their repercussions often extend beyond national borders. For example, seismic events in Japan may influence global markets, while flooding in one coastal nation can impact its neighbours [41]. Consequently, the study of disaster management has seen a rise in international collaboration as countries work jointly to enhance preparedness. Innovations in this domain are continuously emerging, including social media-based tools such as Rescue-Mark [36], drone-enabled surveillance systems [20], and GIS-based solutions [40], all developed to improve the effectiveness of emergency responses through technology integration. The response phase, which forms the focus of this research, encompasses the mobilisation of emergency personnel, medical aid, community involvement, provision of essential services, and the initiation of early recovery activities [56]. Emphasising this phase allows for a targeted examination of a crucial element of disaster management that directly influences immediate survival and overall well-being. Effective responses rely on the convergence of theory and practice, demanding rapid decision-making, strategic allocation of resources, and seamless communication. Importantly, this stage often reveals limitations in earlier mitigation and preparation efforts and thus serves as a critical feedback point. Recent technological developments have particularly enhanced capabilities during this phase, making it a vital area for innovation and scholarly focus.

Theoretical perspectives offer valuable insights into the complexity of decision-making during disaster response. The concept of bounded rationality explains how decision-makers operate under constraints such as time pressure, limited information, and resource scarcity, common conditions during emergencies such as evacuations [12]. This underscores the importance of structured models that facilitate informed and swift decisions. Additionally, a systems-oriented view supports the creation of integrated strategies that account for the interdependencies among stakeholders, resources, and technological infrastructures [62]. These conceptual frameworks underpin the analytical approach of this study, which aims to assess and categorise existing disaster response models for both academic and practical benefits.

Technological advancements, improved communication systems, and a deeper understanding of disaster dynamics have substantially elevated the effectiveness of modern response efforts [14; 56]. Whereas historical responses relied heavily on local capacity and manual coordination, contemporary approaches now utilise satellite imagery, GIS, and real-time analytics to better assess damage and allocate resources. Tools such as predictive models, artificial intelligence, and machine learning further enhance decision-making by generating actionable insights for strategic response and planning [13]. These innovations have transformed the response phase into a more adaptive, informed, and dynamic process. It is important to clarify that this study focuses exclusively on natural disasters—those originating from environmental processes—while excluding human-made crises and pandemics from its analysis.

Despite the recognition of four fundamental disaster management phases, there remains a lack of structured classifications tailored specifically to the decision-making processes intrinsic to the response phase. This gap hampers the strategic application of response mechanisms across varying disaster contexts, where well-informed decisions are indispensable. To address this, the current research presents a detailed examination of 86 publications through bibliometric and content analysis. Various response strategies are explored, including distribution logistics, communication through social media, and evacuation planning, while also identifying emerging trends and innovations that influence decision-making efficacy. The PRISMA method guided the systematic identification, selection, and categorization of relevant studies, which were then organized thematically based on model types and data usage.

The insights generated by this study offer practical relevance for emergency response professionals, governmental bodies, first responders, scholars, and disaster management practitioners. For response teams and authorities, the study offers empirically grounded frameworks to enhance decision-making capabilities. Academics benefit from a consolidated overview of response models, highlighting research deficiencies and future opportunities. Practitioners may use the findings to optimise the allocation of resources, streamline communication channels, and adopt technological solutions, thereby improving overall responsiveness. The value of this research lies in its contribution to the enhancement of disaster management frameworks through the systematic categorisation of response models. This process identifies practical patterns and evaluates the effectiveness of various methodologies, with a specific emphasis on how emerging technologies—such as artificial intelligence, social media analytics, and GIS tools—are augmenting decision-making processes. Ultimately, the study aims to offer a structured foundation for future academic inquiry and operational strategies that support adaptive, data-informed, and resilient responses to natural disasters within management and engineering domains.

The structure of this paper comprises several major components. The Methodology section explains the procedures used for sourcing and analysing the literature. The Content Analysis section presents the classification and thematic interpretation of selected studies. The Bibliometric Analysis investigates global research trends, including national origins and patterns of co-authorship, to identify collaborative strengths and weaknesses. The paper concludes with a summary of findings and proposes avenues for future investigation based on the combined results of the bibliometric and content analyses.

2. Methodology

This study adopts a methodical and systematic approach to identify and evaluate scholarly publications related to natural disaster response strategies. The research design is structured in accordance with the PRISMA framework, an established standard that promotes transparency, consistency, and rigour in conducting systematic reviews, as detailed in [46; 52]. The utilisation of PRISMA ensures the reliability and relevance of the literature selection process through a clearly defined sequence of identification, screening, and inclusion. Although based on secondary data sources, the study integrates an empirical dimension through the application of both bibliometric and content analyses. The bibliometric component focuses on quantifiable indicators, including citation metrics, keyword distributions, and patterns of co-authorship, to reveal trends and collaborative dynamics within the disaster response research domain. In parallel, the content analysis investigates thematic patterns, uncovers existing research gaps, and assesses prevailing challenges associated with disaster response frameworks. This dual analytical strategy enables a holistic and data-oriented exploration of the academic landscape, offering valuable perspectives on current practices, technological innovations, and areas necessitating further investigation. A summary of the procedural steps employed in this methodology is illustrated in Figure 1.

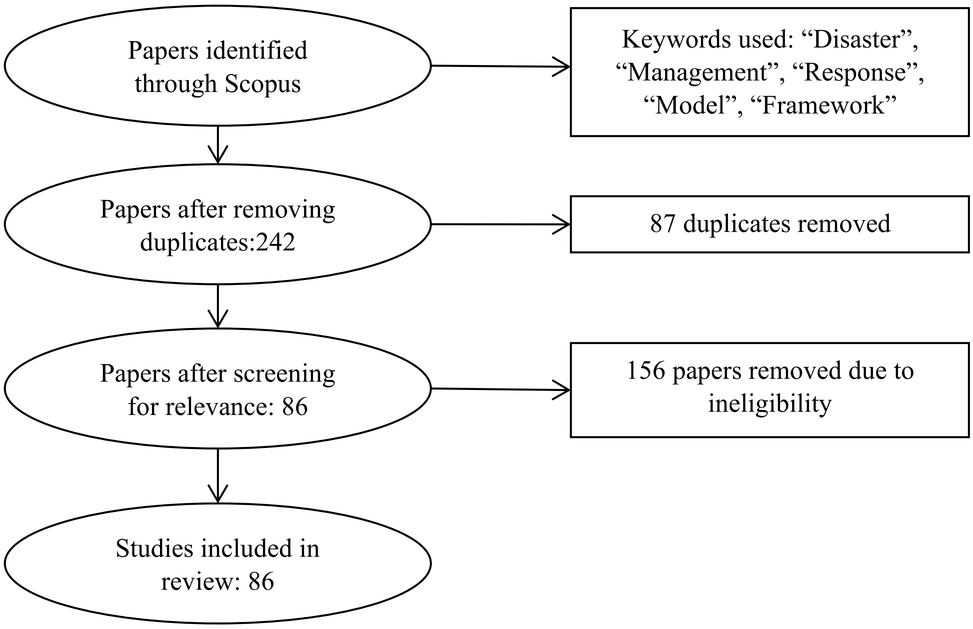

Fig.1: Methodological Steps of PRISMA

The methodology comprises several systematic steps, beginning with literature retrieval. In this initial stage, journal articles and conference proceedings were sourced from the Scopus database, covering publications from 2016 to the present. The search strategy employed specific keyword combinations to ensure the inclusion of relevant studies. The terms used were as follows:

- "Disaster AND Management AND Model" – aimed at identifying works adopting a comprehensive perspective on disaster management frameworks encompassing the entire management cycle.
- "Disaster AND Response AND Model" – refined the search to capture studies concentrated on response-phase-specific models.
- "Disaster AND Response AND Framework" – ensured inclusion of literature proposing conceptual structures pertinent to disaster response, even where formal models were not developed.

Using this search protocol, a total of 329 publications were initially retrieved. Scopus was selected exclusively for its extensive coverage of peer-reviewed journals, robust indexing system, and advanced filtering capabilities, which ensured both quality and diversity across disciplines. Given its comprehensive reach, the inclusion of other databases was considered unnecessary for meeting the study's objectives within the constraints of time and available resources. The second phase involved a meticulous screening process. Initially, duplicate entries were eliminated, reducing the number of publications from 329 to 242. The remaining papers were assessed for topical relevance. Publications found to focus on non-natural disasters—including those addressing man-made incidents, system failures, or pandemics such as COVID-19—were excluded. Following this relevance-based screening, 156 papers were removed, resulting in a final selection of 86 publications deemed suitable for detailed analysis.

Content analysis – Following the final selection of relevant publications, a detailed content analysis was undertaken. Each paper was rigorously examined to extract its core focus and contributions. Based on this analysis, the studies were organised into thematic categories, allowing for the identification and classification of commonalities and distinctions in disaster response strategies. The categorised themes, which emerged from this comprehensive review, are discussed in detail in Section 3.

Bibliometric analysis – In parallel, a bibliometric analysis was carried out to quantitatively assess the landscape of academic research in the field. This process involved evaluating citation patterns, co-authorship networks, and keyword frequencies to uncover structural relationships and knowledge flows across publications. Through this analysis, the study identified key contributors, high-impact publications, emerging thematic areas, and collaborative patterns within the domain of emergency response and disaster management. The approach provides a nuanced understanding of how the research field has evolved, highlights prominent research clusters, and reveals areas that remain underexplored.

The subsequent sections present the outcomes derived from both the content and bibliometric analyses.

3. Content Analysis

The content analysis undertaken in this study offers a comprehensive synthesis of the selected publications, with a particular focus on the type of disaster response addressed and the corresponding models employed. The principal aim of this analysis is to derive substantive insights into the evolution of disaster response models, thereby identifying both effective practices and persisting limitations. This evaluative process contributes to a more precise understanding of the trajectory of disaster response research and the unresolved issues requiring further investigation. The results are organised into primary themes and sub-themes that emerged from the systematic review of the literature. Each thematic category is introduced with contextual background, followed by a synthesis of principal findings and illustrative examples drawn from the analysed publications. This structure facilitates a holistic interpretation of the literature and the derivation of key insights. In addition to summarising the thematic findings, a critical appraisal is conducted under each theme. This appraisal examines the methodological robustness and practical relevance of the various approaches, identifies deficiencies and inconsistencies in the current research landscape, and outlines implications for future scholarly inquiry. To preserve clarity within the main body of the paper, detailed tabular summaries highlighting the contributions and salient features of each included study are presented in Appendix A.

3.1 Relief Distribution in Disaster Response

The subsequent section integrates findings from 15 studies related to relief distribution, organised into three principal themes (refer to Table A-1):

- **Optimisation of Relief Distribution and Emergency Shelter Locations:** The strategic positioning of emergency shelters alongside the optimised allocation of resources is fundamental for effective disaster response. Research has emphasised the significance of multimodal transport systems to enhance efficiency Maghfiroh and Hanaoka [42], while the potential utilisation of drones for rapid relief delivery has also been explored [15]. A critical insight emerging from these studies is the necessity for real-time adaptive systems capable of responding to the evolving conditions typical of disaster scenarios.

- **Stochastic Models for Supply Balancing and Pre-Positioning:** Stochastic approaches contribute to improved disaster preparedness by addressing uncertainties inherent in resource allocation, as demonstrated in previous research [17; 34]. Although effective in optimising pre-positioning strategies, these models often lack robustness in addressing multi-hazard situations and the cascading effects that may arise.
- **Emerging Technologies:** Innovations such as blockchain technology Javadpour et al. [35] and the IoT Yang et al. [72] have been shown to enhance transparency and facilitate real-time monitoring, signalling significant potential for revolutionising relief distribution mechanisms. The integration of these technologies with conventional methods indicates a promising direction toward the development of hybrid systems.

Collectively, the reviewed studies indicate a clear trend towards increasingly technologically sophisticated models for relief distribution, prioritising real-time flexibility, improved coordination, and the efficient deployment of resources. Emerging technologies such as blockchain and IoT offer substantial opportunities to advance disaster response systems.

Several challenges remain in the implementation of effective relief distribution strategies:

- Existing models frequently lack the adaptability required for large-scale disasters, reducing their effectiveness during widespread crises.
- Many approaches depend on static scenarios, failing to provide the necessary flexibility to accommodate the dynamic nature of disaster events.
- Stochastic models face difficulties in accurately representing the complexities of disaster environments, which limits their practical application.
- The adoption of emerging technologies such as blockchain and IoT is constrained by high costs and regulatory barriers.

The analysis identifies significant gaps in current relief distribution research:

- There is a notable absence of comprehensive models capable of managing cascading effects in multi-disaster scenarios.
- Emerging technologies encounter obstacles related to the absence of standardised protocols and interoperability between systems.
- Integration of adaptive systems to support real-time decision-making during disaster response remains limited.

To address these issues, future research should prioritise:

- The development of scalable, robust models capable of adjusting to large-scale and multifaceted disaster contexts.
- Strengthening the validation processes for stochastic models through the incorporation of real-world data to enhance their dependability.
- Resolving interoperability challenges to facilitate the seamless integration of emerging technologies across diverse platforms.
- Focusing on hybrid systems that combine advanced technological solutions with traditional methods, ensuring cost-effectiveness and operational feasibility in disaster management.

3.2 Evaluation of Disaster Response Effectiveness

This section synthesises findings from twelve studies assessing disaster response strategies, organised into three principal themes (Table A-2). The research underscores the significance of structured frameworks, innovative technologies, and advanced training in enhancing disaster response:

- **Response Evaluation and Framework Development:** Structured frameworks are vital for the systematic assessment and enhancement of disaster responses. Studies such as Fontainha et al.

[25] and Bae et al. [4] highlight the necessity for robust evaluation models and effective coordination mechanisms. For instance, deficiencies identified in the National Disaster Response Framework (NDRF) during the 2015 Nepal earthquake [7] illustrate the need for improved coordination within such frameworks.

- **Technology and Methodology in Disaster Response:** Advanced technologies have a transformative effect on the efficiency of disaster response operations. Works including Gonzalez et al. [28] and Way and Yuan [69] demonstrate the potential of methods such as system dynamics and context-aware coordination, which facilitate streamlined processes, yet reveal persistent shortcomings in real-time decision-making and multi-agency cooperation.
- **Training and Preparedness for Disaster Response:** Adequate training is critical for readiness and preparedness in disaster scenarios. Innovative tools such as "Flood Action VR" Sermet and Demir [60] and global public health training programmes [64] exemplify novel approaches, although broader validation across diverse scenarios remains necessary.

The collective examination of these studies highlights the benefits of integrating structured frameworks, cutting-edge technologies, and novel training methodologies to advance disaster response. While framework development bolsters evaluation and coordination, technology-driven methods enhance operational efficiency, and innovative training strengthens preparedness. Nonetheless, challenges related to implementation and scalability remain.

Key obstacles identified for refining disaster response systems include:

- Insufficient real-world testing of models, limiting their practical application.
- Inadequate collaboration across multiple agencies, which impairs operational effectiveness.
- Underdeveloped comprehensive frameworks that incorporate real-time decision-making and multi-perspective evaluations.

To address these deficiencies and foster more adaptive and effective disaster response systems, future efforts should prioritise:

- Refinement and validation of models to suit diverse and complex disaster contexts.
- Development of systems that promote multi-agency collaboration.
- Expansion and rigorous testing of training tools, such as VR, across varied disaster scenarios.
- Design of adaptive frameworks enabling real-time decision-making to enhance responsiveness.

3.3 Social Media Communication in Disaster Response

This section examines 12 studies focusing on the utilisation of social media in disaster response, organised into three primary themes (Table A-3). The research underscores advancements in harnessing social media platforms while also addressing issues related to stakeholder participation, data verification, and real-time deployment:

- **Machine Learning Models for Content Classification**: Various machine learning approaches have been applied extensively to categorise disaster-related content on social media. For instance, models utilising support vector machines have demonstrated superior accuracy compared to Bi-LSTM architectures [2]. Other studies have investigated single-model image classification tailored to novel disaster contexts Firmansyah et al. [24], while multimodal fusion techniques have achieved classification accuracies as high as 96% [39]. Nonetheless, challenges remain in adapting these models effectively across diverse disaster scenarios and integrating multimodal data streams.
- **Decision Support Systems Based on Real-Time Data:** Real-time social media data has been incorporated into decision support systems to enhance disaster management. Dashboards combining critical event information with resource requirements have been developed [36], and social media messages have been employed to gauge disaster severity and public sentiment in

real time [61]. Although these tools contribute to improved coordination, difficulties persist concerning data standardisation and system interoperability.

- **Social Media Disaster Content Analysis:** The analysis of social media content related to disasters can expedite response efforts. Multi-source data analyses have been shown to enhance decision-making processes [8]. However, ensuring the reliability and validation of unverified social media information remains a considerable obstacle.

Collectively, these studies illustrate the increasing significance of social media in disaster management through sophisticated content classification, enhanced decision-making support, and comprehensive content analysis. Despite these advances, significant challenges persist, particularly in data reliability, integration of varied data modalities, and stakeholder engagement, which impede widespread implementation.

Identified limitations that require attention include:

- Persistent difficulties in verifying the accuracy of real-time social media data.
- The complexity involved in effectively integrating text, image, and video data streams.
- Limited engagement of stakeholders in the design and deployment of social media-based solutions.
- Absence of standardised frameworks, resulting in poor interoperability across platforms.

Future research should prioritise:

- The enhancement of machine learning models by employing ensemble techniques to improve adaptability.
- The development of adaptive frameworks capable of managing multimedia content transmission in disaster contexts.
- The establishment of historical disaster data repositories to support improved forecasting and comparative analyses.
- The expansion of operational capabilities, including increased fleet sizes, to better address resource distribution challenges.

3.4 Evacuation Planning in Disaster Response

This section examines research on evacuation planning, a critical aspect of disaster preparedness focused on ensuring the safe and efficient movement of individuals from hazardous areas. The review is organised into two sub-themes, presenting key findings, discussions, challenges, and gaps in the literature (Table A-4):

- **Evacuation Modelling and Optimisation:** Evacuation modelling frameworks seek to enhance the efficiency of disaster evacuations. For example, a network design model combining location, allocation, and evacuation decisions has been proposed to improve humanitarian logistics following earthquakes [23]. Another study developed a stochastic programming approach that accounts for uncertain travel times and network capacities to formulate robust evacuation plans [68]. Additionally, simulation-based frameworks employing real-world data and agent-based modelling have been utilised to optimise evacuation strategies in specific contexts [13]. Although these approaches represent significant progress in adaptive evacuation planning, challenges remain regarding their scalability to larger populations and the incorporation of human behavioural factors, including panic responses and disabilities, into optimisation processes.
- **Technology-Driven Evacuation Solutions:** The application of advanced technologies contributes to improved evacuation management by enhancing decision-making and resource allocation. Examples include intelligent evacuation systems integrating IoT, fog computing, and cloud technologies to guide evacuees while mitigating risks [58]. Furthermore, dynamic tracking models deployed on mobile cloud platforms utilise IoT-enabled real-time data collection to

support evacuation operations [59]. Despite these technological advancements, obstacles such as high implementation costs, challenges related to data interoperability, and limited validation in real-world settings persist.

Collectively, the studies demonstrate progress in evacuation planning through the development of robust frameworks and technology-enhanced solutions. Models incorporating optimisation and IoT integration illustrate potential improvements in evacuation effectiveness [58; 67]. Nonetheless, the integration of human behavioural dynamics, community engagement, and extensive real-world validation remain insufficient. Current models often prioritise technical optimisation, sometimes at the expense of practical feasibility.

Several challenges restrict the effectiveness of existing evacuation planning approaches:

- Difficulty in adapting models for large populations and diverse disaster scenarios.
- Inadequate integration of behavioural factors such as panic, disabilities, and congestion.
- Limited involvement of affected communities in the development of models.
- Insufficient empirical testing of models across a range of disaster contexts.

To bridge these gaps, future research should prioritise:

- Incorporating behavioural characteristics, including age, disabilities, and panic, into optimisation algorithms.
- Expanding simulation-based frameworks to encompass multi-hazard scenarios and simultaneous evacuations over extensive geographic areas.
- Integrating models of pedestrians, cyclists, and vehicles with resource distribution simulations to optimise access to shelters.
- Developing methods that combine deterministic and stochastic variables to create adaptable evacuation strategies.
- Designing user-centred approaches that enhance community participation and the practicality of evacuation plans.

3.5 Resource Allocation in Disaster Response

This section examines research on resource allocation, a critical element of disaster response involving the distribution of supplies, personnel, and aid. The review summarises developments in resource management models while identifying challenges related to scalability, adaptability, and practical implementation (Table A-5):

- **Integrated Logistics and Operations Management:** Models focusing on integrated logistics have been proposed to optimise resource distribution during disasters. One such model improves flood disaster relief by optimising the use of temporary depots and coordinating logistics, enhancing efficiency in dynamic flood scenarios. However, this model requires further adaptation for application in broader disaster types and diverse geographical areas [44].
- **Innovative Technologies:** Emerging technological solutions offer improvements in efficiency and transparency in resource allocation. Examples include blockchain-based federated models facilitating secure transactions and accelerating access to critical resources [3], humanitarian network models integrating distribution centre selection with demand clustering [44], mobile cloud-based frameworks for resource management [29], and reinforcement learning applied to manage interdependencies in critical infrastructure [9]. While these technologies show promise, challenges remain concerning scalability, system interoperability, and validation within real-world contexts.
- **Mathematical Models:** Optimisation techniques provide structured solutions for disaster logistics. For instance, a two-stage mixed-integer stochastic programming model has been developed to address uncertainties in multi-commodity redistribution during large-scale

disasters [27]. Additionally, simulated annealing algorithms have been applied to hurricane scenarios to optimise storage locations, unmanned aerial vehicle (UAV) selection, and delivery routing [22]. Despite their effectiveness, these models require enhancements to incorporate human behavioural factors, dynamic decision-making processes, and adaptability to multi-hazard events.

Collectively, the literature demonstrates advancement in resource allocation through integrated logistics frameworks, innovative technological applications, and optimisation methodologies. Approaches such as those focusing on coordinated logistics Manopiniwes and Irohara [44] and blockchain-enabled operations [3], as well as mobile cloud systems [29], exemplify potential improvements in efficiency. Nevertheless, practical deployment is limited by scalability constraints, adaptability challenges, and insufficient engagement with relevant stakeholders.

Key challenges identified within resource allocation research include:

- Inability of models to effectively address large-scale and complex disaster scenarios.
- Restricted flexibility to accommodate multi-hazard situations and diverse disaster contexts.
- Limited involvement of agencies and affected communities during model development.
- Scarce empirical testing within actual disaster environments.

To address these shortcomings, future research should prioritise:

- Expanding models to manage larger and more complex disaster scenarios.
- Enhancing blockchain-based networks to improve asset visibility and facilitate inter-agency collaboration.
- Developing multi-period redistribution strategies that incorporate budgetary constraints.
- Applying models to realistic logistical topologies and conducting rigorous performance evaluations.
- Integrating human behavioural factors into optimisation algorithms to increase practical relevance.

3.6 Rescue Team Allocation in Disaster Response

This section examines research on rescue team allocation, a crucial aspect of disaster response involving the strategic deployment of emergency personnel to mitigate disaster impacts. The review categorises the literature into two sub-themes (Table A-6):

- **Mathematical Models and Optimisation:** Mathematical approaches are fundamental in enhancing the efficiency of rescue team allocation. Various models have been proposed, including a bi-objective emergency medical services (EMS) model aiming to minimise both mortality and costs by optimising service completion times [63]. Another model focuses on reducing weighted completion times while considering precedence constraints and diverse vehicle types [50]. Multi-objective optimisation frameworks balance cost and time factors using epsilon-constraint algorithms [71]. Additionally, mixed-integer programming models employing algorithms such as NSGA-II and particle swarm optimisation (PSO) have been developed to minimise delays in relief operations [49]. Despite their robustness, these models face limitations in managing uncertainties like variability in processing times and scaling to larger disaster scenarios.
- **Decision Support Systems and Coordination Strategies:** Decision support systems (DSS) enhance decision-making and coordination capabilities during disaster response. For example, a DSS designed to assist local managers in selecting optimal coordination tactics has been developed [32]. Another approach utilises Unified Modelling Language (UML) class diagrams for strategic action planning (SAP), enabling intelligent systems to support incident commanders [51]. While these systems improve planning processes, their practical utility is often constrained by

insufficient integration with spatial databases and real-time information systems.

Collectively, these studies demonstrate substantial advances in rescue team allocation through optimisation models and decision support mechanisms. The mathematical models improve allocation efficiency [50; 63], and DSS applications facilitate better coordination [32]. Nonetheless, challenges such as scalability constraints, limited stakeholder involvement, and inadequate real-time data integration hinder broader implementation.

Key challenges identified in this area include:

- Limited testing of models in large-scale or multi-depot disaster contexts.
- Insufficient input from emergency responders, resulting in reduced applicability to real-world conditions.
- Difficulties in accounting for variability in travel times, disaster severity, and resource limitations.
- Decision support systems lacking seamless integration with spatial and real-time data platforms.

To overcome these challenges, future research should focus on:

- Incorporating fuzzy parameters to manage uncertainty in data and operational processes.
- Investigating alternative objectives, such as minimising total delays and deprivation costs.
- Including factors like responder fatigue, multi-depot configurations, and deprivation costs in models.
- Integrating spatial databases with real-time information systems to enhance coordination effectiveness.
- Refining solution algorithms to accommodate evolving demands of disaster response operations.

3.7 Damage Assessment in Disaster Response

Accurate damage assessment plays a crucial role during disasters by enabling the identification of impacted areas and facilitating efficient resource distribution. This section reviews relevant studies, divided into two sub-themes (Table A-7):

- **Remote Sensing and Imaging Techniques:** These approaches offer detailed visual representations of disaster effects. Techniques such as drone-based photogrammetry have been utilised for three-dimensional mapping, enhancing resource allocation decisions [20]. The integration of hydrodynamic models with satellite imagery has also been employed to delineate flood extents in regions with limited data availability, achieving high precision [1]. Methods addressing image misalignment, such as phase correlation, have improved data quality [48], while rapid and accurate building damage detection frameworks have been developed to expedite assessments [73]. Despite their promise, these techniques face challenges related to cost-efficiency and accessibility, particularly in environments with constrained resources.
- **Structural Damage Estimation Models:** These models concentrate on assessing the physical effects of disasters on infrastructure. Approaches combining regression and machine learning have been applied to predict seismic displacement, supporting safety evaluations [71]. Although these models exhibit robustness, they require further enhancement to incorporate additional variables and adapt to a wider range of disaster scenarios.

Overall, these studies demonstrate notable technological advancements in damage assessment. Remote sensing applications, such as drone mapping Eckert et al. [20], alongside structural damage estimation models [37], contribute to improved visualisation of disaster impacts and infrastructure evaluation. However, limitations including high operational costs, restricted scalability, and insufficient integration of artificial intelligence constrain their widespread implementation.

The key challenges and gaps identified in damage assessment include:

- The high financial cost and extensive data needs restrict application in resource-limited contexts.
- Limited validation across large-scale or geographically diverse disaster events hinders

generalisability.

- Opportunities exist to advance automation for more rapid and efficient assessment processes.

To address these issues, future research should prioritise:

- Automating damage evaluation through artificial intelligence and computer vision technologies.
- Enhancing imaging techniques via three-dimensional Fourier transforms and improved object detection methods.
- Expanding seismic damage models by incorporating deep learning architectures and additional relevant variables.

3.8 Emergency Shelter Location in Disaster Response

Strategic placement of emergency shelters constitutes a critical element of disaster response, facilitating efficient resource allocation and prompt assistance delivery. This section reviews studies concerning emergency shelter location, organised into two principal themes (Table A-8). The studies highlight progress in shelter placement while addressing challenges related to response time, scalability, and integration of health services:

- **Multi-Objective Shelter Location Optimisation Models:** These models aim to determine shelter locations that maximise operational efficiency. For instance, stochastic programming approaches have been applied to account for multi-period planning, diverse products, and fleet variability, thereby enabling adaptable shelter strategies [47]. Multi-objective frameworks using evolutionary algorithms have prioritised factors such as response time, cost-effectiveness, and demand coverage [57]. Despite demonstrating strong optimisation performance, these models exhibit limitations in adapting to dynamic disaster conditions and incorporating stakeholder engagement.
- **Decision Support and Analysis Tools for Shelter Location Planning:** Decision support systems integrate expert judgement to refine shelter location strategies. Tools have been developed that evaluate multiple criteria, such as a framework utilising fourteen factors to identify temporary shelter sites while addressing uncertainty through expert analysis [11]. While these tools offer valuable qualitative insights, they require further validation through advanced analytical methods and inclusion of broader evaluation metrics.

Collectively, the reviewed studies reveal considerable advancements in emergency shelter planning through robust optimisation techniques and expert-driven decision support. Models prioritising demand coverage and cost efficiency complement decision tools that incorporate qualitative assessments. However, shortcomings persist regarding rapid shelter deployment, scalability to large or urban disaster contexts, and the integration of health personnel and casualty prioritisation within Emergency Medical Centres.

The principal limitations identified include:

- Absence of mechanisms enabling rapid shelter establishment during urgent situations.
- Restricted adaptability to extensive or urban-specific disaster scenarios.
- Limited consideration of health workforce planning and casualty urgency in shelter models.

To address these gaps, future research should focus on:

- Investigating three-echelon relief chain models tailored for urban disaster environments.
- Developing heuristic algorithms capable of solving larger-scale shelter location problems.
- Incorporating health personnel allocation and casualty urgency metrics into shelter planning frameworks.
- Expanding evaluation criteria and validating models using sophisticated techniques such as structural equation modelling.

3.9 Summary of Findings

Comprehensive summaries of the studies discussed within each thematic category are presented in Tables A-1 through A-8 in Appendix A, providing detailed information on the models, methodologies, and focal points addressed in the reviewed literature. Figure 2 offers a visual summary of this section via a two-tier spider graph. The primary themes in disaster response are organised based on their relative significance. The size of each bubble corresponds to the number of publications associated with that theme, while the secondary tier of bubbles represents common sub-themes found within each focus area. This method of summarising results facilitates a clear visualisation of the overall research landscape, highlighting which themes are prevalent and which are less explored. The areas receiving the most scholarly attention are Relief Distribution, Evaluating Response Effectiveness, and Social Media Communication.

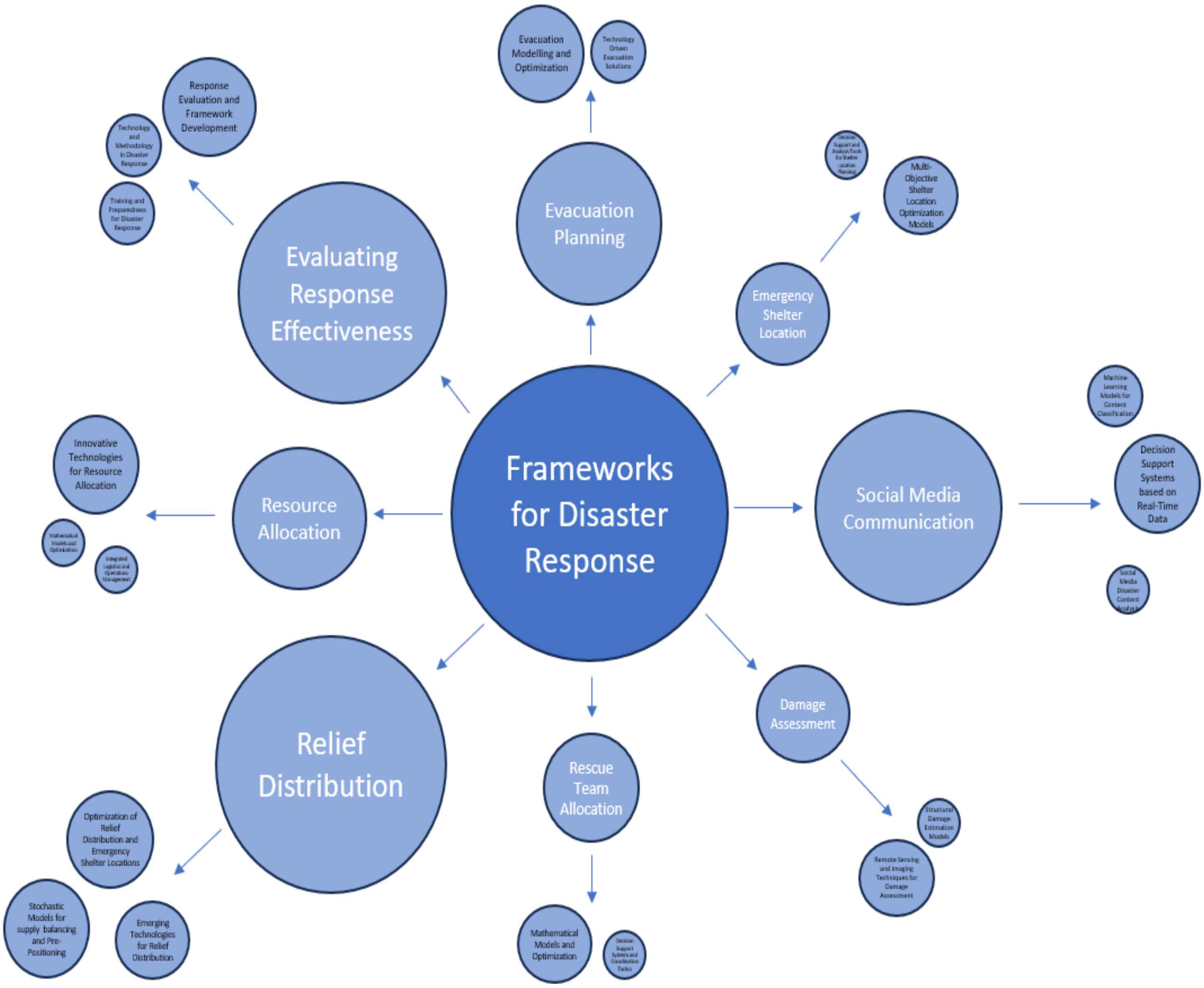

Fig.2: Summary of Disaster Response Research and Frameworks

Conversely, topics such as Damage Assessment, Emergency Shelter Location, and Rescue Team Allocation are comparatively underrepresented in the current body of literature. Additionally, there is minimal research addressing Emergency Response Standards and their application in practical settings. It is also noteworthy that numerous studies fail to specify the disaster type under investigation. Future research would benefit from focusing on determining the most effective response models tailored to particular disaster categories, thereby optimising response strategies for diverse scenarios. These observations reveal a considerable gap within the literature, underscoring the necessity for more exhaustive investigations and practical applications in these less explored domains. Consequently, future research efforts should prioritise the development and standardisation of emergency response protocols, which will not only improve response efficacy but also promote a more coordinated and uniform approach to emergency management.

Figure 3 illustrates the distribution of emphasis across various disaster response strategies, revealing a pronounced focus on "Innovative Technology Solutions" and "Optimization Models." These dominant categories highlight the field's reliance on advanced technologies and data-driven approaches to improve efficiency, accuracy, and scalability in managing disasters. In contrast, areas such as "Training and Preparedness for Disaster Response" and "Response Evaluation and Framework Development" receive relatively limited attention, indicating deficiencies in proactive planning and systematic learning from past events. The moderate emphasis on "Decision Support Systems" and "Stochastic Models" reflects their recognised value in handling uncertainties and supporting decision-making processes, although they remain secondary to technology-centric methods. This analysis underscores the necessity for a more balanced strategy that combines cutting-edge technological innovations with strengthened training programmes, preparedness initiatives, and evaluation frameworks. Enhancing these underexplored domains would contribute to a more holistic and resilient disaster response system, integrating technological advancement with proactive capacity building and continuous improvement.

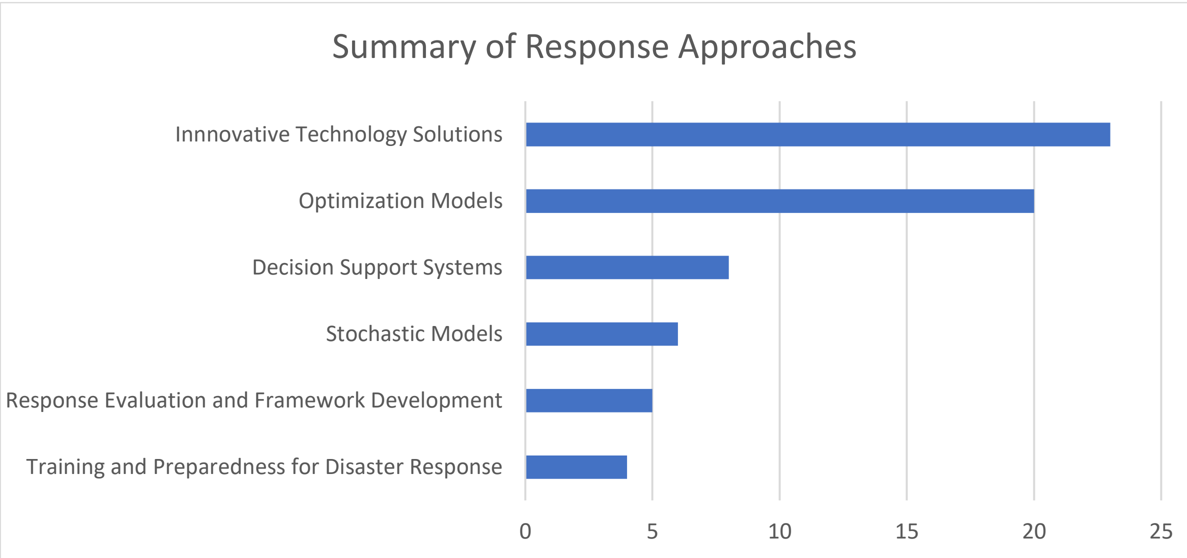

Fig.3: Summary of Disaster Response Approaches

Figure 4 emphasises the primary disaster response strategies across different thematic areas. The predominance of "Optimization & Stochastic Models," particularly within "Relief Distribution" and "Response Effectiveness," indicates a strong focus on efficient resource allocation and managing uncertainties inherent in disaster scenarios. Concurrently, "Innovative Technology Solutions" are extensively utilised across most themes, with notable application in "Relief Distribution" and "Evacuation Planning," demonstrating the versatility of technological interventions in addressing the varied challenges posed by disasters. Conversely, "Framework Development & Preparedness" is markedly underrepresented, especially concerning "Response Effectiveness," revealing a critical shortfall in proactive planning and the establishment of structured preparedness protocols. This gap is particularly evident in important areas such as "Social Media Communication" and "Resource & Team Allocation." Meanwhile, "Decision Support Systems" attract moderate focus, mainly within "Response Effectiveness," indicating potential for their expanded integration into other key domains like "Evacuation Planning."

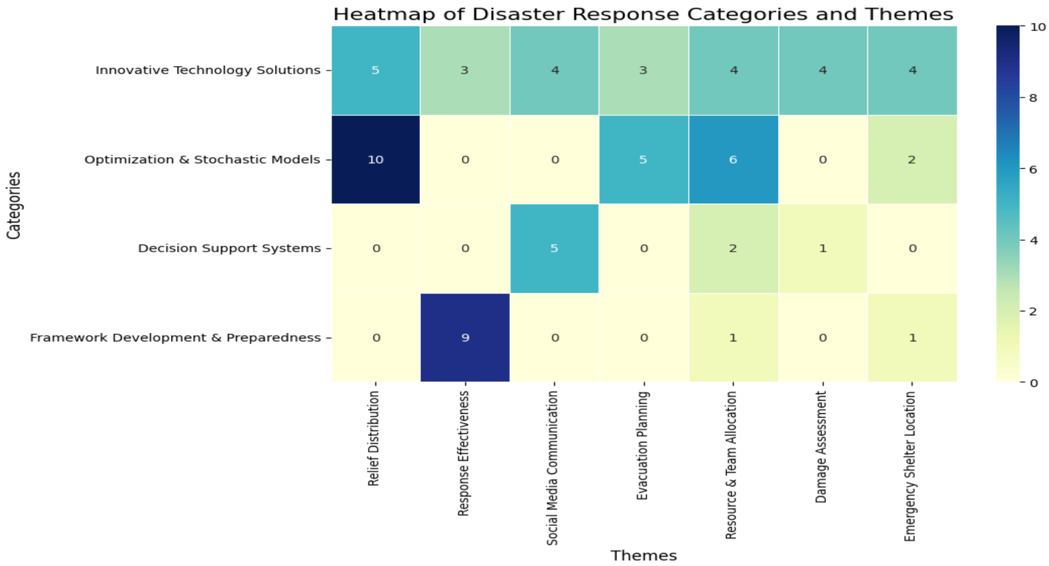

Fig.4: Heatmap of Disaster Response Categories and Themes

4. Bibliometric Analysis

The following section presents a bibliometric analysis focused on research related to responses to natural disasters. This analysis offers a thorough overview of pertinent publications, highlighting the interdisciplinary nature of effective disaster response. By examining the volume and geographical distribution of articles, it provides valuable insights into how various countries approach disaster management. Unlike traditional assessments, this study employs VOSviewer to uncover emerging trends, correlations, and patterns within the literature. VOSviewer has proven to be a vital tool for visualising and interpreting bibliometric data throughout this investigation. The software facilitates the creation of detailed maps and diagrams that illustrate the complex and dynamic relationships among countries, authors, and keywords. In these visualisations, the size of each circle corresponds to the number of connections associated with a particular author or term, enhancing clarity and comprehension. Additionally, the thickness of connecting lines and the proximity of circles indicate the strength of relationships. By utilising VOSviewer, this study delivers a comprehensive and insightful exploration of the intricate network of knowledge pertaining to natural disaster response.

4.1 Co-occurrence Map Based on Keywords

An examination of 86 scholarly works revealed 23 frequently recurring keywords, each appearing no fewer than five times, as illustrated in Figure 5. The resulting co-occurrence map delineates the relationships among these keywords, thereby highlighting the principal focal points within the field of disaster management. Terms such as "Emergency Services," "Disaster Prevention," and "Disaster Management" dominate the network, reflecting a longstanding emphasis on preparedness and response activities. Utilising VOSviewer ensured that terms were standardised and duplicates removed, which enhanced the precision and clarity of the visualised network. The analysis of keyword trends over time offers further insight into the progression of disaster response research. Earlier studies predominantly feature general terms like "Emergency Services," "Risk Management," and "Scheduling," indicative of an initial focus on traditional response procedures. More recent research, particularly since 2021, has seen a surge in keywords related to cutting-edge technologies such as "Deep Learning," "Machine Learning," "IoT," and "SVMs," signifying a paradigm shift towards employing advanced technological solutions in disaster response efforts. Meanwhile, emergent concepts such as “Artificial Intelligence” and "Blockchain"

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remain sparsely represented, highlighting their relatively early stage of integration in this field.

Further dissection of the keyword data is provided in Figures 6 and 7, which separately analyse author-assigned and index keywords.

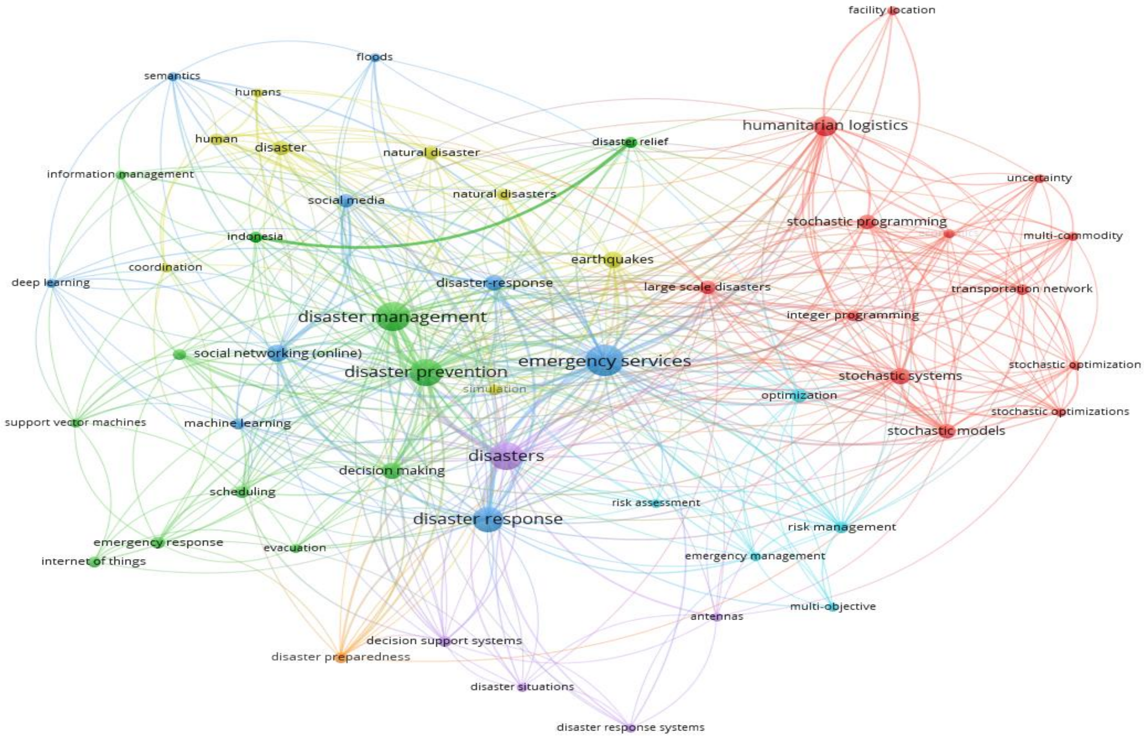

Fig.5: Co-Occurrence Map of all Keywords

Figure 6 features a co-occurrence map of 23 author keywords appearing at least twice, shedding light on terms considered central by researchers themselves. Keywords such as "Disaster Response," "Social Networking," and "Decision Making" suggest a research emphasis on utilising social media platforms for situational awareness and on enhancing decision-making frameworks to improve disaster management outcomes.

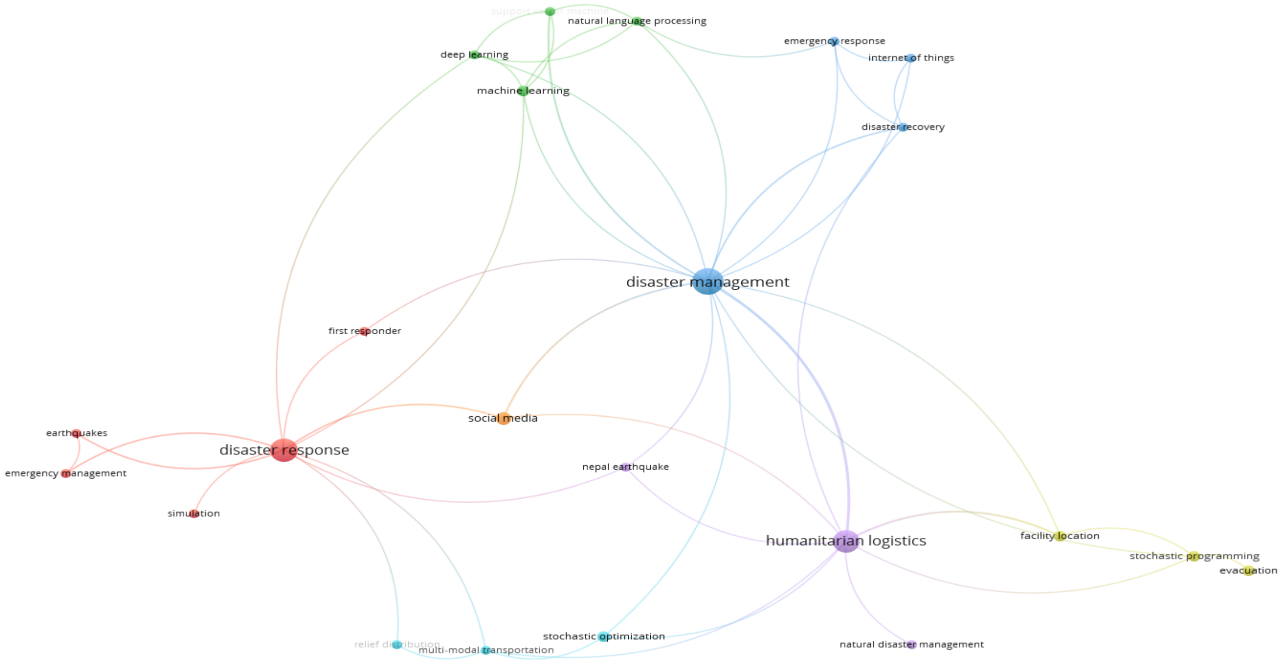

Fig.6: Co-Occurrence Map of Author Keywords

Figure 7, in contrast, maps 28 index keywords, each occurring four or more times, which are assigned by database systems to facilitate article categorisation and retrieval. Prominent among these are "Disaster Management," "Risk Assessment," and "Stochastic Systems," pointing to the classification systems' prioritisation of both applied and theoretical disaster management methodologies. This in-depth keyword analysis not only identifies prevailing themes within disaster response literature but also reveals emergent areas and interdisciplinary connections. Tracking the temporal distribution and frequency of keywords elucidates how strategies and technologies in disaster response have evolved. For instance, the growing presence of "Social Networking" highlights an increasing dependency on social media data for real-time disaster management, while terms such as "Stochastic Systems" and "Decision Making" underscore the rising adoption of sophisticated modelling techniques within contemporary response frameworks.

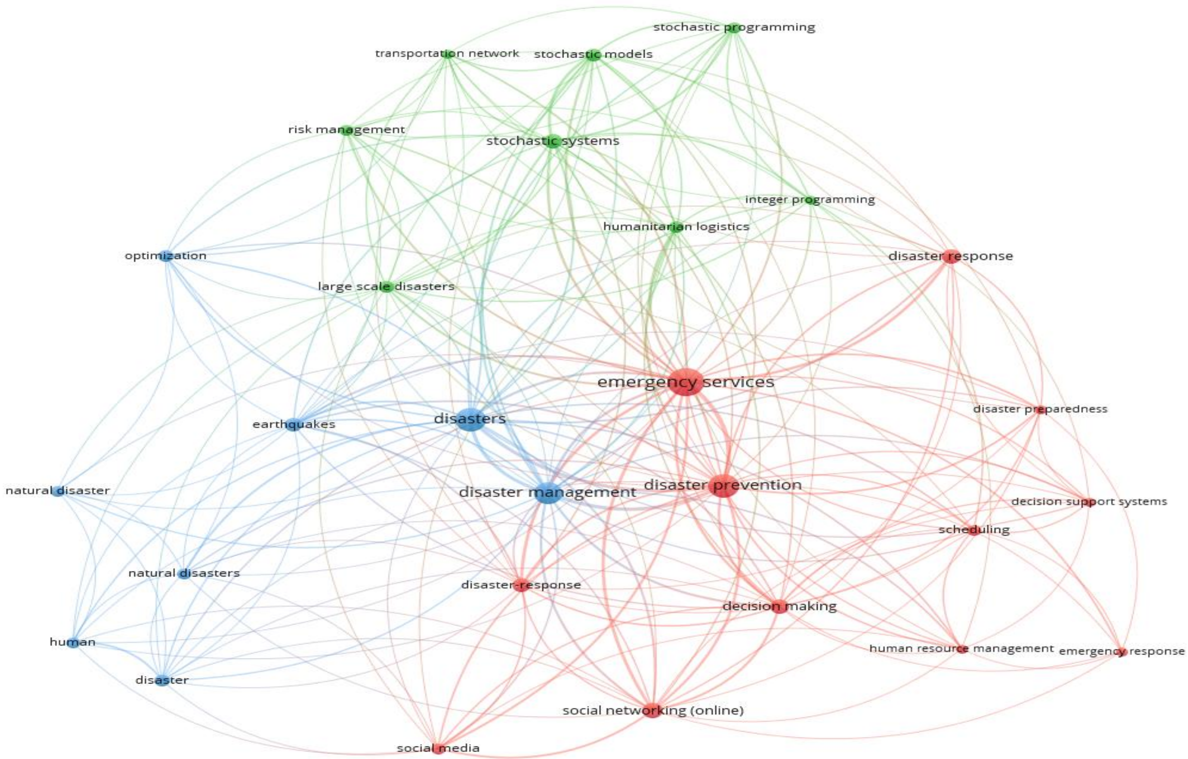

Fig.7: Co-Occurrence Map of Index Keywords

4.2 Co-Occurrence Map Based on Country of Co-Authorship

Figure 8 illustrates the geographic distribution of co-authorship among ten countries that met the minimum publication threshold. The majority of these nations are situated in eastern and south-eastern Asia, areas notably prone to natural hazards such as typhoons, earthquakes, and floods. The geographic features of these regions—including tectonic plate boundaries, monsoonal weather systems, and tropical climates—render disaster management and response essential priorities. Research efforts here primarily concentrate on enhancing resilience, establishing early warning systems, and encouraging regional cooperation to reduce the adverse effects of natural disasters. Nonetheless, the geographic scope of the analysed research remains limited, with only 21 countries producing more than two publications. Significant gaps are evident in regions such as South America and the Middle East, which face increasing disaster risks but are underrepresented in the scholarly discourse. Strengthening collaborative initiatives between disaster-prone countries like Indonesia and emerging risk areas such as the Middle East could facilitate the exchange of knowledge and bolster disaster preparedness on a global scale.

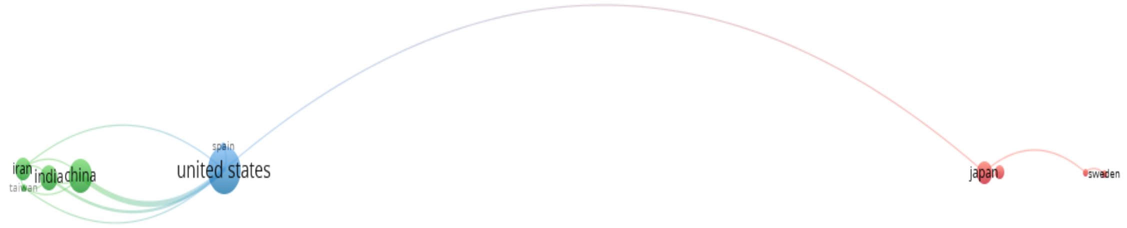

Fig.8: Country of Co-Authorship

4.3 Co-Occurrence Map Based on Authorship

Expanding upon the geographic and thematic findings, this section investigates the collaborative patterns among researchers active in disaster response studies. Figure 9 presents the co-authorship network of scholars with a minimum of five citations. Despite 48 authors meeting this benchmark, the network visualization reveals a highly fragmented structure, with minimal to no evidence of collaborative ties between authors within the analysed publications. This fragmentation highlights a critical shortfall in the current body of research, which is characterised by isolated efforts and a lack of interdisciplinary or joint investigations. Moreover, the analysis indicates limited research output and influence concentrated among individual authors. Only Gao X. and Lee G.M. have produced multiple publications, while the remainder show no significant co-authorship links, reflecting predominantly independent contributions. This fragmentation underscores the necessity for enhanced collaboration within the disaster response research community. Building stronger co-authorship networks could facilitate richer insights, encourage interdisciplinary approaches, and improve research methodologies. Future work should focus on uncovering the barriers to collaboration and devising measures to promote cooperative research, as fostering a more integrated network of authors is crucial for advancing knowledge in this field.

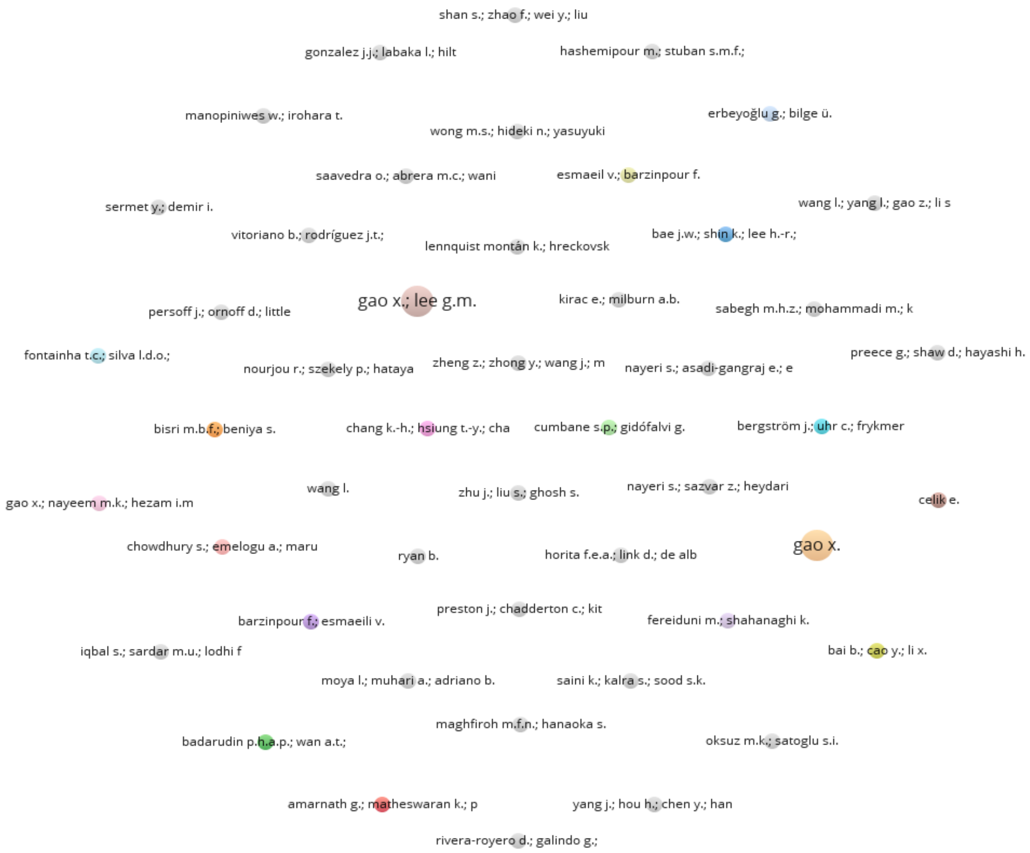

Fig.9: Co-Occurrence Map Based on Authorship

4.4 Data Analysis on Type of Natural Disaster and Response

Figure 10 illustrates the distribution of publications according to the natural disaster types they examine. Notably, a substantial majority—64 out of 86 articles—did not specify any particular disaster category, implying that these models are designed for broad applicability across multiple disaster scenarios. Among the studies that did focus on specific disasters, earthquakes and floods were the most frequently investigated, each featuring in 10 publications. The predominance of non-specific studies reveals a critical gap in disaster response research. Developing models tailored to distinct disaster types can significantly improve their efficacy by addressing the unique challenges associated with each event, such as enhancing structural resilience in earthquake-prone areas or refining early warning systems for flood risks. A specialised focus also facilitates better anticipation of secondary hazards and long-term consequences, supporting more efficient allocation of resources and targeted interventions. Consequently, future research would benefit from explicitly defining the disaster type under consideration, thereby offering more precise insights into the model's objectives and avenues for further refinement.

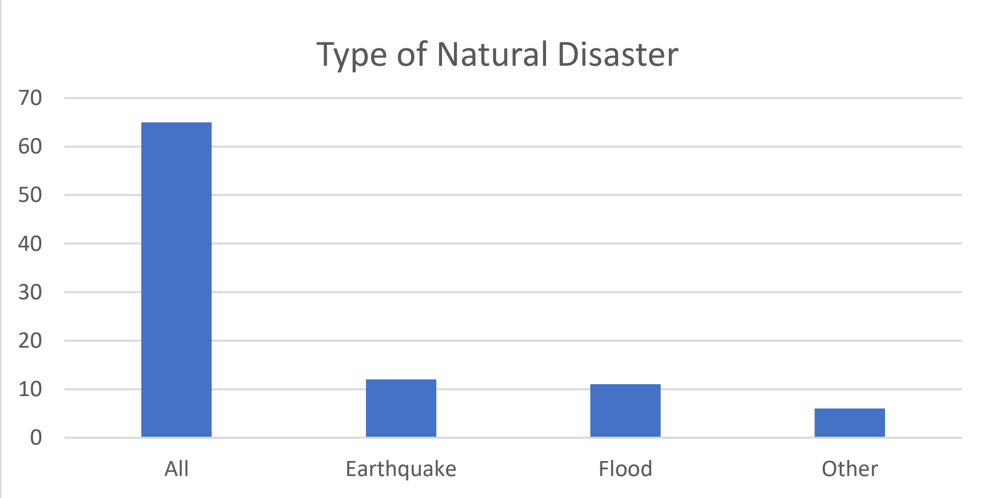

Fig.10: Type of Natural Disaster

As previously noted, the papers were also categorised according to the type of response strategy employed. By tailoring response models to the particular characteristics of each natural disaster, authorities can optimise resource distribution, enhance preparedness measures, and ultimately reduce the adverse effects on affected populations and infrastructure. Accordingly, an analysis was performed to examine the types of response approaches addressed within each publication. Figure 11 illustrates the distribution of emphasis across various disaster response activities. The largest proportions, represented by "Relief Distribution" and "Evaluate Response Effectiveness" (each accounting for 17.3%), highlight the focus on immediate assistance delivery and subsequent evaluation aimed at refining future response strategies. The segment for "Social Media Communication" (11.5%) underscores the increasing significance of real-time information dissemination and public interaction during emergencies.

Moderate attention to "Evacuation Planning" and "Resource Allocation" (each comprising 9.6%) reflects their acknowledged importance, although these domains could benefit from enhanced focus. Lower representation is observed in activities such as "Rescue Team Allocation" (7.7%), "Damage Assessment" (5.8%), and both "Emergency Shelter Location" and "Disaster Education" (3.8% each), signalling deficiencies in proactive and preparatory measures crucial for bolstering resilience and readiness. The 13.5% classified as "Other" indicates a range of diverse response requirements that remain insufficiently addressed. This distribution points to the necessity for a more balanced approach, where immediate relief efforts are complemented by strengthened emphasis on education, planning, and preparedness, thereby fostering a more comprehensive and resilient disaster management system.

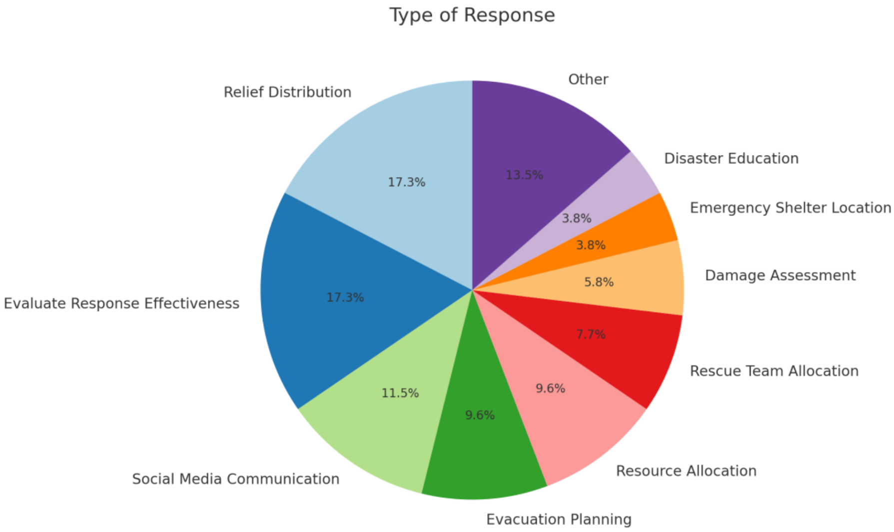

Fig.11: Type of Response Pie Chart

4.5 Analysis on Technology Adoption in Response Models

Figure 12 reveals a clear progression towards technology-driven solutions between 2014 and 2023. The blue line, denoting technology-based approaches, exhibits a steady upward trajectory with notable peaks around 2021 and 2023. This pattern reflects the escalating dependence on digital innovations, largely driven by advancements in artificial intelligence, the Internet of Things, and data analytics, which collectively enhance the efficiency, accuracy, and scalability of disaster management. The surge observed in 2021 likely corresponds to the accelerated adoption of digital tools during the COVID-19 pandemic, which hastened transformation in crisis response practices. Conversely, the orange line representing traditional methods remains relatively stable but shows a slight downward trend over the period. This indicates that conventional approaches are increasingly considered supplementary as modern technologies offer more comprehensive solutions to complex disaster challenges. Nonetheless, the gradual decline may also expose gaps in areas where human-centric strategies continue to play a vital role.

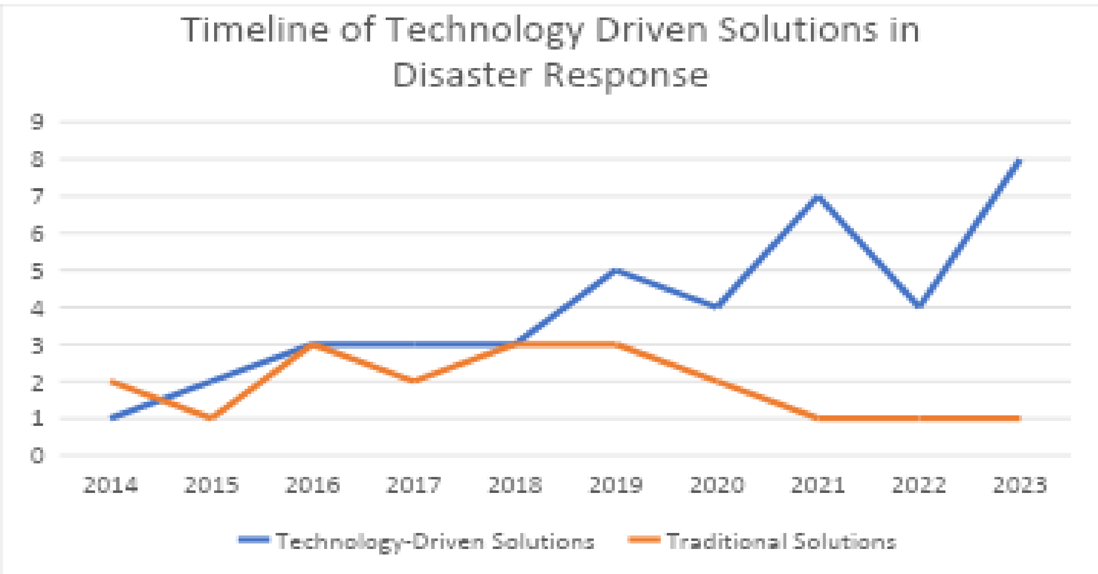

Fig.12: Technology Adoption

5. Conclusion and Future Research

The examination of keyword trends within the existing literature indicates a clear progression towards the adoption of technological innovations, with concepts such as "machine learning" and "SVM" increasingly featured in recent studies. Despite this, cutting-edge technologies like AI and blockchain remain sparsely represented, suggesting that their full potential has yet to be integrated into disaster response research. This paper emphasises the significant contribution these technologies can make to improving decision-making processes in disaster management. For example, AI-powered image recognition can expedite and enhance the accuracy of damage assessments, facilitating more effective resource distribution. Similarly, IoT devices enable the optimisation of logistics by providing real-time updates on resource status and distribution pathways, promoting more efficient stocking and allocation. Blockchain technology offers a novel framework for secure and transparent tracking and management of resources, ensuring accountability and efficiency in aid delivery. Furthermore, advanced sensors and interactive platforms supply decision-makers and first responders with precise and timely information critical for disaster event management. While these technologies hold substantial promise for enhancing disaster response decision-making, the study also identifies several impediments to their widespread implementation, including inadequate infrastructure, limited technical skills, and the lack of comprehensive regulatory frameworks. Overcoming these obstacles is essential to fully harness the capabilities of advanced technologies to support equitable, efficient, and informed decision-making within disaster management systems.

Beyond highlighting these emerging technological trends, this research proposes several future directions to bolster decision-making effectiveness in disaster response:

- Explore the influence of climate change on the frequency and intensity of natural disasters, developing adaptive strategies that respond to shifting climate patterns and associated risks.
- Investigate the opportunities and challenges of cross-border collaboration in disaster response, focusing on the sharing of resources, information, and expertise among neighbouring countries or regions during large-scale emergencies.
- Critically review current emergency response protocols and recommend enhancements that incorporate technological advancements, best practices, and lessons learned from recent disaster events to improve overall efficiency and efficacy.
- Assess the integration of autonomous technologies, including drones and robotics, during response operations to enhance rapid damage evaluation, resource distribution, and communication capabilities.
- Further develop AI and machine learning applications for decision support, such as predictive modelling for resource allocation, optimisation of evacuation procedures, and the analysis of large datasets to identify emerging disaster trends and patterns.
- Examine the role of partnerships across sectors—including government, private industry, academia, and civil society—in strengthening coordination, resource sharing, and information exchange throughout all disaster management phases.
- Identify effective communication methods to deliver timely and accurate information to the public, encourage community participation, combat misinformation, and foster trust.
- Investigate innovative funding approaches for disaster response, leveraging technologies like blockchain and crowdfunding to secure timely and sustainable financial support.
- Explore the contribution of biodiversity and ecosystem services in enhancing community resilience, focusing on nature-based solutions for risk mitigation and recovery efforts.

Addressing these areas of inquiry will enable disaster response research to move towards more sophisticated, technology-driven frameworks that enhance decision-making and community resilience globally. Achieving these advancements will require robust collaboration among researchers, practitioners, and stakeholders to transform innovative concepts into practical, impactful disaster management solutions.

6. Author Contributions

The conceptualization of the research V.A., Z.B, O.A, H.A.; methodology, V.A., Z.B, O.A, H.A; formal analysis, O.A; investigation, V.A., Z.B, O.A; resources, V,.A, Z.B..O.A; data curation, N.B, V.A., Z.B, CA..; writing—original draft preparation, O.A.; writing—review and editing, V.A., Z.B, O.A, H.A.; visualization, V.A., Z.B, O.A. H.A.; supervision, V.A. Z.B; project administration, V.A., Z.B, O.A, H.A.; funding acquisition, VA and Z.B. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

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Appendix A

Table A-1
Relief distribution in disaster response

Sub-Themes	Authors	Source	Focus
Optimization of Relief Distribution and Emergency Shelter Locations	[42]	Progress in Disaster Science	Multi-modal relief distribution model with a three-level chain (supply nodes, logistics areas, affected areas) and multi-modal transport considerations.
	[15]	International Journal of Production Economics	Continuous Approximation (CA) model optimizing drone use for emergency commodity distribution and distribution center placement.
	[74]	Journal of Combinatorial Optimization	Emergency relief distribution focusing on routes, transportation times, and disaster updates with a new route reliability definition.
	[21]	International Journal of Industrial Engineering Computations	Multi-objective model for urban disaster management preparation using neighboring wards' demand influence and a genetic algorithm for efficient solutions.
	[12]	European Journal of Operational Research	Network flow model for post-disaster commodity distribution, optimizing inventory routing decisions for actionable post-earthquake insights.
Stochastic Models for Supply Balancing and Pre-positioning	[17]	Journal of Global Optimization	Three-stage stochastic model optimizing 5G UAV disaster services across preparedness, response, and recovery stages.
	[34]	International Journal of Disaster Risk Reduction	Statistical model evaluating relief supply distribution in natural disasters, considering stochastic factors like path and vehicle destruction.
	[26]	Annals of Operations Research	Bi-level model for multi-commodity rebalancing under uncertainty, aiding disaster severity sensitivity analysis and decision-making.
	[55]	Socio-Economic Planning Sciences	Dynamic relief distribution model prioritizing demand points by urgency, considering relief product type and waiting time.
Leveraging Emerging Technologies for Disaster Response and Relief Distribution	[30]	Springer Proceedings in Business and Economics	IT-enabled relief network model for disaster management, focusing on efficient coordination and streamlined supply flow with ICT integration.
	[35]	Journal of Innovation and Knowledge	Blockchain, IoT, and IoE model for disaster management, improving task migration, error reduction, and energy efficiency.
	[66]	Human and Ecological Risk Assessment	Intelligent decision-making models (SEDD and HADS) addressing uncertainty and multicriteria decision-making with a focus on collaboration.
	[72]	Library Hi Tech	IoT-based emergency material distribution model focusing on direct allocation to disaster zones, minimizing delivery time, casualties, and property loss.

Table A-2
Evaluation of disaster response effectiveness

Sub-Themes	Authors	Source	Focus
Response Evaluation and Framework Development	[25]	International Journal of Logistics Research and Applications	Systematic review and critical analysis of disaster response models, leading to a comprehensive reference process model.
	[4]	IEEE Transactions on Systems, Man, and Cybernetics: Systems	Agent-based model evaluating disaster response efficiency in MCIs, integrating geospatial and medical data.
	[7]	Procedia Engineering	Partial implementation of the NDRF post-2015 Nepal earthquake, highlighting gaps in coordination.
	[45]	Natural Hazards and Earth System Sciences	Evaluation of international disaster response frameworks in the Danube and Tisza basins, proposing integrated approaches for transboundary disasters.
	[53]	Journal of Emergency Management	Preliminary method assessing disaster response from responder and victim perspectives, addressing gaps in evaluation literature.

Technology and Methodology in Disaster Response	[28]	Proceedings of the Annual Hawaii International Conference on System Sciences	System dynamics model revealing feedback loops in organizational procedures during large-scale disasters.
	[69]	Lecture Notes in Business Information Processing	Framework for context-aware multi-party coordination in collaborative disaster response.
	[38]	Periodica Polytechnica Civil Engineering	Improved disaster response management for earthquake-damaged railway systems.
Training and Preparedness for Disaster Response	[19]	Journal of Information Science	Development of Flood Disaster Support Ontology (FDSO) to address deficiencies in urban flood response.
	[64]	JBI Evidence Synthesis	Scoping review exploring disaster preparedness and response training for global public health personnel.
	[60]	ACM SIGGRAPH 2019 Posters, SIGGRAPH 2019	Flood Action VR, a virtual reality framework for disaster preparedness and training.
	[16]	Proceedings - 2023 IEEE 8th International Conference on Information and Communication Technologies for Disaster Management, ICT-DM 2023	Assessing disaster management system behavior using extended Stochastic Reward Nets (SRNs) and UPPAAL Model Checking.

Table A-3
Social media communication in disaster response

Sub-Themes	Authors	Source Title	Focus
Machine Learning Models for Content Classification	[39]	Neural Computing and Applications	Application of a transformer-based bidirectional attention model for multimodal tweet classification in disaster response systems.
	[24]	ACM International Conference Proceeding Series	Comparison of single and ensemble models for social media image classification in disaster response.
	[2]	2023 9th International Conference on Advanced Computing and Communication Systems, ICACCS 2023	Categorization of disaster-related tweets using learning-based models to enhance emergency crisis management.
Decision Support Systems based on Real-Time Data	[61]	Safety Science	Introduction of a real-time disaster damage assessment model based on mobile social media data, specifically Weibo (Chinese Twitter).
	[33]	Proceedings of the Annual Hawaii International Conference on System Sciences	Development of ODMN, an integrated model connecting decision-making needs to emerging data sources in disaster management.
	[70]	Proceedings - 16th IEEE International Symposium on Parallel and Distributed Processing with Applications	Incorporation of social media into an emergency supply and demand framework for disaster response.
	[43]	International Journal of Advanced Computer Science and Applications	Proposal of a multimedia content transmission model for disaster management using Delay Tolerant Mobile Adhoc Networks (MANETs).
	[36]	2019 IEEE Conference on Visual Analytics Science and Technology, VAST 2019 - Proceedings	Development of RescueMark, a visual analytics tool for guiding emergency response in disaster situations using social media data.
Social Media Disaster Content Analysis	[8]	International Journal of Advanced Media and Communication	Development of an intelligent, real-time alert model for disaster management utilizing information retrieval from multiple sources.

Table A-4
Evacuation planning in disaster response

Sub-Themes	Authors	Source	Focus
Evacuation Modelling and Optimization	[31]	IFIP Advances in Information and Communication Technology	Route choice and relaxation-based algorithm for adaptable evacuation models.
	[23]	Journal of Industrial Engineering	Network design model for location, allocation, and evacuation

		International	decisions in earthquake response using emergency tents
	[72]	Computers and Industrial Engineering	Two-stage stochastic programming for evacuation planning, using heuristic solutions.
	[13]	European Journal of Operational Research	Simulation model using real data and agent-based methods to improve post-earthquake evacuation in Taiwan.
	[68]	Transportation Research Part C: Emerging Technologies	Stochastic programming for evacuation plans with scenario-based travel times and capacities.
Technology-Driven Evacuation Solutions	[58]	Future Generation Computer Systems	IoT, fog, and cloud computing system for efficient building evacuations.
	[5]	Computer Communications	Mobile cloud IoT platform using DTMM for efficient post-disaster evacuations.

Table A-5
Resource Allocation in Disaster Response

Sub-Themes	Authors	Source	Focus
Integrated Logistics and Operations Management	[44]	Natural Hazards	Location-routing model for flood disaster relief, addressing temporary depot issues with multi-period and multimodal logistics.
Innovative Technologies for Resource Allocation	[29]	Proceedings - 5th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering, MobileCloud 2017	Augmented resource allocation in mobile cloud environments for streamlined disaster response coordination.
	[9]	GHTC 2018 - IEEE Global Humanitarian Technology Conference, Proceedings	i2Sim tool using reinforcement learning to address critical infrastructure interdependencies during disasters.
	[3]	2020 8th International Conference on Information and Communication Technology, ICoICT 2020	Blockchain-based model ensuring secure financial transactions and faster material allocation via smart contracts.
Mathematical Models and Optimization	[22]	Proceedings of 2019 IEEE 8th Joint International Information Technology and Artificial Intelligence Conference, ITAIC 2019	Optimization model for storage locations, UAV selection, and delivery routes during hurricanes, supported by simulated annealing.
	[27]	*International Conference on Optimization and Control*	Two-stage stochastic programming model for efficient multi-commodity redistribution in large-scale disasters.

Table A-6
Rescue team allocation in disaster response

Sub-Themes	Authors	Source	Focus
Mathematical Models and Optimization	[49]	RAIRO - Operations Research	Bi-objective decision support model for disaster management.
	[50]	Operational Research	Fuzzy robust planning model in disaster response under precedence constraints.
	[71]	Lecture Notes in Computer Science	Rescue resource assignment model based on Demand-Ability-Equipment matching.
	[63]	International Journal of Supply and Operations Management	Bi-objective model for ambulance routing considering priority of patients.
Decision Support Systems and Coordination Tactics	[32]	Australian Journal of Emergency Management	Community-based disaster coordination framework for preparedness and response.
	[51]	Journal of Disaster Research	UML-based data model for Strategic Action Planning in disaster response.

Table A-7
Damage assessment in disaster response

Sub-Themes	Authors	Source Title	Focus
Remote Sensing and Imaging Techniques for Damage Assessment	[20]	Sustainability (Switzerland)	Drone-based 3D models for efficient and low-cost resource allocation during recovery.
	[48]	Remote Sensing of Environment	Change detection using phase correlation for non-co-registered images in large-scale disasters like earthquakes.
	[73]	Remote Sensing of Environment	ChangeOS, a deep-learning framework for building damage assessment, outperforming existing methods in speed and accuracy.
	[1]	Proceedings of the National Academy of Sciences India Section A - Physical Sciences	Hydrodynamic models with satellite imagery to map flood extents in data-scarce areas, showing high prediction accuracy.
Structural Damage Estimation Models	[37]	Advances in Intelligent Systems and Computing	Displacement estimation models using linear regression, SVM, and Gaussian process regression (GPR)

Table A-8
Emergency shelter location in disaster response

Sub-Themes	Authors	Source	Focus
Multi-Objective Shelter Location Optimization Models	[47]	DYNA (Colombia)	Bi-objective stochastic programming model for multi-period, multi-product, and heterogeneous fleet contexts, compared with mono-objective models.
	[57]	International Journal of Services and Operations Management	Multi-objective NSGA-II model for therapeutic centers, optimizing response time, costs, and coverage.
Decision Support and Analysis Tools for Shelter Location Planning	[11]	International Journal of Disaster Risk Reduction	Decision-making tool considering 14 criteria for shelter location, analyzing cause-and-effect relationships and linguistic ambiguities.