Humanitarian Logistics in Emergency Response: A Systematic Literature Review

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Abstract: Humanitarian logistics (HL) is crucial for efficient disaster management, facilitating the swift allocation of vital resources to alleviate the effects of crises. This systematic review examines 40 papers (2015-2023) on HL, emphasising significant trends, innovations, and problems in crisis response. It analyses decision-making frameworks, inventory prepositioning, equitable resource allocation, transportation reliability, and the application of modern technology such as artificial intelligence and optimisation algorithms. The assessment emphasises the significance of collaborative methods, including public-private partnerships, and the impact of training programs on improving operational preparedness. Moreover, it assesses case studies to extract essential lessons from both successful and unsuccessful HL operations, providing insights into optimal practices and opportunities for enhancement. The results underscore the necessity for flexible, technology-oriented, and equitable strategies to tackle the growing intricacies of disaster logistics, offering practical recommendations for practitioners, policymakers, and researchers.

Keywords: Humanitarian Logistics, Literature, Response.

Introduction

Humanitarian logistics (HL) is fundamental to disaster management, concentrating on the prompt provision of critical commodities and services to people impacted by natural and anthropogenic disasters. HL is crucial in alleviating the effects of disasters by guaranteeing that impacted communities obtain food, water, medicine, shelter, and other vital resources. In light of the increasing prevalence and severity of catastrophes, including hurricanes, earthquakes, floods, and pandemics, the domain of humanitarian logistics has experienced notable progress in methodologies, technologies, and practices aimed at enhancing efficiency and equity in emergency responses (Kovács & Spens, 2007).

The present work attempts to consolidate the results of current investigations to examine the changing dynamics of HL. It analyses progress in decision-making frameworks, inventory prepositioning, equity in resource distribution, technological integration, public-private collaborations, environmental sustainability, and other essential elements. The findings offer insights into developing patterns, practical issues, and prospects for future enhancements in HL. This review seeks to assist practitioners and scholars in formulating more effective disaster response techniques.

Humanitarian logistics (HL) is fundamental to disaster management, concentrating on the prompt and effective distribution of vital commodities and services to communities impacted by natural and anthropogenic disasters. It includes planning, sourcing, transportation, storage, and distribution to meet the requirements of vulnerable communities during emergencies. Given the rising frequency and severity of catastrophes such as earthquakes, hurricanes, floods, and pandemics, the significance of HL in alleviating human suffering and managing disaster effects has become paramount. Recent studies emphasise the progress in HL techniques alongside the ongoing difficulties in attaining effective, equitable, and sustainable emergency responses (Goerlandt & Islam, 2021).

As disasters increase in magnitude and intricacy, there is an escalating demand for resilient humanitarian logistics systems that can meet urgent requirements while also contemplating long-term sustainability. Natural disasters, such as hurricanes and floods, along with man-made crises like armed wars, provide substantial logistical issues that necessitate inventive solutions. This systematic review consolidates findings from previous studies to offer a thorough knowledge of the present state of HL, emphasising new trends, significant difficulties, and avenues for enhancement (Negi, S. 2022).

The Importance of Humanitarian Logistics in Disaster Response

HL is vital to disaster response, guaranteeing that impacted communities obtain essential supplies including food, water, medication, and shelter. The efficacy of HL systems can profoundly alter the velocity and effectiveness of disaster relief operations, directly influencing the survival and recuperation of impacted communities. With the increasing frequency and intensity of disasters attributed to climate change, urbanisation, and geopolitical instability, the demand for sophisticated HL methods has surged significantly. Researchers and practitioners have increasingly concentrated on optimising HL operations to improve preparedness, reaction, and recovery capacities Pourhosseini et al. (2015).

The primary aims of HL encompass the swift provision of resources, the reduction of operating expenses, the accommodation of the varied requirements of impacted communities, and the enhancement of resilience to future calamities. To attain these objectives, HL must incorporate innovative technology, collaborative alliances, and flexible decision-making frameworks (Sandifer & Walker, 2018)..

Objectives of the Review

This review consolidates information from 40 studies published between 2015 and 2024, emphasising ten pivotal investigations. The aims of this review are to:

1. To perform a comprehensive review that provides insights into practices in humanitarian logistics and disasters response to enhance logistics operations and emergency efficacy.
2. To identify journals that publish studies on humanitarian logistics and emergency response from 2015 to 2024, and to analyse the types of disasters covered, evaluating their effects on logistics operations and response tactics.
3. To examine key variables, research methodologies, and analysis techniques in humanitarian logistics studies, and evaluate their efficacy in addressing difficulties related to disaster response.
4. To summarise principal findings, delineate limits, and investigate future research avenues to rectify deficiencies and trends in formulating adaptable, technology-driven, and equitable humanitarian logistics solutions.

This review seeks to provide a comprehensive knowledge of the changing dynamics of HL and its essential function in disaster response.

5. To Examine case studies to discern essential insights from both successful and unsuccessful humanitarian logistics operations.

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METHODOLOGY

A systematic literature review was performed to identify pertinent research on humanitarian logistics and disaster response published from 2015 to 2024. The Scopus database used as the principal source because to its extensive coverage of peer-reviewed academic publications. The search utilised the terms “Humanitarian logistics” and “Emergency Response,” which were important to the review's focus. Filters were implemented to narrow the results, encompassing language (English exclusively), document type (journal articles), and publication stage (final publications). Initially, 66 papers were obtained, subsequently reduced to 40 following the application of inclusion and exclusion criteria.

This review's inclusion criteria concentrated on research that specifically examined humanitarian logistics in the realm of disaster response. Studies were required to be peer-reviewed, published between 2015 and 2024, and pertinent to logistics strategies, technical advancements, or obstacles in disaster assistance to be included as shown in Table 1. Only empirical or theoretical journal papers were included, whereas research not directly pertinent to the review's scope were omitted. Furthermore, publications not in English or beyond the designated publication timeframe were omitted.

The data extraction process entailed analysing the chosen 40 articles to extract essential insights concerning logistics operations, problems, technological innovations, and coordinating tactics in the delivery of humanitarian relief. Data was gathered regarding logistical obstacles (e.g., infrastructure, security), the application of emerging technologies (e.g., drones, blockchain, AI), and methods for disaster preparedness. The data underwent qualitative analysis through thematic analysis to discern repeating themes, trends, and gaps in the literature. Results were classified into primary categories including operational difficulties, technical advancements, and cooperation among multiple stakeholders. This qualitative summary offered a thorough examination of the present condition of humanitarian logistics in disaster response, emphasising optimal practices and opportunities for more research.

Table 1: Methodology of Systematic Literature Review Using PRISMA Framework (Source: Created by author adapted from Moher, D et al., 2009))

Phase	Description
Identification	A systematic literature review was performed to identify research on humanitarian logistics and disaster response published from 2015 to 2024.
	The Scopus database was used as the principal source due to its extensive coverage of peer-reviewed academic publications.
	Search terms: “Humanitarian logistics” and “Emergency Response.”
Screening	**Filters applied**
	Language: English exclusively.

	Document type: Journal articles.
	Publication stage: Final publications.
	Initially obtained 66 papers.
Eligibility	**Inclusion criteria**
	Focus on humanitarian logistics in disaster response.
	Published between 2015 and 2024.
	Pertinent to logistics strategies, technical advancements, or obstacles in disaster assistance.
	Only empirical or theoretical journal papers included.
	Exclusion criteria:
	Research not directly pertinent to the review's scope.
	Publications not in English or beyond the designated publication timeframe.
	Final selection resulted in 40 papers.
Included	**Data extraction process**
	Analyzing the chosen 40 articles to extract essential insights on logistics operations, problems, technological innovations, and coordinating tactics.
	Data gathered regarding logistical obstacles, application of emerging technologies, and methods for disaster preparedness.
	Qualitative analysis through thematic analysis to discern repeating themes, trends, and gaps in the literature.

KEY THEMES IN PREVIOUS RESEARCHES ON HUMANITARIAN LOGISTICS

Humanitarian logistics (HL) is essential in coordinating disaster response, facilitating the prompt and effective allocation of vital resources to impacted communities. In the last ten years, researchers have concentrated on enhancing HL systems using many approaches, strategies, and technology. This synthesis consolidates five principal themes discovered in a systematic evaluation of 40 research published from 2015 to 2023, highlighting accomplishments, problems, and emerging trends in HL. The five issues addressed here are: decision-making models, inventory prepositioning and equity in resource distribution, technological integration and public-private partnerships, coordination, efficiency, and preparedness, and sustainability and training.

Advancements in Decision-Making Models

Effective decision-making is essential for enhancing humanitarian logistics due to the uncertainty and instability present in crisis contexts. The study emphasises various decision-making approaches designed to enhance logistics planning, resource distribution, and operational efficacy in humanitarian efforts.

Stochastic and Mixed-Integer Programming Models: Researchers have investigated multi-stage stochastic programming to enhance supplier selection in disaster preparedness. Olanrewaju, Dong, and Hu (2020) proposed a model that considers elements such as supplier capacity and cost structures, with the objective of minimising delays and costs in the supplier selection process. This model mitigates the uncertainty of crisis scenarios, allowing relief agencies to make strategic decisions that enhance reaction time and alleviate logistical bottlenecks.

Cao et al. (2023) developed a multistage mixed-integer programming approach that incorporates real-time data into logistics scheduling. This model facilitates the adaptive allocation of resources and routes, reacting to the always evolving circumstances in the catastrophe context. The authors illustrated through case studies how this method might substantially reduce costs while guaranteeing the prompt delivery of essential supplies during emergencies.

Liu et al. (2023) expanded upon this foundation by concentrating on dynamic network architecture that adjusts to disturbances in transportation networks during disasters. Their methodology offers a versatile framework for resource allocation and facility placement, guaranteeing that logistical operations maintain efficiency despite obstacles or infrastructure damage. These studies demonstrate the increasing significance of data-driven, adaptable decision-making models in improving the efficiency and responsiveness of HL systems.

These developments in decision-making models indicate a transition towards more proactive, adaptive, and data-driven methodologies in humanitarian logistics, highlighting the essential importance of preparation, real-time information, and flexibility in enhancing disaster response capabilities.

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Inventory Prepositioning and Equity in Resource Allocation

A fundamental aspect of efficient humanitarian logistics is the prepositioning of emergency resources in critical sites. This method dramatically decreases reaction times and logistical challenges during disasters. The fair allocation of resources continues to be a significant concern, especially in meeting the needs of vulnerable groups.

Inventory Prepositioning Models: Richardson et al. (2016) examined the factors affecting inventory prepositioning decisions through a Delphi research, identifying critical determinants including infrastructure quality, reaction time, and operational expenses. Their research highlighted the necessity of synchronising resource prepositioning with local requirements and logistical capacities, hence facilitating the prompt and efficient activation of relief activities. Furthermore, Di Pasquale, Fruggiero, and Iannone (2020) verified a numerical model for prepositioning resources in seismic zones, illustrating its efficacy in diminishing operational costs and response times.

Equitable Resource Allocation: The equitable distribution of resources has emerged as a critical emphasis in HL, particularly in guaranteeing that marginalised communities receive prompt and sufficient assistance. Macea, Cantillo, and Arellana (2018) advocated for the incorporation of psychosocial elements, including risk perception and safety culture, into resource allocation frameworks. Their research emphasised that comprehending community-specific demands and circumstances could enhance equitable resource allocation. Similarly, Huang and Rafiei (2019) emphasised the prioritisation of fairness in supply timeframes and amounts, especially during significant emergencies such as the Haiti earthquake. Their research highlighted that fair resource access is essential for effective disaster response.

Sarma et al. (2019) proposed an adaptive redistribution approach employing neutrosophic programming to save expenses while guaranteeing fair resource allocation post-disaster. These findings highlight the significance of flexibility, adaptability, and equity-centered criteria in health literacy decision-making. Efficient inventory prepositioning and equitable resource allocation are crucial for ensuring that relief reaches those most in need, hence minimising inequities during crisis response.

Technological Integration and Public-Private Partnerships

The incorporation of sophisticated technology has significantly altered HL, offering unique tools and processes to enhance efficiency, decision-making, and operational scalability. Concurrently, public-private partnerships (PPPs) have surfaced as an essential method for enhancing HL operations and mitigating resource limitations during crises.

Technological Progressions: The significance of technology in augmenting HL is seen in the increasing utilisation of AI, machine learning, and optimisation techniques. Goerlandt and Islam (2021) created a Bayesian network model to assess maritime transport delays resulting from earthquakes, applicable for disaster preparedness planning. Souza Almeida and Goerlandt (2022) suggested a Greedy Randomised Adaptive Search Procedure (GRASP) to optimise road-clearing activities. This model exhibited considerable enhancements in computing performance, rendering it an essential instrument for rehabilitating transport networks during disaster reactions.

Additionally, Biswas et al. (2024) presented an AI-driven approach for anticipating demand in disaster relief. Their strategy incorporates machine learning algorithms to forecast resource requirements, enhancing preparedness and responsiveness in humanitarian supply chains.

Public-Private Partnerships (PPPs): The incorporation of private sector expertise and resources into HL operations has demonstrated significant efficacy in improving logistical efficiency. Shokr, Jolai, and Bozorgi-Amiri (2021) investigated a bi-level stochastic model for the integration of humanitarian organisations with third-party logistics providers, illustrating that decentralised decision-making and collaborative planning are essential for optimising resource allocation. By cultivating trust and alignment among stakeholders, PPPs facilitate more scalable and efficient catastrophe responses. These collaborations enable humanitarian organisations to utilise private sector resources, expertise, and infrastructure, thereby improving the efficiency and efficacy of disaster relief operations.

The expanding influence of technology and public-private partnerships highlights the escalating complexity and necessity for innovation in humanitarian logistics, especially for the improvement of scalability, adaptability, and efficiency in resource allocation during crises.

Coordination, Efficiency, and Preparedness

Efficient collaboration among stakeholders is essential for guaranteeing a prompt and organised response in disaster management. Inadequate coordination may lead to delays, redundant efforts, and ineffective resource utilisation. Investigations in this area have examined strategies for enhancing logistical efficiency and optimising communication among various stakeholders engaged in disaster response.

Coordination Mechanisms: Collaboration among many stakeholders, including humanitarian organisations, governmental bodies, and corporate companies, is essential for the efficacy of humanitarian logistics. Octavia et al. (2016) analysed Indonesia's disaster response system and discovered that centralised planning and simulation-based coordination enhanced efficiency, decreasing response times by as much as 20 hours. This research emphasised that defining distinct roles and duties among various stakeholders might enhance resource allocation, minimise operational inefficiencies, and improve disaster response outcomes through coordinated efforts.

Efficiency in Post-Disaster Rescue Operations: Post-disaster rescue operations necessitate effective routing and resource allocation to reduce mortality and assist impacted communities. Liu et al. (2020) presented an enhanced Data Envelopment Analysis (DEA) model to optimise rescue routing, achieving a 21.2% performance improvement during the Wenchuan earthquake. These findings underscore the significance of dynamic decision-making and data-driven methodologies in enhancing rescue efficacy and preserving lives.

Preparing for Uncertainty: The unpredictability of disaster scenarios necessitates proactive preparing techniques. Patrisina et al. (2019) investigated hybrid delivery solutions for disaster preparedness, integrating direct and indirect supply networks to enhance flexibility. This method facilitates improved flexibility to fluctuating circumstances, guaranteeing that resources are allocated efficiently and effectively under unforeseen disaster scenarios.

Sustainability and Training in Humanitarian Logistics

The increasing emphasis on environmental sustainability and the necessity for extensive training programs in HL are vital for guaranteeing long-term efficacy in disaster management. As climate change escalates the frequency and severity of disasters, HL systems must incorporate sustainable practices and ensure staffs is sufficiently prepared to manage the intricacies of emergency responses.

Sustainability in Higher Learning: Saari (2023) examined the application of renewable energy in humanitarian medical cold chains, emphasising its capacity to diminish reliance on fossil fuels and improve environmental sustainability. The study identified constraints including substantial initial expenditures and restricted resource availability, while underscoring the necessity for new solutions to incorporate sustainable principles into HL operations. By emphasising sustainability, HL systems can diminish their ecological impact while enhancing their overall resistance against escalating environmental issues.

Training and Capacity Development: Efficient training initiatives are crucial for enhancing HL capacity and augmenting catastrophe readiness. Gralla et al. (2015) analysed the World Food Programme's Logistics Response Team (LRT) training initiative, which employed scenario-based simulations to equip participants for practical challenges. Heaslip and Stuns (2019) underscored the necessity of ongoing training for logistics staff to tackle emerging difficulties. These studies highlight the necessity for continuous information dissemination and skill enhancement to improve the capabilities of logistics teams in disaster response.

Humanitarian logistics is a multifaceted and dynamic domain, influenced by progress in decision-making frameworks, technical breakthroughs, and the growing demand for equitable, efficient, and sustainable methodologies. The analyses conducted underscore the significance of proactive readiness, efficient coordination, and the incorporation of sophisticated technologies to enhance disaster response. As the frequency and severity of disasters increase, the area of humanitarian logistics must evolve via ongoing innovation, collaboration, and capacity enhancement to address the escalating obstacles and guarantee the prompt provision of assistance to those in most need.

DESCRIPTIVE ANALYSES

A comprehensive overview of the current trends and gaps in disaster response and humanitarian logistics research was given by the descriptive analysis of the 40 research publications that were part of this systematic literature assessment. Strong scholarly interest in the topic is demonstrated by the studies' publication in numerous prestigious academic publications, with an emphasis on those devoted to operations management, logistics, and catastrophe management. From man-made crises like pandemics and conflicts to natural catastrophes like hurricanes, floods, and earthquakes, the studies covered a broad spectrum of disaster kinds. In terms of methodology, most of the studies used quantitative techniques, making use of mathematical modelling, simulations, and optimisation models. To give a more thorough grasp of practical applications, several studies did, however, also include qualitative techniques like case studies and interviews. Transportation, inventory control, resource allocation, stakeholder coordination, and the application of cutting-edge technologies like artificial intelligence (AI), blockchain, and drones were among the major logistical issues that were explored in the study.

To increase operational efficiency, optimise resource allocation, and improve catastrophe preparedness, the evaluated research used a range of analysis methodologies, such as network analysis, optimisation models, and decision-support systems. The studies' limitations included issues including the inability to obtain real-time data, the difficulty of effectively simulating crisis scenarios, and the challenge of scaling solutions. Numerous studies also emphasised the unpredictability of disaster response and the need for further field data. The results highlighted the significance of adopting more equitable and sustainable logistics methods, the transformative potential of technology, and the crucial role of better coordination among diverse stakeholders. All things considered, this descriptive analysis offers insightful information about the advantages of the current body of research while also highlighting areas where more study could fill in the gaps and enhance disaster response plans.

Relevant Journals

The journal publishing table (Table 2) offers a comprehensive analysis of research trends in logistics, crisis management, and humanitarian supply chains from 2015 to 2024. The publications are categorised by journal source, publication year, and frequency, underscoring the growing academic emphasis on enhancing logistics for disaster response and humanitarian initiatives.

Table 2: Overview of Relevant Journals in Humanitarian Logistics and Disaster Response (2015-2024).

Serial No.	Journal/Source	Year	Number of Journals
1	Reliability Engineering and System Safety	2021	1
2	Computers and Industrial Engineering	2020, 2019	2
3	Transportation Research Part E: Logistics and Transportation Review	2015,2015,2018, 2023	4
4	Journal of Business Logistics	2016	1
5	Journal of Humanitarian Logistics and Supply Chain Management	2015,2015,2017,2019,2020, 2021,2023, 2024	8
6	Advances in Production Engineering And Management	2023	1
7	International Journal of Logistics Systems and Management	2017	1
8	Journal of Disaster Research	2016	1
9	Computers and Operations Research	2022	1
10	Socio-Economic Planning Sciences	2022	1
11	International Journal of Disaster Risk Reduction	2021,2021,2021 2024	4
12	Disasters	2021	1
13	Annals of Operations Research	2019	1
14	International Journal of Logistics Management	2021	1
15	TechTrends	2019	1
16	Peer-to-Peer Networking and Applications	2022	1
17	European Journal of Operational Research	2020, 2019	2
18	Sustainability (Switzerland)	2022	1
19	Ocean Engineering	2023	1
20	Mathematics	2024	1
21	Multimodal Transportation	2022	1
22	International Journal of Supply Chain Management	2016	1
23	International Journal on Advanced Science, Engineering and Information Technology	2019	1
24	Transportation Journal	2020	1
25	Computers in Industry	2019	1

The Table 2 demonstrates a robust presence of publications focused on logistics and supply chain management, especially with disaster assistance. Prominent journals encompass the Journal of Humanitarian Logistics and Supply Chain Management, distinguished by eight articles published over several years, underscoring its critical influence on humanitarian logistics research. Likewise, Transportation Research Part E: Logistics and Transportation Review has published numerous works focussing on transportation optimisation, network analysis, and risk management under disturbed situations. Specialised publications, such as Computers and Operations Research and Peer-to-Peer Networking and Applications, offer significant insights into technical progress, including optimisation algorithms and artificial intelligence applications for disaster response. Other specialised magazines, such as Sustainability and Ocean Engineering, indicate increasing apprehensions over sustainability and maritime logistics in crisis scenarios.

The years 2019 and 2021 experienced a surge of publications, indicating a heightened urgency in tackling logistical issues related to disaster management and humanitarian assistance. In 2019, publications such as TechTrends and Annals of Operations Research included studies on optimisation and supply chain networks, whereas 2021 included articles addressing disaster risk reduction and preparedness in the International Journal of Disaster Risk Reduction.

From 2023 to 2024, the emphasis has transitioned to the integration of advanced technologies, sustainability, and logistics, with journals such as Advances in Production Engineering and Management and Mathematics examining the impact of machine learning, optimisation models, and sustainable practices in disaster logistics.

The table 2 also illustrates the differing publishing frequencies among journals. The Journal of Humanitarian Logistics and Supply Chain Management is the most productive, continuously releasing articles, although others, such as the International Journal of Disaster Risk Reduction, have also demonstrated a rise in contributions, especially in recent years. Certain publications publish only one article, typically concentrating on specialised fields like marine logistics or environmental sustainability, exemplified by Reliability Engineering and System Safety and Ocean Engineering.

The data reveals a wide range of study interests. Numerous publications concentrate on logistical optimisation, investigating algorithms and decision-support systems to enhance catastrophe response. Journals such as Computers and Operations Research emphasise technological breakthroughs, especially in AI and machine learning, which provide answers for supply chain routing, demand forecasting, and inventory management. The focus is on humanitarian and disaster response logistics, with research addressing resource allocation and coordination in relief operations. Sustainability is an emerging focus, with publications like Sustainability (Switzerland) integrating environmental issues into logistics and highlighting eco-friendly approaches in disaster assistance. Moreover, several periodicals, such as Ocean Engineering, focus on region-specific issues, including maritime logistics during catastrophe situations.

The data indicates a developing body of study that progressively incorporates modern technologies, sustainability, and regional factors into catastrophe logistics and supply chain management. This indicates a wider trend towards enhancing disaster response systems to be more flexible, resilient, and efficient in response to escalating global concerns.

Types of Disaster

The table (Table 3) provides a thorough summary of research on humanitarian logistics issues across different crisis types, highlighting the variety and depth of studies in this domain. The research is classified by disaster type, specifically concentrating on earthquakes, floods, hurricanes, epidemics, landslides, tsunamis, and operational incidents. Each disaster subject is examined through diverse logistical obstacles, optimisation methods, and technical innovations, illustrating the increasing intricacy of disaster response initiatives.

Earthquakes are the most commonly examined event, with extensive research addressing logistical challenges such as transportation interruptions and post-disaster assistance. Significant contributions comprise Goerlandt and Islam (2021), who examined maritime transportation interruptions resulting from earthquakes, and Di Pasquale et al. (2020), who discussed inventory pre-positioning solutions for regions susceptible to earthquakes. Research conducted by Olanrewaju et al. (2020) and Oktarina et al. (2016) examines supply chain management and the requisite criteria for earthquake assistance. Furthermore, recent study by Oksuz and Satoglu (2024) introduced models that integrate casualty distribution and medical personnel planning, hence enhancing earthquake logistics.

Floods and hurricanes garner significant interest, as evidenced by research such as Souza et al. (2022), which provide multi-period optimisation models for shelter allocation during flooding events. Nagarajan and Shaw (2021) model evacuee behaviour in large-scale situations, highlighting the logistics of evacuation management and the robustness of transit networks. Olanrewaju et al. (2020) examine supplier selection for disaster response, which is essential in both flood and hurricane situations.

The COVID-19 pandemic presented distinct logistical issues, prompting research by Cao et al. (2023) on logistics scheduling for emergency medical supplies during pandemics. This study underscores the necessity for real-time decision-making and adaptive supply chain management during health crises characterised by rapid demand fluctuations.

Landslides and tsunamis, though less commonly addressed, are also included in the table. Islam et al. (2021) examined the resilience of maritime transport in the context of landslides, whereas Octavia et al. (2016) investigated coordination solutions for tsunami-related disasters in Indonesia. Patrisina et al. (2019) developed networks for the distribution of relief in tsunami response, emphasising readiness and the uncertainty of response.

Table 3: Types of Disasters and Relevant Authors in Humanitarian Logistics and Disaster Response Research.

Serial No.	Types of Disaster	Author(s)
1	Earthquakes	Goerlandt, F., & Islam, S. (2021); Macea, L.F., Cantillo, V., & Arellana, J. (2018); Oktarina, R., Bahagia, S.N., Diawati, L., & Pribadi, K.S. (2016); Biswas, S., et al. (2024); Oksuz, M.K., & Satoglu, S.I. (2024); Bronfman, A., Diego, B.G., Alvarez, P.P. (2022); Sarma, D., Das, A., Bera, U.K., & Hezam, I.M. (2019)

2	Floods	Souza, J.S., et al. (2022); Nagarajan, M., & Shaw, D. (2021)
3	Hurricanes	Olanrewaju, O.G., Dong, Z.S., & Hu, S. (2020)
4	Epidemics (COVID-19-related)	Cao, J., Han, H., Wang, Y.J., & Han, T.C. (2023)
5	Landslides	Islam, S., et al. (2021)
6	Tsunamis	Oktavia, T., Halim, C., Widyadana, I.G.A., & Palit, H. (2016)
7	General Natural Disasters	Richardson, D.A., De Leeuw, S., & Dullaert, W. (2016); Jahre, M., & Fabbe-Costes, N. (2015); Fernandez, T.E., & Suthikarnnarunai, N. (2017); Goldschmidt, K.H., & Kumar, S. (2019); L'Hermitte, C., & Nair, N.-K.C. (2021); Fan, J., Chang, X., Mišić, J., Mišić, V.B., & Kang, H. (2022); Huang, K., Jiang, Y., Yuan, Y., & Zhao, L. (2015); Heaslip, G., & Stuns, K.-K. (2019); Liu, K., Yang, L., Zhao, Y., & Zhang, Z.-H. (2023); Shokr, I., Jolai, F., & Bozorgi-Amiri, A. (2021); Gralla, E., Goentzel, J., & Chomilier, B. (2015); Sanci, E., & Daskin, M.S. (2019)
8	Mass-Injury Disasters (e.g., Earthquakes)	Bronfman, A., Diego, B.G., Alvarez, P.P. (2022)
9	Operational Accidents (e.g., South China Sea)	Wang, Y., Fan, J., Wu, S., & Yang, Y. (2023)
10	Medical/Logistics for Disasters	Edrissi, A., Nourinejad, M., & Roorda, M.J. (2015); Edrissi, A., & Askari, M. (2020); Saari, S. (2023)
11	Maritime Transportation & Logistics	Souza Almeida, L., Goerlandt, F., Pelot, R., & Sörensen, K. (2022); Islam, S., et al. (2021)
12	Network Optimization in Disaster Relief	Liu, B., Sheu, J.-B., Zhao, X., Chen, Y., & Zhang, W. (2020)
13	Supply Chain Optimization	Goerlandt, F., & Islam, S. (2021)
14	Blockchain for Disaster Relief	L'Hermitte, C., & Nair, N.-K.C. (2021)
15	Community Adaptation in Disasters	Yulianto, E., et al. (2021)
16	Resource Allocation & Scheduling	Souza, J.S., et al. (2022); Oksuz, M.K., & Satoglu, S.I. (2024)

The Table 3 additionally incorporates research on comprehensive catastrophe management, including studies relevant to various disaster situations. Macea et al. (2018) investigated the impact of perceptions on post-disaster logistics, whereas Jahre and Fabbe-Costes (2015) analysed methods to enhance the responsiveness of humanitarian supply chains. Recent research by Fan et al. (2022) and L'Hermitte and Nair (2021) highlights technical advancements such as deep reinforcement learning and blockchain to improve logistical operations in crisis scenarios.

Mass-casualty events, such as significant earthquakes resulting in substantial fatalities, are another primary emphasis. Bronfman et al. (2022) examined the challenges of transportation and casualty stabilisation associated with mass-injury disasters, a vital consideration for efficient relief operations. Wang et al. (2023) investigate operational incidents in certain areas, like the South China Sea, and propose algorithms to enhance resource storage and positioning during these emergencies.

The information illustrated in the table 3 indicates a wide array of logistical issues across various disaster types. It emphasises the significance of optimisation, technology innovations (such as AI and blockchain), and readiness in the management of humanitarian logistics. As global difficulties progress, these studies highlight the essential function of logistics in disaster response and the necessity for flexible, efficient systems to tackle intricate, swiftly evolving situations.

Key Variables

The table 4 offers an extensive compilation of research on humanitarian logistics, emphasising main themes, variables and methodologies employed to tackle disaster response issues. The studies are categorised by common characteristics, including resilience, coordination, inventory management, training, and the application of developing technologies, providing a comprehensive perspective on the field's development.

The core issue is Disaster Response and Supply Chain Resilience, with numerous research examining the robustness of transportation and supply chain networks amid interruptions. Goerlandt and Islam (2021) examine vulnerabilities in marine supply chains during coastal interruptions, whereas Islam et al. (2021) investigate the impact of infrastructure damage on recovery. These studies underscore the necessity for robust logistics networks to sustain supply chains during emergencies. Research conducted by Olanrewaju et al. (2020) examines procurement strategies and supplier reliability, focussing on factors such as cost minimisation and reserve capacity, which are essential for guaranteeing the timely availability of resources.

Logistical coordination and response time represent another vital issue, with research investigating how effective coordination might diminish response durations. Richardson et al. (2016) examine determinants affecting inventory pre-positioning, including infrastructure quality and labour availability, to facilitate swift disaster response. Additional study, such as that by Yulianto et al. (2021), emphasises the significance of local resources and community adaptability in enhancing the efficacy of response initiatives, highlighting the necessity of collaboration between humanitarian organisations and local stakeholders.

Inventory and Resource Management is often addressed, emphasising the optimisation of stock levels, the reduction of procurement expenses, and the assurance of timely delivery. Di Pasquale et al. (2020) and Liu et al. (2023) investigate inventory pre-positioning and resource allocation strategies to improve response efficiency. Cao et al. (2023) and Fan et al. (2022) investigate dynamic scheduling for medical supplies, employing sophisticated optimisation techniques such as Markov Decision Processes (MDPs) and Deep Q-Networks to enhance distribution and guarantee equitable resource allocation.

Training and capacity building are crucial for efficient disaster response. Research conducted by Heaslip and Stuns (2019) and Gralla et al. (2015) evaluates the influence of training programs and simulation exercises on disaster logistics, highlighting the necessity for adequately prepared responders. These studies underscore the importance of varied skill sets and authentic training environments in enhancing logistical operations during emergencies. Studies by Breman et al. (2019) and Liu et al. (2020) underscore the significance of technology access, including mobile phones and computers, in enhancing communication and coordination during disaster response.

Equity and fairness in distribution is a critical domain, with study aimed at ensuring equitable allocation of resources. Huang and Rafiei (2019) investigate methods to reduce deprivation durations and guarantee equity in relief distribution, whereas Biswas et al. (2024) examine AI-driven forecasting models for enhancing resource allocation. These studies seek to guarantee that resources are allocated to the most disadvantaged people, hence diminishing inequities in aid distribution.

Sustainability and environmental impact have gained prominence in humanitarian logistics. Saari (2023) examines the application of renewable energy sources in sustaining medical cold chains, hence preserving the viability of temperature-sensitive supplies during a crisis. This emphasis on sustainability corresponds with wider initiatives to mitigate the environmental effects of humanitarian operations while addressing immediate requirements.

The design and optimisation of humanitarian logistics networks is another significant area, with research by Shokr et al. (2021) and Sanci and Daskin (2019) concentrating on network restoration and location-allocation issues in disaster relief. These research employ sophisticated optimisation techniques, including bi-level stochastic programming, to develop durable and economical relief networks. Patrisina et al. (2019) examine demand uncertainty in relief distribution, seeking to enhance delivery options within uncertain circumstances.

Table 4: Key Variables in Humanitarian Logistics and Disaster Response Research (2015-2024).

S.No	Authors & Year	Key Variables
1	Goerlandt, F., & Islam, S. (2021); Islam, S., Goerlandt, F., Uddin, M. J., Shi, Y., & Abdul Rahman, N. S. F. (2021)	Earthquake intensity, infrastructure damage, shipping operability, community needs, delay times, ferry transport, maritime supply chains, vulnerability, resilience
2	Olanrewaju, A., Dong, L., & Hu, W. (2020); Nagarajan, M., & Shaw, D. (2021)	Commitment quantity, reserve capacity, cost minimization, supplier reliability, evacuee behaviour, evacuation time, shelter overcrowding
3	Macea, J., Cantillo, J., & Arellana, J. (2018); Maghsoudi, A., & Moshtari, M. (2021)	Risk perception, safety culture, humanitarian logistics challenges, social media impact, legitimacy regulations
4	Richardson, C., De Leeuw, S., & Dullaert, W. (2016); Yulianto, E., Yusanta, D. A., Utari, P., & Satyawan, I. A. (2021)	Speed of response, infrastructure quality, business support services, emergency response actions, community characteristics, disaster preparedness
5	Di Pasquale, D., Fruggiero, F., & Iannone, F. (2020); Liu, Y., et al. (2023)	Stock levels, response time, procurement costs, geographical characteristics, unmet demand, operational costs
6	Cao, Y., et al. (2023); Fan, W., et al.	Medicine demand, delay costs, transportation network

	(2022)	efficiency, Markov Decision Process (MDP), humanitarian goals
7	Fernandez, E., & Suthikarnnarunai, N. (2017); Huang, K., & Rafiei, R. (2019)	Roles of organizations, relief distribution, delivery times, equity measures, deprivation times, vehicle capacity
8	Oktarina, D., et al. (2016); Timperio, M., et al. (2017)	Emergency goods, population needs, survey responses, capacity constraints, inventory fluctuations
9	Jahre, M., & Fabbe-Costes, N. (2015); Shokr, M., et al. (2021)	Standards, modularity, adaptability, emergency response performance, relief chain design, robust models for uncertainty
10	Souza Almeida, F., et al. (2022); Souza, J. S., Lim-Apo, F. A., Varella, L., Coelho, A. S., & Souza, J. C. (2022)	Road conditions, connectivity restoration, vehicle routing optimization, logistical costs, shelter capacity, supply demand
11	L'Hermitte, C., & Nair, N.-K. C. (2021); Goldschmidt, K. H., & Kumar, S. (2019)	Sharing economy, logistics resources, blockchain technology, communication trust, real-time data sharing, disaster preparedness investments
12	Biswas, S., Kumar, D., Hajiaghaei-Keshteli, M., & Bera, U. K. (2024); Bronfman, M., et al. (2022)	Earthquake data, demand for relief assistance, socioeconomic factors, machine learning techniques, demand forecasting models, casualties
13	Oksuz, M. K., & Satoglu, S. I. (2024); Edrissi, A., et al. (2015)	Earthquake data, facility location, casualty allocation, medical staff planning, network reliability, relief inventory
14	Huang, X., et al. (2015); Saari, M. (2023)	Lifesaving utility, delay cost, fairness in resource allocation, cold chain infrastructure, environmental impact
15	Heaslip, G., & Stuns, T. (2019); Gralla, E., et al. (2015)	Training effectiveness, Kirkpatrick's training model, participant observation data, learning objectives, success factors in training
16	Liu, H., et al. (2020); Patrisina, S., et al. (2019)	Rescue efficiency, affected people, building damage, travel time, decision making, location-allocation model, relief items
17	Sanci, A., & Daskin, M. S. (2019); Sarma, A., et al. (2019)	Restoration equipment location, network restoration times, uncertainty in network availability, demand uncertainty, cost, time
18	Wang, H., et al. (2023)	Resource allocation, response time, storage location, cost
19	Ogazón, J., et al. (2024)	Supply/demand uncertainty, food bank operations, decision strategies

Ultimately, Innovative Technologies and Blockchain increasingly influence disaster logistics. L'Hermitte and Nair (2021) investigate the application of blockchain for instantaneous data dissemination and resource distribution in emergency situations. The ability of blockchain to augment transparency, increase communication, and mitigate logistical bottlenecks renders it an attractive tool for disaster response.

The research included in this table provide a holistic approach to humanitarian logistics, merging conventional logistics concepts with cutting-edge technology such as AI, blockchain, and optimisation models. These studies underscore the significance of resilience, effective coordination, equitable allocation, and capacity enhancement in augmenting disaster response and recovery initiatives. Integrating human experience with technological advancements enables humanitarian logistics to more effectively address the varied and changing requirements of people impacted by disasters.

Methodology

The Table 5 presents a detailed summary of different methodologies employed in humanitarian logistics and disaster management, each designed to enhance resource allocation, increase response efficiency, and address the intricate issues encountered during disasters. These methodologies encompass several approaches, including simulation, optimisation, machine learning, and case studies, illustrating the diverse strategies utilised to improve disaster response and recovery.

Simulation, modelling, and optimisation techniques are fundamental to catastrophe logistics research, emphasising the enhancement of operations and the reduction of delays. Research conducted by Goerlandt and Islam (2021) and

Di Pasquale et al. (2020) employs models like Bayesian Networks and numerical simulations to predict and alleviate interruptions in transport networks, especially during coastal and seismic incidents. Other studies, such as Cao et al. (2023), utilise mixed-integer programming models to optimise logistics scheduling in emergencies, using dynamic elements like disease forecasting (e.g., SEIR models) to bolster readiness. Souza Almeida et al. (2022) employ metaheuristics such as GRASP to enhance road-clearing activities, an essential activity in post-disaster recovery.

Surveys and empirical analyses yield significant insights into community requirements and human behaviour in crisis situations. Oktarina et al. (2016) do surveys to ascertain minimum standards for emergency supplies, providing insight into the experiences and responses of local populations during emergencies. Macea et al. (2018) employ a Hybrid Latent Variable-Discrete Choice Model to analyse how attitudes and perceptions influence logistics decisions, particularly with deprivation costs, emphasising the human aspect in logistics planning.

Conceptual frameworks and decision-making models provide theoretical foundations to enhance disaster response coordination. Olanrewaju et al. (2020) employ multi-stage stochastic programming to address supplier selection issues, whereas Richardson et al. (2016) concentrate on determinants affecting global inventory pre-positioning. Fernandez and Suthikarnnarunai (2017) propose a framework to delineate the functions of humanitarian, military, and commercial entities in disaster assistance, hence enhancing intersectoral coordination.

Optimisation and Mathematical Models enhance decision-making in catastrophe logistics. Souza et al. (2022) and Oksuz & Satoglu (2024) utilise optimisation approaches, including mixed-integer linear programming and multi-objective stochastic programming, to enhance shelter distribution, facility location, casualty management, and medical personnel planning in emergencies. These models emphasise cost minimisation, reaction time reduction, and optimal resource allocation.

Machine Learning and AI Models have become potent instruments for improving forecast accuracy and optimising resource distribution. Fan et al. (2022) utilise deep reinforcement learning to enhance supply distribution, whilst Biswas et al. (2024) apply machine learning methodologies such as regression and decision trees to predict demand during earthquakes, hence increasing accuracy and response efficacy.

Geographic Information Systems and Location-Based Decision-Making are crucial in identifying suitable sites for relief efforts. Timperio et al. (2017) employ GIS and fuzzy logic methodologies to formulate disaster relief networks, incorporating geographical factors into decision-making processes to improve operational efficacy.

Case studies and empirical research offer practical insights into the problems and achievements of catastrophe response. Maghsoudi and Moshtari (2021) perform a case study on the 2017 Kermanshah earthquake, pinpointing logistical challenges and avenues for enhancement. Yulianto et al. (2021) examine community adaptation and local responses in Indonesia, offering significant data on community contributions to disaster relief initiatives.

Innovative technologies, including blockchain, are examined to improve logistical transparency and efficiency. L'Hermitte and Nair (2021) illustrate how blockchain technology might enhance resource sharing and coordination in emergencies by assuring transparency and mitigating bottlenecks.

Sustainability and renewable energy are becoming progressively significant in the humanitarian industry. Saari (2023) emphasises the incorporation of renewable energy sources into medical cold chains, guaranteeing the environmental sustainability of logistics operations while preserving the integrity of temperature-sensitive products.

Table 5: Methodologies Employed in Humanitarian Logistics and Disaster Response Research.

Serial No.	**Methodology Group**	**Authors**
1	Simulation/Modeling & Optimization	Goerlandt & Islam (2021); Di Pasquale, Fruggiero, & Iannone (2020); Cao et al. (2023); Souza Almeida et al. (2022)
2	Survey/Empirical Analysis	Oktarina et al. (2016); Macea, Cantillo, & Arellana (2018)
3	Conceptual Framework & Decision-Making Models	Olanrewaju, Dong, & Hu (2020); Richardson, De Leeuw, & Dullaert (2016); Fernandez & Suthikarnnarunai (2017)
4	Case Study/Longitudinal Analysis	Jahre & Fabbe-Costes (2015)
5	Optimization & Mathematical Models	Souza et al. (2022); Oksuz & Satoglu (2024); Huang & Rafiei (2019); Liu K., Yang L., Zhao Y., Zhang Z.-H. (2023); Shokr I., Jolai F., Bozorgi-Amiri A. (2021); Liu B., Sheu J.-B., Zhao X., Chen Y., Zhang W. (2020); Huang K., Jiang Y., Yuan Y., Zhao L. (2015); Edrissi A., Nourinejad M., Roorda M.J. (2015); Wang Y., Fan J., Wu S., Yang Y. (2023); Souza Almeida L., Goerlandt F. (2022)
6	GIS & Location-Based Decision Making	Timperio G., Panchal G.B., Samvedi A., Goh M., De Souza R. (2017)
7	Simulation & Case	Gralla E., Goentzel J., Chomilier B. (2015); Heaslip G., Stuns K.-K.

	Studies	(2019)
8	Machine Learning & AI Models	Fan J., Chang X., Mišić J., Mišić V.B., Kang H. (2022); Biswas et al. (2024)
9	Case Studies & Empirical Analysis	Maghsoudi & Moshtari (2021); Yulianto et al. (2021); Islam et al. (2021)
10	Survey-Based & Needs Analysis	Breman J., Giacumo L.A., Griffith-Boyes R. (2019)
11	Stochastic Programming & Uncertainty	Sanci E., Daskin M.S. (2019)
12	Behavioral & Simulation Models	Nagarajan & Shaw (2021)
13	Blockchain & Technology-Based Frameworks	L'Hermitte & Nair (2021)
14	Quantitative & Longitudinal Analysis	Goldschmidt & Kumar (2019)
15	Heuristic & Metaheuristic Algorithms	Souza Almeida L., Goerlandt F. (2022)
16	Game Theory & Budget Optimization	Edrisi A., Askari M. (2020)
17	Resource Redistribution & Cost Minimization	Sarma D., Das A., Bera U.K., Hezam I.M. (2019)
18	Sustainability & Renewable Energy	Saari S. (2023)
19	Logistics & Casualty Stabilization	Bronfman A., Diego B.G., Alvarez P.P., Reid S., Paredes-Belmar G. (2022)
20	Stochastic & Two-Stage Models	Ogazón E., Smith N.R., Ruiz A. (2024); Patrisina R., Sirivongpaisal N., Suthummanon S. (2019)
21	Simulation & Dynamic Systems	Octavia T., Halim C., Widyadana I.G.A., Palit H. (2016)

The approaches presented in this Table 5 demonstrate a comprehensive strategy for enhancing catastrophe logistics. These studies emphasise the significance of integrated, data-driven solutions to tackle the intricate and evolving difficulties of disaster response and recovery, utilising advanced optimisation models, machine learning, empirical analysis, and emerging technologies such as blockchain. These techniques seek to improve the efficiency, equity, and sustainability of humanitarian logistics by integrating technical breakthroughs with human-centered insights.

Analysis techniques

The Table 6 consolidates many approaches to analysis in humanitarian logistics and catastrophe response, highlighting the varied methods employed to optimise resource allocation, enhance decision-making, and improve operational efficiency during emergencies. The research are categorised according to analytical methodologies, encompassing optimisation models, qualitative analysis, machine learning, and simulation techniques, each targeting distinct issues in disaster assistance.

Optimisation and Mathematical Programming are crucial in enhancing catastrophe logistics by tackling intricate decision-making amongst uncertainty. Methods include multi-stage stochastic programming, mixed-integer linear programming (MILP), and Benders decomposition are employed to enhance resource allocation and logistical scheduling. Goerlandt and Islam (2021) created a Bayesian Network model to assess transport delays during coastal disturbances, whereas Olanrewaju et al. (2020) employed multi-stage programming for supplier selection in disaster response. Di Pasquale et al. (2020) and Cao et al. (2023) utilised optimisation models to address dynamic demand and inventory pre-positioning in emergency contexts.

Qualitative analysis and case studies provide significant insights into human behaviour, social dynamics, and community responses during disasters. Research such as Macea et al. (2018) examined the impact of perceptions and attitudes on decision-making in disaster assistance, whereas Yulianto et al. (2021) performed interviews in Palu, Indonesia, to investigate local community adaptations during the 2018 earthquake. These qualitative methodologies facilitate the identification of deficiencies in logistical planning and enhance comprehension of the human dynamics pertinent to disaster response.

The Delphi Method and qualitative frameworks are employed to ascertain key elements affecting catastrophe preparedness and decision-making. Richardson et al. (2016) utilised the Delphi technique to prioritise elements influencing global inventory pre-positioning, whilst Timperio et al. (2017) integrated Fuzzy Analytical Hierarchy Process (AHP) with Geographic Information Systems (GIS) to develop efficient disaster relief networks. These frameworks assist in prioritising essential logistical and operational components in disaster planning.

Metaheuristics and heuristic algorithms are utilised to optimise routing and scheduling issues in intricate disaster situations. Souza et al. (2022) employed the Greedy Randomised Adaptive Search Procedure (GRASP) to optimise multi-vehicle routing, while Souza Almeida & Goerlandt (2022) conducted a comparative analysis of various metaheuristics, including Ant Colony Optimisation (ACO), for analogous issues. These algorithms are especially effective in tackling the difficulties posed by dynamic settings and constrained resources in post-disaster logistics.

Simulation and Sensitivity Analysis are extensively employed to simulate logistics systems amid uncertainty and enhance decision-making optimisation. Nagarajan and Shaw (2021) employed integer programming to model the distribution of evacuees in shelters, taking into account behavioural factors and evacuation durations. Fan et al. (2022) utilised Deep Q-Networks (DQN) and Markov Decision Processes (MDP) to enhance supply distribution, whereas Huang et al. (2019) integrated multi-objective optimisation with simulation to augment last-mile distribution equity in humanitarian operations.

Statistical and Quantitative Analysis employ machine learning and statistical techniques to forecast demand and enhance resource allocation. Biswas et al. (2024) employed regression and decision tree algorithms to predict earthquake relief demand, thereby improving response precision. Furthermore, Saari (2023) utilised statistical analysis to enhance the utilisation of renewable energy in medical cold chains, hence advancing sustainable emergency logistics.

Efficiency and Data Envelopment Analysis (DEA) models are employed to assess and enhance post-disaster activities, including rescue routing and food bank distribution. Liu et al. (2020) utilised DEA to evaluate rescue efficiency, whereas Breman et al. (2019) employed DEA for the assessment of food bank networks, facilitating the optimisation of routes and decision-making in resource-limited contexts.

Stochastic Programming and Network Design methodologies are utilised to address uncertainty in catastrophe logistics. Huang and Rafiei (2019) employed two-stage stochastic programming to address location-allocation issues, whereas Shokr et al. (2021) utilised bi-level stochastic programming to develop resilient relief networks, taking into account the contributions of humanitarian and commercial sector participants in network recovery.

Humanitarian training and efficacy are crucial for enhancing disaster response. Gralla et al. (2015) and Heaslip & Stuns (2019) concentrated on assessing training programs for humanitarian logistics teams, highlighting the necessity for efficient training models and frameworks to equip responders for practical situations.

Table 6: Analysis Techniques in Humanitarian Logistics and Disaster Response Research.

S.No	Authors	Analysis Technique
1	Goerlandt F.; Islam S. (2021); Olanrewaju O.G.; Dong Z.S.; Hu S. (2020); Cao J.; Han H.; Wang Y.J.; Han T.C. (2023); Di Pasquale V.; Fruggiero F.; Iannone R. (2020)	**Optimization & Mathematical Programming**: Multi-stage stochastic programming, Mixed Integer Linear Programming (MILP), multi-stage mixed-integer programming, Benders decomposition algorithm, and numerical modeling
2	Macea L.F.; Cantillo V.; Arellana J. (2018); L'Hermitte C.; Nair N.-K.C. (2021); Yulianto E.; Yusanta D.A.; Utari P.; Satyawan I.A. (2021)	**Qualitative Analysis & Case Studies**: Hybrid latent variable–discrete choice models, qualitative analysis, in-depth interviews, focus groups, case study analysis
3	Richardson D.A.; De Leeuw S.; Dullaert W. (2016); Timperio G.; Panchal G.B.; Samvedi A.; Goh M.; De Souza R. (2017); Gralla E.; Goentzel J.; Chomilier B. (2015); Heaslip G.; Stuns K.-K. (2019)	**Delphi & Qualitative Frameworks**: Delphi method, conceptual framework development, survey analysis, Kirkpatrick's Four-Level Training Evaluation Model, framework evaluation
4	Souza Almeida L.; Goerlandt F.; Pelot R.; Sörensen K. (2022); Souza J.S.; Lim-Apo F.A.; Varella L.; Coelho A.S.; Souza J.C. (2022); Liu K.; Yang L.; Zhao Y.; Zhang Z.-H. (2023)	**Metaheuristics & Heuristic Algorithms**: GRASP metaheuristic optimization, Ant Colony Optimization (ACO), heuristic algorithms, and numerical simulations
5	Nagarajan M.; Shaw D. (2021); Fan J.; Chang X.; Mišić J.; Mišić V.B.; Kang H. (2022); Huang K.; Jiang Y.; Yuan Y.; Zhao L. (2015)	**Simulation & Sensitivity Analysis**: Integer programming simulation, sensitivity analysis, Markov Decision Process (MDP), deep reinforcement learning, and multi-objective optimization
6	Maghsoudi A.; Moshtari M. (2021); Islam	**Case Study & Vulnerability Analysis**: Semi-

	S.; Goerlandt F.; Uddin M.J.; Shi Y.; Abdul Rahman N.S.F. (2021)	structured interviews, vulnerability and resilience analysis, and case study analysis
7	Goldschmidt K.H.; Kumar S. (2019); Biswas S.; Kumar D.; Hajiaghaei-Keshteli M.; Bera U.K. (2024); Saari S. (2023); Patrisina R.; Sirivongpaisal N.; Suthummanon S. (2019)	**Statistical & Quantitative Analysis**: Statistical methods, machine learning algorithms (Linear Regression, Decision Tree), least angle regression, and optimization algorithms for demand forecasting and resource allocation
8	Liu B.; Sheu J.-B.; Zhao X.; Chen Y.; Zhang W. (2020); Breman J.; Giacumo L.A.; Griffith-Boyes R. (2019)	**Efficiency & Data Envelopment Analysis (DEA)**: Efficiency-based routing model, DEA, group decision constraints
9	Huang K.; Rafiei R. (2019); Shokr I.; Jolai F.; Bozorgi-Amiri A. (2021); Edrissi A.; Nourinejad M.; Roorda M.J. (2015); Sarma D.; Das A.; Bera U.K.; Hezam I.M. (2019)	**Stochastic Programming & Network Design**: Two-stage stochastic programming, robust optimization, bi-level Stackelberg game, and network reliability modeling
10	Oktarina R.; Bahagia S.N.; Diawati L.; Pribadi K.S. (2016); Edrisi A.; Askari M. (2020)	**Location-Allocation & Network Restoration**: Mixed delivery strategy, location-allocation problem, particle swarm optimization (PSO) for facility location
11	Gralla E.; Goentzel J.; Chomilier B. (2015)	**Humanitarian Training & Effectiveness**: Case study analysis, training evaluation, and effectiveness frameworks
12	Wang Y.; Fan J.; Wu S.; Yang Y. (2023); Ogazón E.; Smith N.R.; Ruiz A. (2024); Liu K.; Yang L.; Zhao Y.; Zhang Z.-H. (2023)	**Multi-objective Optimization & Simulation**: Multi-objective optimization, immune algorithm (IA), improved immune algorithm (IIA), simulation, and numerical experiments for relief resource planning and network optimization
13	Saari S. (2023); Bronfman A.; Diego B.G.; Alvarez P.P.; Reid S.; Paredes-Belmar G. (2022); Shokr I.; Jolai F.; Bozorgi-Amiri A. (2021)	**Heuristic Methods & Simulation for Relief Operations**: Heuristic algorithms for prioritization of care, simulation models for emergency logistics, and optimization techniques for casualty transportation
14	Sanci E.; Daskin M.S. (2019)	**Stochastic Models & Network Restoration**: Two-stage stochastic programming, network restoration, and sample average approximation methods

The studies in the table demonstrate a variety of techniques that tackle the complex difficulties in humanitarian logistics and catastrophe response. By integrating optimisation models, machine learning, qualitative insights, and simulation-based techniques, these methodologies offer robust tools for enhancing the efficiency, effectiveness, and resilience of disaster management operations. This amalgamation facilitates a more comprehensive and adaptive strategy for addressing the complexities of disaster relief.

Findings from the literature

Recent research in disaster logistics and preparedness emphasises the optimisation of resource allocation, enhancement of operational efficiency, and resolution of logistical difficulties during and subsequent to natural disasters. The study encompasses many locations and emphasises the significance of sophisticated models, innovative technology, and intersectoral collaboration in improving disaster response.

A main focus of research is maritime transportation and disaster risk mitigation. Goerlandt and Islam (2021) examined the delays in coastal maritime shipping subsequent to natural disasters, highlighting the susceptibility of maritime supply systems and the necessity of preparedness. Islam et al. (2021) examined the marine resilience of Vancouver Island, demonstrating that disturbances, such as ferry cancellations, can be alleviated through deliberate resilience enhancement, including the deployment of tugs and barges.

Research on supply chain optimisation and resource allocation frameworks seeks to improve catastrophe readiness. Olanrewaju et al. (2020) introduced a multi-stage stochastic programming approach for supplier selection, aimed at optimising costs and reaction times in disaster scenarios. Di Pasquale et al. (2020) validated a model for inventory pre-positioning in seismic events to enhance resource stockpiling. In a similar vein, Souza et al. (2022) employed a multi-period optimisation model to enhance shelter allocation and aid distribution in catastrophe scenarios, shown by a case study in Southern Brazil. Liu et al. (2023) employed stochastic programming to enhance relief distribution by modifying facilities and locations according to changing disaster requirements.

Blockchain and technical advancements are revolutionising disaster logistics. L'Hermitte and Nair (2021) presented a blockchain-based logistics-sharing system that enhances trust and collaboration between humanitarian organisations and commercial logistics providers, resulting in more efficient resource mobilisation. Fan et al. (2022) employed deep reinforcement learning (DRL) to optimise the distribution of emergency supplies, showcasing improved efficiency in minimising response times and costs.

Training and capacity enhancement are essential for augmenting disaster response efficacy. Breman et al. (2019) discovered that participatory, scenario-based training is superior to traditional lecture formats in cultivating practical skills. Heaslip & Stuns (2019) examined logistics training for the Finnish Red Cross, emphasising the necessity of immersion exercises to prepare responders with practical skills.

The matter of equality in disaster relief has garnered attention. Huang and Rafiei (2019) examined last-mile delivery challenges in Haiti post-earthquake, emphasising the importance of prioritising deprivation time equity to guarantee equitable and prompt resource allocation. This strategy guarantees that the most at-risk groups obtain assistance without delay.

Timperio et al. (2017) established a methodology for location selection in disaster relief networks in Indonesia, enhancing resource allocation through the strategic positioning of distribution centres. Patrisina et al. (2019) employed stochastic location-allocation models to enhance disaster assistance logistics, incorporating mixed delivery tactics for improved coordination during emergencies.

Clearing roads and restoring infrastructure are essential in post-disaster logistics. Souza Almeida et al. (2022) employed the GRASP metaheuristic to enhance road-clearing efforts, thereby expediting recovery and ensuring the delivery of supplies. Sanci and Daskin (2019) incorporated road restoration decisions into their models, enhancing logistical efficiency by mitigating road damage.

Additional research has investigated communal and behavioural elements. Nagarajan and Shaw (2021) emphasised the influence of evacuee behaviour on shelter utilisation and evacuation durations, underscoring the necessity for behavior-oriented measures in disaster planning.

Sustainability and resilience are crucial in disaster logistics. Saari (2023) examined the use of renewable energy into medical cold chains for disaster response, providing a sustainable method for the storage of vaccines and pharmaceuticals. Ogazón et al. (2024) evaluated stochastic models for food bank operations, facilitating prompt responses while balancing regular and emergency activities.

These studies underscore the significance of sophisticated models, innovative technology, and interdisciplinary collaboration in catastrophe logistics. The amalgamation of blockchain, machine learning, and renewable energy, coupled with an emphasis on equity, training, and community dynamics, underscores the necessity for a comprehensive, adaptive strategy in disaster management. Collectively, these technologies enhance the efficiency and efficacy of humanitarian logistics, tackling both logistical and social aspects of disaster response.

Limitations in the previous studies

The analysed research on humanitarian logistics and catastrophe response reveals numerous constraints that impact the practical implementation of their concepts. The constraints generally pertain to generalisability, assumptions regarding real-world situations, computational challenges, and insufficient empirical validation, all of which impede the conversion of theoretical models into practical disaster management solutions.

A primary constraint is the generalisability of findings, as several research concentrate on particular geographic regions or disaster types, hence constraining their wider applicability. Goerlandt & Islam (2021) established a risk model to estimate delays in maritime transportation; nevertheless, it depended on hypothetical scenarios and expert opinions, which constrains its relevance in practical applications. Likewise, research conducted by Macea et al. (2018) and Souza et al. (2022), which concentrates on particular nations or areas (Colombia, Brazil, Indonesia), may not be relevant to other situations characterised by distinct infrastructure, cultural influences, or catastrophic trends. This dependence on context-specific data is a difficulty for creating universal models applicable to various disaster scenarios worldwide.

A notable issue is the presumption of fixed, predetermined conditions in numerous models. Numerous studies, such as those by Di Pasquale et al. (2020) and Cao et al. (2023), presume static disaster scenarios or supply chains, neglecting the dynamic and unexpected characteristics of actual disasters. In actual crisis scenarios, factors like resource availability, infrastructure damage, and changing needs can fluctuate swiftly, rendering models based on static assumptions less dependable. The disparity between theoretical models and the unpredictable circumstances of real-world catastrophe response is a persistent difficulty in the discipline.

Numerous research depend on expert-driven or subjective data, potentially introducing biases. Richardson et al. (2016) employed the Delphi technique to prioritise aspects affecting disaster aid, while recognising that subjective biases can influence the results. Likewise, Breman et al. (2019) concentrated on a limited sample of NGOs, which may not represent the wider humanitarian context. These biases, along with qualitative data from community-level studies (e.g., Gralla et al., 2015), may constrain the robustness and generalisability of the findings.

Computational complexity represents another significant concern. Numerous models, including those put out by

Liu et al. (2023) and Shokr et al. (2021), have scaling issues when implemented in extensive disaster contexts. Liu et al. (2023) observed that their stochastic programming model would probably encounter performance challenges when the magnitude of interruptions escalates. Moreover, heuristic algorithms, such as those employed by Souza Almeida et al. (2022) and Edrissi et al. (2015), frequently fail to ensure optimal solutions in extensive, real-time crisis scenarios owing to the intricacies of parameter calibration and the necessity for real-time data analysis.

A significant constraint in numerous studies is the absence of empirical confirmation. Numerous models, especially those utilising modern technology such as blockchain (L'Hermitte & Nair, 2021) and AI-driven methodologies (Fan et al., 2022), are deficient in real-world case studies or practical applications. The lack of empirical testing casts doubt on the practicality of these models in real crisis scenarios, particularly in areas with inadequate infrastructure or volatile weather. Moreover, most studies, like Biswas et al. (2024), depend on synthetic or limited case studies, complicating the evaluation of the scalability and robustness of the presented models.

Furthermore, assumptions on resource availability present considerable issues. Numerous models presume the accessibility of resources such as medical facilities, transportation, and energy supplies, which may be unrealistic in post-disaster contexts, particularly in resource-limited areas. This error complicates the effective use of such models in real-world crisis scenarios characterised by restricted or highly changeable resources.

Ultimately, improved uncertainty management is essential in disaster response models. Numerous studies presume near-perfect information regarding disaster scenarios; yet, actual disasters are intrinsically ambiguous. Models that fail to consider the unpredictability of elements such as resource requirements, infrastructure loss, and supply chain interruptions may yield unreliable answers in dynamic crisis contexts.

In conclusion, although the examined studies provide significant insights into disaster logistics, their limits highlight the difficulties in developing models that can respond to real-world complexities. Future research must concentrate on developing more scalable models, empirical validation, and enhanced incorporation of real-world uncertainty, while also giving greater attention to social, cultural, and equity considerations to enhance disaster management efficacy. Creating universally applicable models necessitates a comprehensive grasp of the multi-faceted nature of catastrophe response and the demand for adaptable, dynamic solutions.

CASE STUDIES:

Humanitarian logistics (HL) operations are essential in disaster response, as demonstrated by several studies highlighting effective techniques and insights gained from failures. Effective operations highlight the significance of anticipatory planning, cutting-edge technology, and flexible logistical structures.

Di Pasquale et al. (2020) emphasised the importance of inventory prepositioning in relation to Italian earthquakes. Their research indicated that the deliberate pre-positioning of critical resources prior to disasters markedly lowered delays and expenses. Through a numerical model, they determined appropriate inventory levels for things such as sanitary kits, blankets, and tents, leading to expedited emergency response times and reduced procurement expenses. This methodology, based on sophisticated modelling, offers a reproducible framework for global disaster preparedness. Likewise, the World Food Programme's (WFP) Logistics Response Team (LRT) training initiative, examined by Gralla et al. (2015), demonstrated that organised, immersive training improved responder preparedness. The LRT program developed adaptability and problem-solving abilities in participants through scenario-based exercises, while reflective feedback loops facilitated the incorporation of lessons learnt into subsequent operations. These findings emphasise the need of meticulously crafted training programs in establishing robust logistics systems.

Islam et al. (2021) examined the maritime transport infrastructure of Vancouver Island, emphasising its resistance to disruptions from landslides and other calamities. Their research underscored the essential function of tugs and barges in sustaining supply lines for coastal communities, stressing the necessity for redundancy and adaptive infrastructure. Edrissi et al. (2015) expanded upon this concept by examining transportation reliability in the context of disasters. Retrofitting essential transport infrastructure can alleviate interruptions, facilitating more efficient logistics and economic disaster response. Targeted investments in infrastructure were crucial for sustaining logistical networks during crises.

Bronfman et al. (2022) examined the significance of prioritisation in life-saving efforts, specifically addressing casualty stabilisation in mass-casualty incidents. Their research, focused on seismic scenarios in Chile, demonstrated that resource allocation strategies prioritising patient stabilisation according to injury severity and age could markedly enhance survival rates. Wang et al. (2023) devised heuristic models to improve operational response times. Their multi-objective optimisation system, which considered geographical limits and resource allocation expenses, showcased the efficacy of real-time decision-making tools, resulting in an 83% decrease in response times during crisis scenarios in the South China Sea.

Ogazón et al. (2024) conducted a study addressing the difficulty of reconciling standard food bank operations with heightened demand during disasters. They optimised resource allocation and delivery with stochastic models, ensuring that impacted people received essential resources efficiently. In a pertinent study, Souza Almeida and Goerlandt (2022) examined the restoration of road connection following disasters, employing Ant Colony Optimisation (ACO) to identify best pathways for debris clearance. Their method demonstrated greater efficiency than conventional approaches, providing a computationally effective alternative for logistical recovery.

Timperio et al. (2017) investigated decision-support systems for optimising facility locations in Indonesia, integrating Geographic Information Systems (GIS) with fuzzy analytical hierarchy processes. This interdisciplinary approach ensured the optimal placement of distribution centres, harmonising with community needs and available resources. Patrisina et al. (2019) investigated location-allocation strategies for disaster preparedness, demonstrating that mixed delivery networks, which integrate direct and indirect supply methods, exhibited greater flexibility and efficiency in uncertain settings.

Notwithstanding these achievements, humanitarian logistics encounters considerable hurdles, frequently exposed by unsuccessful missions. Oktarina et al. (2016) examined Indonesia's earthquake relief initiatives and observed a discrepancy between the allocated resources and the genuine needs of the impacted populace. Some items were oversupplied, while others were inadequately allocated, underscoring the necessity of localised strategies for resource distribution. Octavia et al. (2016) also criticised the disjointed coordination during catastrophes in East Java, highlighting the necessity for enhanced integrated planning and sophisticated simulation models to augment response efficiency.

Maghsoudi and Moshtari (2021) analysed the 2017 Kermanshah earthquake in Iran, highlighting that insufficient needs assessments and the disruptive impact of social media activists resulted in delays in response operations. The absence of coordination and inadequate technological utilisation intensified logistical inefficiencies. Sanci and Daskin (2019) found difficulties in catastrophe recovery, especially for the rebuilding of road networks. Their two-stage stochastic programming model, while promising, encountered practical implementation issues due to delays in restoring essential transit linkages, which compromised the model's efficacy.

These failures highlight the necessity of rectifying deficiencies in sustainability, planning, and coordination within HL operations. They underscore the necessity for localised and community-specific strategies for resource allocation, improved centralised management systems, and enhanced integration of technological tools to augment catastrophe preparedness and response. The successful instances illustrate the considerable potential of preemptive planning, sophisticated modelling, and customised decision-support systems in enhancing the efficiency, resilience, and responsiveness of humanitarian logistics. Collectively, these studies underscore the imperative for ongoing enhancements in HL tactics, including insights gained to more effectively tackle the intricate and evolving nature of disaster response.

Table 7: Summary of Key Humanitarian Logistics Case Studies and Findings

Authors	**Case Study**	**Key Findings**
Di Pasquale et al. (2020)	Italian Earthquakes	Pre-positioning of resources (e.g., hygienic kits, blankets, tents) minimized delays and costs.
Gralla et al. (2015)	WFP Logistics Response Team (LRT) Training	Immersive simulations and scenario-based exercises build adaptable problem-solving skills, improving operational readiness.
Islam et al. (2021)	Vancouver Island Maritime Transport System	Tugs and barges were crucial in maintaining supply chains despite disruptions like landslides.
Edrissi et al. (2015)	Transportation Reliability During Disasters	Retrofitting critical transportation infrastructure reduced delays and improved reliability during crises.
Souza Almeida and Goerlandt (2022)	Post-Disaster Road Connectivity Restoration	Ant Colony Optimization (ACO) methods outperformed traditional techniques in clearing debris and restoring road connectivity.
Bronfman et al. (2022)	Mass-Casualty Events (Chile Earthquake)	Prioritizing patient stabilization based on injury severity improved survival rates in resource-constrained situations.
Wang et al. (2023)	Disasters in South China Sea	Heuristic models reduced response times by 83% through real-time decision-making and resource allocation optimization.
Ogazón et al. (2024)	Food Banks in Mexico	Stochastic models optimized resource allocation to ensure timely delivery of aid during disasters.
Timperio et al. (2017)	Facility Location Optimization in Indonesia	GIS and fuzzy analysis integrated with local insights helped determine optimal facility locations for disaster

		relief.
Patrisina et al. (2019)	Disaster Preparedness in Indonesia	Mixed delivery networks combining direct and indirect methods enhanced flexibility and efficiency in resource distribution.
Oktarina et al. (2016)	Indonesia Earthquake Relief	Mismatch between distributed resources and actual needs led to inefficiencies.
Octavia et al. (2016)	East Java Disaster Coordination	Fragmented planning and lack of centralized management caused delays.
Maghsoudi and Moshtari (2021)	2017 Kermanshah Earthquake (Iran)	Delays in response due to inadequate needs assessments and social media interference.
Sanci and Daskin (2019)	Road Network Restoration After Disasters	Delays in restoring transportation links undermined recovery efforts.

CONCLUSION & FUTURE RESEARCH DIRECTIONS

In order to mitigate the effects of disasters, facilitate recovery, and increase community resilience, humanitarian logistics, or HL, is essential. Key findings from previous studies are compiled in this study, which also highlights notable advancements in equitable frameworks, inventory prepositioning, decision-making models, technology integration, and public-private collaborations. These developments highlight the necessity of adaptable, collaborative, and sustainable approaches to deal with the increasingly complex logistical problems in disaster relief.

There are still enduring gaps in spite of these developments, especially when it comes to coordination, equality, and the incorporation of sustainable logistics techniques. This assessment highlights the need for comprehensive policies that guarantee equitable resource distribution, use emerging technology, and include interdisciplinary expertise. Resilient, creative, and responsive HL systems are desperately needed as urbanisation and climate change continue to increase the frequency and intensity of disasters.

Future studies should focus on a few important aspects in order to improve humanitarian logistics even more. First, it's imperative to address equity in the distribution of resources. Even while equality is a common concept in HL literature, its practical application is frequently lacking. To guarantee that disaster response is both efficient and equitable, future research must concentrate on developing frameworks that guarantee the equitable and efficient distribution of resources, especially for marginalised and vulnerable communities.

The incorporation of cutting-edge technologies is another important topic. The Internet of Things (IoT), blockchain, and artificial intelligence (AI) have the potential to revolutionise disaster response decision-making. These technologies can improve coordination, optimise resource allocation, and raise situational awareness by using real-time data from sources including social media, satellite imagery, and sensor networks. This can result in quicker and more effective disaster management.

It's also critical to improve intersectoral coordination. Governmental, business, and humanitarian organisations must work together to respond to disasters effectively. Models that align the objectives of these various stakeholders and promote cooperation and trust should be investigated in future studies. Through these collaborations, coordination and resource allocation can be improved, increasing the overall efficacy of disaster response activities.

Another important concern for HL's future is sustainability. Logistics networks need to implement sustainable practices since lowering carbon emissions and minimising environmental effect are becoming more and more important global goals. This entails putting circular supply chains into place, utilising renewable energy, and aiming for carbon-neutral operations. In addition to reducing environmental issues, these techniques will increase the resilience and adaptability of HL systems, making it easier for them to handle the increasing number of climate-related calamities.

Lastly, increasing the effectiveness of disaster response activities requires funding for training and capacity building. Humanitarian teams can be better equipped to handle the complexity of HL by participating in scenario-based training programs that mimic actual crisis scenarios. These courses can improve problem-solving abilities, promote teamwork, and better prepare teams to deal with the unpredictability of emergencies.

By emphasising these interrelated areas—training, intersectoral collaboration, equity, technological integration, and sustainability—humanitarian logistics can adapt to the growing demands of disaster response. A foundation for creating HL systems that are more robust, inclusive, and sustainable is provided by the future research directions mentioned in this review. These advancements will assist scholars, politicians, and humanitarian organisations in developing systems that are better suited to handle today's problems, ultimately building a more resilient international community that can effectively handle disasters in the future.

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