A systematic literature review of infrastructure resilience in humanitarian logistics: infrastructure types, failure causes and resilience dimensions

Nizar Shbikat
Logistics Sciences Department, Business School, German Jordanian University, Amman, Jordan, and
Omar M. Bwaliez
Management Sciences Department, Business School, German Jordanian University, Amman, Jordan

Abstract

Purpose – This study conducts a systematic literature review to examine infrastructure resilience in humanitarian logistics, focusing on types, failure causes and resilience dimensions of the infrastructure. This study aims to provide an integrated understanding of how critical infrastructures function under disruptions and the strategies that enhance their robustness.

Design/methodology/approach – Using the preferred reporting items for systematic reviews and meta-analyses framework, 41 peer-reviewed articles were analyzed to classify infrastructure types, identify root causes of failure and synthesize resilience dimensions. The review adopted a thematic approach to highlight interdependencies and systemic vulnerabilities.

Findings – This study identifies six major causes of infrastructure failure: natural disasters, man-made disasters, aging and deteriorating infrastructure, interdependencies, communication and coordination failures and other contextual constraints. It also revealed four resilience dimensions of the infrastructure, namely, structural and systematic features, operational and functional capabilities, adaptive and management capacities, as well as institutional and governance mechanisms, underscoring resilience as a dynamic, multi-layered capability rather than a static attribute.

Practical implications – The findings provide resilience strategies such as investing in adaptive infrastructure, enhancing cross-sector coordination and leveraging emerging technologies for policymakers, humanitarian organizations and infrastructure planners to enhance risk management. By addressing identified vulnerabilities and leveraging resilience dimensions, stakeholders can enhance disaster preparedness, response and recovery efforts.

Originality/value – This study bridges fragmented literature on infrastructure resilience in humanitarian logistics by introducing a unified framework that integrates technical and institutional perspectives. It advances theory through the system-of-systems and dynamic capability lenses and offers practical guidance for policymakers and humanitarian organizations to strengthen preparedness, response and recovery.

Keywords Humanitarian logistics, Disaster management, Infrastructure types, Infrastructure failure causes, Infrastructure resilience dimensions, Systematic literature review

Paper type Literature review

1. Introduction

Humanitarian logistics is a cornerstone of disaster response and recovery, ensuring the timely delivery of essential goods and services to affected populations under extreme conditions (Kashav and Garg, 2025). The global frequency and severity of disasters have increased significantly due to climate change, rapid urbanization and geopolitical instability, affecting billions of people and causing substantial economic losses (Rojas Trejos *et al.*, 2023; Shrivastav and Bag, 2024). In such contexts, delays in logistics operations can result in loss of life and prolonged suffering, underscoring the critical importance of resilient infrastructure (Holguín-Veras *et al.*, 2012; Shakibaei *et al.*, 2024).

Infrastructure resilience is fundamental to the success of humanitarian logistics because transportation networks, communication systems, utilities and storage facilities form the backbone of relief operations (Goncalves and Chang, 2026).

The current issue and full text archive of this journal is available on Emerald Insight at: **https://www.emerald.com/insight/2042-6747.htm**

Journal of Humanitarian Logistics and Supply Chain Management
Emerald Publishing Limited [ISSN 2042-6747]
[DOI 10.1108/JHLSCM-07-2025-0135]

Received 30 July 2025
Revised 20 January 2026
20 April 2026
Accepted 22 May 2026

When these infrastructures fail, cascading disruptions occur across supply chains, delaying aid and increasing operational costs (Overstreet *et al.*, 2011; Fekete *et al.*, 2021). Real-world examples illustrate these vulnerabilities. For example, the 2010 Haiti earthquake paralyzed logistics networks due to collapsed roads, bridges and communication lines (Holguín-Veras *et al.*, 2012; Shakibaei *et al.*, 2024), the 2019 Cyclone Idai in Zimbabwe, inadequate infrastructure severely constrained relief operations (Chari *et al.*, 2021), while the 2023 Turkey-Syria earthquake caused catastrophic damage to infrastructure and logistics networks, destroying roads, bridges, hospitals and utilities, while severely disrupting supply chains, fuel distribution and humanitarian aid delivery across both countries (Ahmed, 2023). These cases highlight the urgent need for proactive resilience strategies that address both physical robustness and institutional coordination (Mutebi *et al.*, 2025).

Despite its importance, existing literature on infrastructure resilience remains fragmented. Many studies focused narrowly on technical robustness, such as structural integrity of roads or bridges, or on specific disaster types, while neglecting systemic interdependencies and governance dimensions (Mostafavi and Inman, 2016; Paciarotti *et al.*, 2021). Furthermore, resilience frameworks often adopt reactive approaches, emphasizing post-disaster recovery rather than anticipatory planning (Nateghi, 2018; Imbriale, 2026). Few works provided a holistic synthesis of infrastructure types, failure causes and resilience strategies within humanitarian logistics, leaving a critical gap in both theory and practice (Sonesson *et al.*, 2021; Kashav and Garg, 2025). This gap limits the ability of policymakers and practitioners to design integrated resilience strategies that address multi-dimensional vulnerabilities.

This study addresses these gaps by conducting a systematic literature review of 41 peer-reviewed articles to examine infrastructure resilience in humanitarian logistics. Specifically, it categorizes infrastructure types, identifies root causes of failure and synthesizes resilience dimensions to develop a comprehensive framework for strengthening humanitarian logistics. The novelty of this research lies in its system-of-systems and dynamic capability theories (Teece, 2007; Eusgeld *et al.*, 2011), which bridge technical and institutional domains to conceptualize resilience as a dynamic, multi-layered capability rather than a static attribute (Osei-Kyei *et al.*, 2021; Shishodia *et al.*, 2023). By integrating academic insights with real-world cases, this study advances theory and offers actionable strategies for strengthening preparedness, response and recovery.

The objectives of this study are to provide a comprehensive understanding of infrastructure resilience in humanitarian logistics by classifying the types of infrastructure critical to humanitarian logistics, identifying and analyzing the major causes of their failure and synthesizing resilience dimensions into an integrated framework. By doing so, the study seeks to bridge technical and institutional perspectives, offering both theoretical insights and practical guidance for strengthening preparedness, response and recovery in humanitarian supply chains.

The remainder of this study is organized as follows: Section 2 reviews prior literature; Section 3 outlines the methodology; Section 4 presents the results; Section 5 discusses findings and provides theoretical and practical implications; and Section 6 concludes with the main findings, limitations and directions for future research.

2. Literature review

2.1 Role of infrastructure resilience in humanitarian logistics

Infrastructure is a fundamental enabler of humanitarian logistics, shaping the capacity of organizations to respond effectively to crises (Fekete *et al.*, 2021). It includes both physical components (e.g. roads, bridges, airports, seaports, storage facilities) and digital systems that support communication and coordination (Daousis *et al.*, 2024). The performance of humanitarian supply chains is closely tied to the condition and accessibility of these infrastructures, especially in disaster-prone or conflict-affected regions (Damoah, 2022). Without reliable infrastructure, humanitarian supply chains face severe delays, increased costs and operational inefficiencies, ultimately compromising the effectiveness of disaster response (Overstreet *et al.*, 2011; Fekete *et al.*, 2021). Table 1 presents different scholarly definitions of infrastructure from selected studies, highlighting how the concept has been conceptualized across various disciplines, including humanitarian logistics, disaster management and urban planning. Each definition emphasizes different aspects of infrastructure, reflecting its multidimensional nature.

The ability of systems to withstand shocks, adapt to changing conditions and recover functionality while sustaining essential services is called infrastructure resilience (Goncalves and Chang, 2026). As illustrated in Figure 1, this concept is underpinned by five interrelated general dimensions: robustness, adaptive capacity, network and interdependency management, information visibility and sensing and governance and preparedness. Robustness ensures physical strength and protection against hazards, whereas adaptive capacity enables flexibility and operational reconfiguration during crises. Network and interdependency management addresses connectivity and mitigates cascading failures across interconnected systems. Information visibility and sensing provide timely, accurate data for informed decision-making, while governance and preparedness emphasize proactive planning and coordinated action among multiple stakeholders. Collectively, these dimensions position resilience as a dynamic, multi-layered capability rather than a static attribute, consistent with established frameworks in disaster logistics and broader resilience research (Bruneau *et al.*, 2003; Christopher and Peck, 2004; Mostafavi and Inman, 2016; Shishodia *et al.*, 2023).

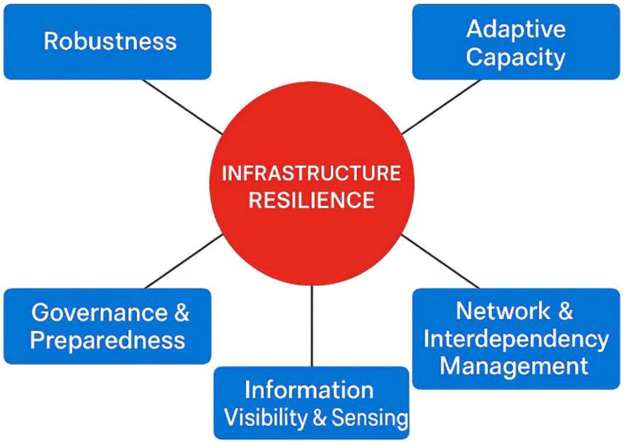
In humanitarian logistics, resilience is vital because infrastructure breakdowns can propagate disruptions throughout supply chains, delaying relief and amplifying human suffering (Osei-Kyei *et al.*, 2021; Anjomshoae *et al.*, 2022). This capability integrates structural robustness, operational agility and adaptive management to maintain continuity under stress (Shishodia *et al.*, 2023). Practical examples include modular warehouses, mobile clinics and flexible transport networks that enable rapid deployment and reconfiguration during emergencies (Croope and McNeil, 2011; Morshed *et al.*, 2021). Beyond physical assets, digital and

Table 1 Definition of infrastructure

Study	Definition	Key focus	Relevance to humanitarian logistics
Anand (2009)	"Various services whose availability is crucial to the functioning of economic activity"	Economic functionality: infrastructure is framed as a facilitator of economic operations, implying that disruptions in infrastructure can hinder productivity and trade	In disaster scenarios, economic stability is often disrupted, making infrastructure restoration critical for recovery (e.g. reopening supply chains, markets)
Jaller *et al.* (2015)	"The type of facilities, services, and installations (e.g., transportation, communication, energy systems) that are essential for the functioning of a community, city, or country"	Community and societal functionality: expands beyond economics to include critical facilities (e.g. hospitals, roads, power grids) necessary for societal survival	Humanitarian operations depend on these facilities (e.g. transport networks for aid delivery, communication systems for coordination)
Niewöhner (2022)	"Networked technical devices that support social action"	Technical and social interdependence: highlights that infrastructure is not just physical but also networked, meaning failures in one component can cascade	Disruptions in one infrastructure (e.g. power outages) can paralyze others (e.g. water pumps, digital systems) and complicate disaster response
Daousis *et al.* (2024)	"The physical and virtual assets, systems, and networks that are crucial for the functioning of a society. These infrastructures are considered vital due to their significant impact on national security, economic stability, and public health and safety"	Holistic and security-oriented: expands the definition to include virtual (cyber) infrastructure and links resilience to national security and public health	Cyber infrastructure (e.g. data systems for tracking aid) is increasingly critical in modern humanitarian operations

Source(s): Authors' own work

Figure 1 General infrastructure resilience dimensions



Source: Authors' own work

organizational dimensions strengthen resilience through real-time communication systems, predictive analytics and internet of things (IoT)-enabled monitoring, which enhance situational awareness and optimize resource allocation (Papadopoulos *et al.*, 2017; Habibi Rad *et al.*, 2021; Abushaikha *et al.*, 2025). Governance mechanisms such as multi-agency coordination and equity-focused recovery strategies further reinforce resilience by aligning priorities and ensuring inclusive restoration (Mostafavi and Inman, 2016; Sonesson *et al.*, 2021).

Recent literature underscores the importance of anticipatory strategies that extend beyond reactive recovery (Abushaikha *et al.*, 2026). Scenario-based stress testing, redundancy planning and proactive maintenance of aging infrastructure are critical for mitigating systemic risks before disasters occur (Nateghi, 2018; Nasrazadani *et al.*, 2025). Emerging technologies such as artificial intelligence (AI) and blockchain offer opportunities for predictive risk modeling and transparent coordination, though their success depends on reliable enabling systems like power and communication networks (Habibi Rad *et al.*, 2021; Younis *et al.*, 2024). Taken together, these insights highlight that infrastructure resilience in humanitarian logistics requires integrated approaches combining technical robustness, adaptive capacity and governance agility to sustain operations in increasingly complex and uncertain environments.

2.2 Infrastructure failure in humanitarian logistics

Infrastructure failure represents one of the most critical vulnerabilities in humanitarian logistics, often resulting in delayed aid delivery, increased operational costs and heightened risks for affected populations. Failures can stem from natural disasters such as earthquakes, hurricanes, floods and volcanoes, which damage transportation networks, utilities and communication systems, creating disruptions across supply chains (Cimellaro *et al.*, 2019; Bi *et al.*, 2023). For example, the destruction of key routes during the 2010 Haiti earthquake severely constrained logistics operations and delayed the arrival of essential supplies (Holguín-Veras *et al.*, 2012; Shakibaei *et al.*, 2024). Similarly, during the 2019 Cyclone Idai in Zimbabwe, damaged roads and communication failures significantly disrupted aid delivery, highlighting the vulnerability of logistics systems to infrastructural breakdowns (Chari *et al.*, 2021).

Man-made disruptions compound these challenges, including cyberattacks, terrorism and operational errors that compromise critical infrastructure functionality. Cybersecurity threats targeting control systems can cripple communication networks, undermining coordination and situational awareness during emergencies (Kuraganti *et al.*, 2020). Social unrest and economic shocks also exacerbate fragility by destabilizing supply chains and limiting resource availability for infrastructure maintenance and recovery (Hecht *et al.*, 2019). These failures are particularly severe in low-income or conflict-affected regions, where chronic underinvestment and institutional fragmentation hinder resilience-building efforts (Chester *et al.*, 2021; Shrivastav and Bag, 2024).

Beyond acute shocks, systemic weaknesses such as aging infrastructure, interdependencies and governance gaps magnify the impact of failures. Underinvestment in maintenance leaves transportation and utility networks vulnerable to collapse even under moderate stress (Chester *et al.*, 2021). Interdependencies among systems, such as electricity powering water pumps and traffic management, mean that localized failures can escalate into regional crises (Eusgeld *et al.*, 2011; Dasuni *et al.*, 2025). Communication and coordination failures further delay recovery, as fragmented responsibilities and siloed decision-making impede rapid response (Papadopoulos *et al.*, 2017; Sonesson *et al.*, 2021). These insights underscore that infrastructure failure in humanitarian logistics is not merely a technical issue but a multidimensional challenge requiring integrated resilience strategies across physical, digital and institutional domains.

2.3 Gaps in humanitarian logistics infrastructure resilience literature

Although research on humanitarian logistics has grown, several gaps remain. First, most studies focus on planning and descriptive reviews rather than integrating resilience concepts across preparedness, response and recovery phases (Overstreet *et al.*, 2011; Leiras *et al.*, 2014). Second, the complex, multi-actor nature of humanitarian operations is acknowledged but rarely addressed through frameworks that link technical infrastructure resilience with governance and coordination (Tatham and Houghton, 2011; Leiras *et al.*, 2014). Third, standards and interoperability, critical for coordination, are inconsistently applied, creating fragmentation during surge operations (Overstreet *et al.*, 2011; Paciarotti *et al.*, 2021). Fourth, accessibility constraints and network vulnerabilities are underrepresented in resilience models, limiting strategies for intermodal and redistribution planning (Leiras *et al.*, 2014; Rojas Trejos *et al.*, 2023). Fifth, procurement strategies rarely embed resilience considerations beyond cost and lead time, weakening upstream readiness (Overstreet *et al.*, 2011; Bhusiri *et al.*, 2021). Sixth, insights from broader supply chain resilience research are seldom adapted to humanitarian infrastructure contexts, reducing theoretical and practical consistency (Leiras *et al.*, 2014; Shishodia *et al.*, 2023). Finally, while digital technologies are emerging as enablers, evidence remains fragmented and lacks assessment of infrastructure dependencies such as power and connectivity (Paciarotti *et al.*, 2021; Shrivastav and Bag, 2024).

These gaps highlight the need for a comprehensive framework that addresses both technical and institutional dimensions of infrastructure resilience in humanitarian logistics. This study responds by classifying critical infrastructure types and their interdependencies to overcome fragmentation and accessibility challenges, identifying and synthesizing the root causes of infrastructure failure across disaster phases to develop phase-aware resilience strategies and proposing multidimensional resilience dimensions, covering structural, operational, adaptive and governance aspects, that integrate technical robustness with coordination, procurement and digital enablers. By bridging these gaps, the study seeks to provide a holistic, actionable framework that strengthens preparedness, response and recovery in humanitarian supply chains.

2.4 System-of-systems and dynamic capability theoretical perspectives

The system-of-systems theory refers to a class of complex systems composed of multiple, independent and operationally autonomous systems that interact to deliver emergent capabilities not achievable by individual components alone. In the context of critical infrastructure, the system-of-systems theory emphasizes autonomy, interdependencies, interoperability and cascading effects, explaining how disruptions in one system can propagate across others and generate systemic failure (Eusgeld *et al.*, 2011; Ouyang, 2014). Infrastructure systems supporting humanitarian logistics such as transportation, utilities, communication, logistics facilities and social services fit this definition, as they are governed independently yet become tightly coupled during disaster response. Prior infrastructure and logistics research demonstrated that resilience outcomes are shaped by these cross-system interactions rather than by individual asset robustness alone (Mostafavi and Inman, 2016; Cimellaro *et al.*, 2019). Accordingly, the system-of-systems perspective provides a theoretical foundation for conceptualizing infrastructure resilience in humanitarian logistics as a system-level property emerging from coordinated performance across multiple infrastructures.

By contrast, dynamic capability theory focuses on how organizations and institutions build and sustain performance under conditions of change by continuously adapting their resources and processes. Dynamic capabilities are commonly defined as the abilities to sense emerging threats and opportunities, seize appropriate responses and reconfigure assets and routines to remain effective in turbulent environments (Teece, 2007). In supply chain and humanitarian logistics research, this theory has been used to explain how organizations develop resilience through preparedness planning, rapid adaptation during crises and post-event learning rather than through static buffers alone (Christopher and Peck, 2004; Tomasini and Van Wassenhove, 2009). More recent resilience studies further emphasized that dynamic capabilities manifest through coordination, learning, governance mechanisms and strategic flexibility (Pettit *et al.*, 2010; Shishodia *et al.*, 2023). Within this study, dynamic capability theory underpins the interpretation of infrastructure resilience dimensions as adaptive, managerial and institutional capabilities, explaining how resilience evolves across preparedness, response and recovery phases and complementing the system-of-systems view of systemic interdependence.

3. Methodology

3.1 Systematic literature review approach

This study used a systematic literature review approach guided by the preferred reporting items for systematic reviews and meta-analyses (PRISMA) framework to ensure methodological rigor and transparency (Moher *et al.*, 2009). The SLR method was chosen for its ability to synthesize fragmented research systematically and transparently, ensuring rigor and reproducibility (Denyer and Tranfield, 2009; Agarwal *et al.*, 2020), while PRISMA was selected to provide a structured process for identification, screening, eligibility and inclusion, thereby minimizing bias and enhancing clarity (Moher *et al.*, 2009; Mishra and Mishra, 2023; Samawi *et al.*, 2026). Searches were conducted across two major databases, Scopus and Google Scholar, selected for their extensive coverage of peer-reviewed and interdisciplinary literature (Rojas Trejos *et al.*, 2023; Shishodia *et al.*, 2023; Younis *et al.*, 2024); Scopus offers high-quality indexed journals, whereas Google Scholar captures additional scholarly works including gray literature, thus ensuring the inclusivity and comprehensiveness essential for research on humanitarian logistics and infrastructure resilience research (Agarwal *et al.*, 2020; Rojas Trejos *et al.*, 2023).

3.2 Search strategy

The literature search was conducted using Scopus and Google Scholar, adopting a conceptually consistent yet database-specific search process to account for differences in indexing scope and search functionality. The timeframe was restricted to 2010–2025 to capture contemporary developments in resilience theory and practice. The same core search string, combining the keywords “infrastructure”, “resilience” and “humanitarian logistics,” was used in both databases to ensure conceptual alignment and replicability. However, the execution of the search was not identical. In Scopus, the search string was applied to titles, abstracts and keywords, leveraging the database’s advanced filtering options and curated journal coverage. By contrast, Google Scholar was used to perform a broader search across full texts due to its inclusive indexing approach and limited field-specific search controls. This differentiated but conceptually equivalent approach is consistent with PRISMA-guided systematic literature reviews and established practices in humanitarian logistics research (Moher *et al.*, 2009; Agarwal *et al.*, 2020; Mishra and Mishra, 2023).

When the finalized search strings were applied, 92 records were retrieved from Scopus and 148 records from Google Scholar, yielding a total of 240 records at the identification stage. The results from each database were first screened separately and then aggregated into a single data set for further analysis (Rojas Trejos *et al.*, 2023). Because articles indexed in Scopus are typically also indexed in Google Scholar, a structured duplicate removal procedure was applied during screening. Duplicates were identified based on matching titles, authors, publication year and journal outlet. When identical records appeared in both databases, the Scopus-indexed version was retained due to its verified indexing and bibliographic reliability, while Google Scholar-only records were retained when they met all inclusion criteria and were not indexed in Scopus. This procedure was explicitly incorporated into the exclusion criteria to prevent double counting while maintaining comprehensive coverage of relevant literature, in line with best practices in systematic reviews within humanitarian logistics and supply chain research (Rojas Trejos *et al.*, 2023; Shishodia *et al.*, 2023).

3.3 Inclusion and exclusion criteria

Inclusion criteria focused on studies addressing infrastructure types, failure causes and resilience dimensions in humanitarian contexts, while exclusion criteria eliminated non-scholarly sources, technical reports and studies outside the scope of logistics resilience. This systematic approach ensured the retrieval of high-quality, relevant literature for subsequent screening and analysis (Moher *et al.*, 2009; Agarwal *et al.*, 2020; Rojas Trejos *et al.*, 2023).

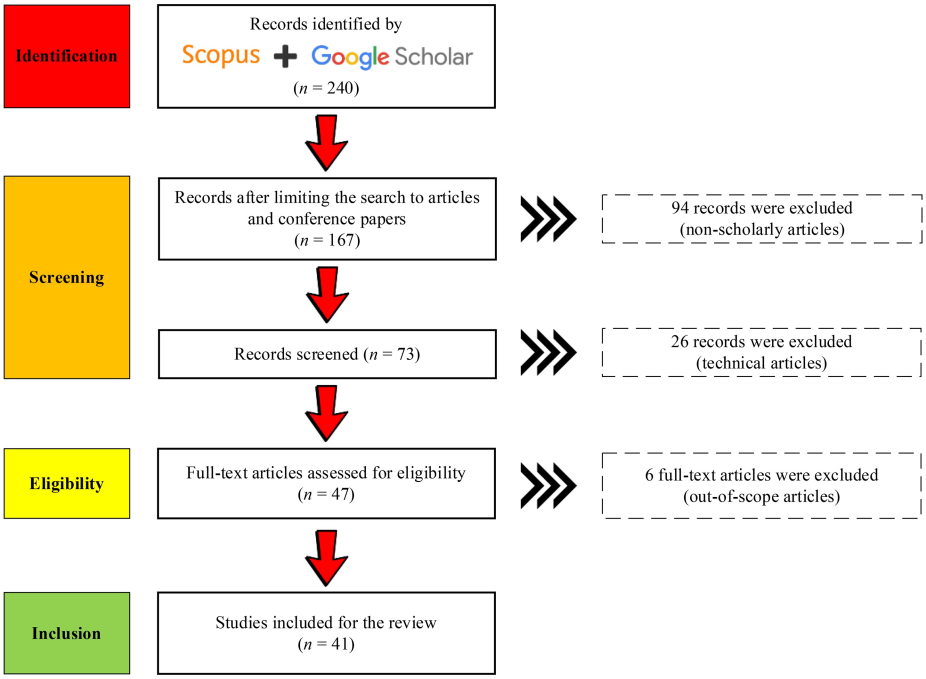
3.4 Screening process

The PRISMA-based screening process, depicted in Figure 2, began with the identification of 240 records from Scopus and Google Scholar databases using the search string. Following an initial refinement to include only peer-reviewed articles and conference papers, 167 records remained, after which 94 non-scholarly articles were excluded, leaving 73 records for further review. Subsequent screening eliminated 26 technical articles, resulting in 47 full-text articles assessed for eligibility. Of these, six were excluded due to irrelevance to the study scope, yielding a final selection of 41 studies included in the review. This multi-stage process minimized bias and ensured that the review captured high-quality, representative literature for subsequent data extraction and analysis.

3.5 Data extraction and analysis

To ensure rigor and transparency, data extraction followed a structured protocol aligned with best practices in systematic literature reviews (Moher *et al.*, 2009; Paciarotti *et al.*, 2021; Younis *et al.*, 2026). A standardized extraction form was developed to capture key attributes from each study, including publication details, humanitarian context, infrastructure types, identified failure causes and resilience dimensions (Mottahedi *et al.*, 2021; Sathurshan *et al.*, 2022; Mishra and Mishra, 2023; Rojas Trejos *et al.*, 2023). The coding process was iterative and guided by resilience frameworks proposed in prior research, emphasizing robustness, redundancy, resourcefulness and rapidity as core dimensions (Morshed *et al.*, 2021; Shishodia *et al.*, 2023). Thematic analysis was used to synthesize findings across studies, grouping them into three overarching categories: infrastructure types, failure causes and resilience dimensions (Osei-Kyei *et al.*, 2021; Nasrazadani *et al.*, 2025). Cross-comparison techniques were applied to identify patterns, gaps and interdependencies among these categories, enabling the development of an integrated conceptual framework for infrastructure resilience in humanitarian logistics (Mostafavi and Inman, 2016; Papadopoulos *et al.*, 2017). To enhance reliability, coding decisions were validated against definitions and classifications from established resilience literature, ensuring consistency and minimizing subjectivity (Nateghi, 2018; Habibi Rad *et al.*, 2021). This systematic approach allowed for a comprehensive synthesis of fragmented knowledge and provided a robust foundation for subsequent analysis and discussion.

Figure 2 PRISMA-based screening process



Source: Authors' own work

4. Results

4.1 Most popular keywords

An analysis of the 41 studies highlighted the growing importance of infrastructure resilience within the humanitarian logistics sector. To support this investigation, we developed a web-based word cloud generator (https://sites.google.com/view/wordcloudgenerator/word-cloud-generator) to identify the most frequently used keywords in this field. A total of 198 keywords were analyzed, with the resulting word cloud (shown in Figure 3) emphasizing some dominant terms: "Resilience," "Critical infrastructure" and "Infrastructure." These findings reflected the effectiveness of our identification and screening process in capturing the core themes relevant to this research.

4.2 Infrastructure types critical to humanitarian logistics

Humanitarian logistics relies on a diverse set of infrastructures that collectively enable the timely delivery of aid and essential services during crises. The reviewed literature revealed various infrastructure types, classified by function in Table 2. These infrastructures can be grouped into six functional categories: transportation networks, utilities, communication and information systems, logistics and storage facilities, social and public services and production and supply networks. Transportation networks, including roads, bridges, airports and seaports, are indispensable for moving relief goods and facilitating evacuations, yet they are highly vulnerable to disruptions from natural hazards and systemic failures (Holguín-Veras *et al.*, 2012; Polater, 2020; Gerges *et al.*, 2022). Utilities such as electrical grids and fuel systems sustain critical operations, while water and cooling systems support health services and vaccine storage (Chester *et al.*, 2021). Communication and information infrastructures, including traffic management and information and communication technology (ICT) platforms, enable real-time coordination among stakeholders, which is essential for synchronizing multi-agency efforts during emergencies (Van Wassenhove, 2006; Day *et al.*, 2012). Similarly, logistics hubs, such as warehouses, distribution centers and food banks, facilitate pre-positioning and rapid dispatch of supplies, reducing lead times and improving response efficiency (Balcik and Beamon, 2008; Duran *et al.*, 2013). Social and public service infrastructures, such as hospitals and educational facilities, provide emergency care and shelter, while production and supply systems, including agriculture and manufacturing, ensure continuity of essential goods in prolonged crises.

A critical insight from the literature is the high degree of interdependence among these infrastructures, which amplifies systemic vulnerability during disasters. Transportation systems, for example, depend on electricity for traffic control and fuel for mobility, while communication networks require stable power and data connectivity to function effectively (Jaller *et al.*, 2015). Failures in one sector can cascade across others, as illustrated by the 2012 Hurricane Sandy's impact on New York, where power outages disrupted transportation, fuel distribution and health services simultaneously (Cimellaro *et al.*, 2019). This system-of-systems dynamic underscores the need for integrated resilience planning that accounts for functional, spatial and operational linkages among infrastructures (Eusgeld *et al.*, 2011; Dasuni *et al.*, 2025). Temporary solutions such as modular logistics hubs and mobile clinics can partially mitigate these vulnerabilities, but long-term resilience requires proactive investment in adaptive

Figure 3 Word cloud analysis for infrastructure resilience in humanitarian logistics

Source: Authors' own work

and redundant systems capable of maintaining continuity under stress (Morshed *et al.*, 2021). Recognizing these interdependencies is essential for policymakers and humanitarian actors to prioritize interventions that prevent cascading failures and strengthen the overall robustness of humanitarian logistics networks.

4.3 Infrastructure failure causes

The resilience of humanitarian logistics infrastructures is undermined by a complex interplay of disruptive causes, both acute and chronic. A synthesis of the 41 peer-reviewed articles revealed six overarching categories of contributing causes: natural disasters, manmade disasters, aging and deteriorating infrastructure, infrastructural interdependencies, communication and coordination failures and other contextual factors such as funding shortages, institutional rigidity and topographic barriers. These categories are visually represented in the fishbone diagram (also called an Ishikawa diagram or cause-and-effect diagram), shown in Figure 4. A fishbone diagram visually maps potential causes of a specific problem (the "effect") by categorizing them into main branches leading to the problem's head (Ilie and Ciocoiu, 2010; Goetsch and Davis, 2014). Figure 4 illustrates the causes and the references in brackets. It should be noted that some causes were mentioned by a large number of references, specifically, the natural disasters. The citation of the references in this case took into consideration the distribution of the references over the causes such that all references are mentioned at least once.

Natural disasters remain the most frequently studied trigger events for infrastructure failure. Floods, hurricanes, earthquakes and snowstorms are among the most prominently discussed hazards. For instance, the 2012 Hurricane Sandy's cascading effects on transportation, power and fuel networks in New York highlighted how storm surges and flooding can paralyze multiple systems simultaneously (Cimellaro *et al.*, 2019). Climate change has further exacerbated the frequency and intensity of such hazards, increasing the vulnerability of infrastructures worldwide (Habibi Rad *et al.*, 2021; Bi *et al.*, 2023). Volcanic hazards, though less commonly addressed, were examined by Weir *et al.* (2024), who demonstrated how lahars and ashfall disabled water pipelines and electricity lines, reinforcing the need for hazard-specific resilience strategies.

Man-made disruptions constitute another critical category of infrastructure vulnerability. Terrorism, cyberattacks and operational mistakes can cripple communication networks, transportation systems and utilities. Cybersecurity threats targeting control systems have been shown to undermine coordination and situational awareness during emergencies (Kuraganti *et al.*, 2020). Social unrest, riots and economic shocks further destabilize supply chains and limit resource availability for infrastructure maintenance and recovery (Day, 2014; Hecht *et al.*, 2019). Unlike natural hazards, which often follow predictable geographic patterns, man-made threats introduce uncertainty and require robust security protocols, redundancy measures and contingency planning to safeguard critical infrastructure.

Beyond sudden shocks, chronic issues such as aging and deteriorating infrastructure represent persistent sources of fragility. Underinvestment in maintenance and modernization leaves transportation and utility networks susceptible to collapse even under moderate stress (Chester *et al.*, 2021). Bridges, roads and pipelines that are not adequately maintained often fail during disasters, compounding the effects of natural or man-made hazards. This slow-onset deterioration is predictable yet frequently overlooked, highlighting the need for proactive investment in resilient design and preventive maintenance (Nateghi, 2018). The literature consistently emphasizes that resilience cannot be achieved without addressing the chronic fragility of aging infrastructure systems.

Table 2 Infrastructure types critical to humanitarian logistics

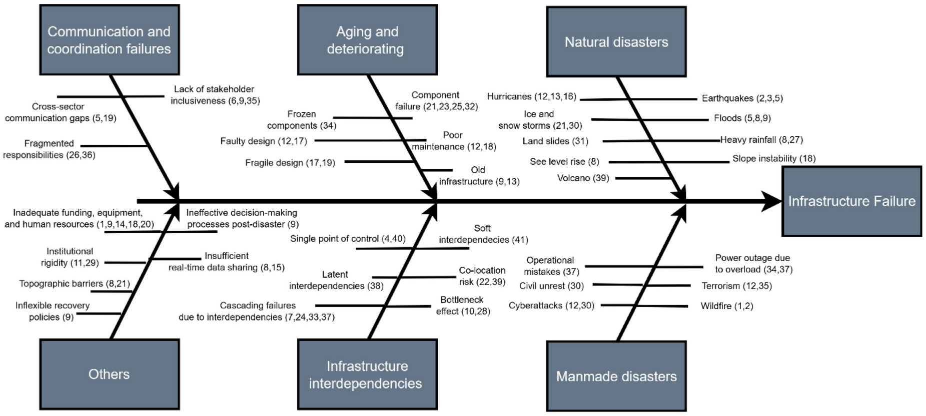
Infrastructure type	Description
Transportation networks	
Roads	Facilitate access to affected areas and enable the efficient ground transportation of humanitarian aid
Bridges	Fundamental links within road networks, serving a critical role in connecting local areas and supporting regional material flows
Highways	Link cities and facilitate rapid long-distance deliveries and evacuations
Arterial roads	Main roads in cities, usually linking urban areas with highways
Railways	Carry bulk materials over long distances
Subways	Underground rail-based public transportation systems
Airports	Air transportation hubs used to handle airborne cargo and passengers
Seaports	Coastal transportation hubs used for docking ships to load and unload cargo and passengers
Transit systems	Public transport systems including buses, subways and light rails, usually administered by a single agency
Intermodal networks	Transportation systems that integrate and link multiple modes; ports are examples of intermodal nodes
Evacuation routes	Designated transportation corridors for evacuating people during emergencies
Utilities	
Electrical grids	Interconnected systems for generating, storing and transmitting electricity. Crucial for logistics operations such as electric transport and warehouses
Fuel systems	Infrastructure and operations needed to produce, store and distribute fuels (e.g. gasoline, diesel, aviation fuel, propane)
Gas pipelines	Underground or aboveground pipe systems transporting gas or liquified petroleum gas (LPG) from production/storage facilities to end-users
Water systems	Network used to produce, store and distribute drinking water to end-users
Stormwater pipelines	Underground networks designed to drain or collect rainwater from streets and houses and transport it to designated areas
Cooling systems	Systems designed to regulate heat and preserve temperature, essential in data centers and vaccine storage facilities
Communication and information systems	
Communication systems	Technological infrastructure for transmitting information (e.g. data, video, voice) via wired and wireless means
Information systems	Tangible and intangible assets used to create, process, store and disseminate information to support decision-making
Traffic management systems	Technologies and policies to monitor, regulate and optimize the movement of vehicles and people
Logistics and storage facilities	
Warehouses	Facilities used to stockpile, sort and dispatch materials to end-users
Distribution centers	Similar to warehouse but designed for faster throughput; materials are temporarily stored before dispatch
Retail facilities	Facilities such as pharmacies, grocery stores and fulfillment centers that support humanitarian response due to their wide geographical dispersion and accessibility
Food banks	Non-profit or public facilities that collect, store and distribute food to people facing food insecurity
Social and public services	
Public health systems	Institutions and organizations providing health services (e.g. hospitals, clinics, laboratories)
Educational systems	Institutions and facilities delivering education services (e.g. schools, universities), often used as shelters during disasters
Housing facilities	Structures and spaces where people live in, including private houses, shelters and camps
Government infrastructures	Administrative and governance facilities maintaining order and civil services (e.g. police stations, national databases, emergency operation centers)
Production and supply systems	
Agricultural systems	Processes, infrastructures, technologies and workforce for producing, harvesting, storing and distributing food and agricultural products
Industrial productions	Infrastructure and facilities for producing or assembling products (e.g. factories, workshops), crucial for local self-reliance and rapid response

Source(s): Authors' own work

Interdependencies among infrastructures amplify systemic vulnerabilities and contribute to cascading failures. For example, electricity outages can disrupt water supply systems, communication networks, transportation operations and healthcare services simultaneously, demonstrating the system-of-systems nature of infrastructure resilience (Eusgeld *et al.*, 2011). These interdependencies can be functional, spatial or physical, meaning that localized damage can rapidly escalate into regional crises (Dasuni *et al.*, 2025). The 2010 Haiti earthquake and 2019 Cyclone Idai in Zimbabwe both illustrated how interdependent failures paralyzed humanitarian logistics, delaying aid and increasing human suffering (Chari *et al.*, 2021; Shakibaei *et al.*, 2024).

Communication and coordination failures further exacerbate infrastructure breakdowns. Fragmented responsibilities, poor cross-sector communication and siloed decision-making often delay recovery efforts and paralyze response operations (Papadopoulos *et al.*, 2017; Sonesson *et al.*, 2021). For example, Sonesson *et al.* (2021) emphasized the importance of having a central actor to steer cross-sector collaboration, highlighting that without effective coordination, infrastructural

Figure 4 Fishbone diagram for infrastructure failure



Note(s): [1] Morshed *et al*., 2021; [2] Twumasi-Boakye and Sobanjo, 2019; [3] Soltani-Sobh *et al*., 2016; [4] Turnquist and Vugrin, 2013; [5] Chang *et al*., 2014; [6] Singh *et al*., 2018; [7] Rachunok and Nateghi, 2020; [8] Watson and Ahn, 2022; [9] Croope and McNeil, 2011; [10] Papadopoulos *et al*., 2017; [11] Orengo Serra and Sanchez-Jauregui, 2022; [12] Mottahedi *et al*., 2021; [13] Sun *et al*., 2020; [14] Bhusiri *et al*., 2021; [15] Kopanaki, 2022; [16] Gerges *et al*., 2022; [17] Santos *et al*., 2020; [18] Mostafavi and Inman, 2016; [19] Sathurshan *et al*., 2022; [20] Esmalian *et al*., 2022; [21] Nateghi, 2018; [22] McDaniels *et al*., 2015; [23] Blagojević *et al*., 2023; [24] Day, 2014; [25] Afrin and Yodo, 2019; [26] Cedergren *et al*., 2018; [27] Dargin and Mostafavi, 2020; [28] Wang *et al*., 2019; [29] Chester *et al*., 2021; [30] Hecht *et al*., 2019; [31] Liu *et al*., 2022; [32] Murdock *et al*., 2018; [33] Rehak *et al*., 2018; [34] Tiedmann *et al*., 2023; [35] Cantelmi *et al*., 2021; [36] Habibi Rad *et al*., 2021; [37] Bi *et al*., 2023; [38] Cimellaro *et al*., 2019; [39] Weir *et al*., 2024; [40] Kuraganti *et al*., 2020; [41] Dasuni *et al*., 2025
Source: Authors' own work

interdependencies remain unmanaged and recovery is delayed. These failures are particularly severe in humanitarian contexts, where rapid coordination among multiple agencies is essential to minimize human suffering.

Contextual factors such as funding shortages, institutional rigidity and topographic barriers also contribute to infrastructure failures. Funding constraints often prevent investment in resilient infrastructure or limit recovery to "like-for-like" replacement of damaged assets, ignoring opportunities to improve resilience (Chester *et al.*, 2021). Institutional rigidity, such as inflexible procurement policies or fragmented governance structures, further undermines adaptive responses (Leiras *et al.*, 2014). Topographic barriers, including mountainous terrain or flood-prone regions, exacerbate accessibility challenges and delay humanitarian logistics operations (Shrivastav and Bag, 2024). These contextual constraints highlight that resilience is not only a technical issue but also a socio-political challenge requiring integrated solutions.

Taken together, these six categories of failure causes demonstrate that infrastructure vulnerability is multi-dimensional and systemic. While disasters act as immediate triggers, the underlying condition of infrastructure and its governance systems ultimately determines the scale and duration of disruption. Addressing these causes requires holistic resilience strategies that integrate technical robustness, adaptive management and institutional coordination. By situating these insights within system-of-systems and dynamic capability theories, this study underscores the need for proactive, multi-layered approaches to strengthen infrastructure resilience in humanitarian logistics.

4.4 Infrastructure resilience dimensions in humanitarian logistics

As the previous section discussed the causes of infrastructure failure, it is crucial to address the factors that strengthen infrastructures and reduce their vulnerability before, during and after disasters. Table 3 demonstrates the dimensions of infrastructure resilience in humanitarian logistics grouped into four main categories: structural and systematic features, operational and functional capabilities, adaptive and management capacities and institutional and governance mechanisms. Each dimension is defined by its role in sustaining infrastructure performance, its stage of occurrence and the codified strategies that represent it. This categorization reflects resilience as a dynamic, multi-layered capability rather than a static attribute (Mostafavi and Inman, 2016; Shishodia *et al.*, 2023). By integrating these dimensions, humanitarian logistics can better anticipate risks, sustain operations under stress and accelerate recovery (Christopher and Peck, 2004; Tomasini and Van Wassenhove, 2009). The subsequent sections explain each category of these infrastructure resilience dimensions.

4.4.1 Structural and systematic features

Structural and systematic features form the foundation of resilience by ensuring physical durability and continuity under stress. Robustness refers to the ability of infrastructure to resist damage against hazards (e.g. floods, earthquakes or hurricanes) through strength and design (Holguín-Veras *et al.*, 2012;

Table 3 Infrastructure resilience dimensions in humanitarian logistics

Category	Dimension	Supporting studies	Definition	Occurrence stage	Coded strategy
Structural and systematic features	Robustness	1, 2, 3, 5, 7, 9, 12, 13, 15, 20, 21, 23, 25, 31, 32, 33, 35, 37	Resists or prevents damage through strength or design	Before disruption	Strength-based
	Redundancy	1, 2, 3, 5, 9, 11, 12, 13, 20, 21, 22, 23, 24, 25, 26, 30, 32, 33, 35, 37	Substitutes or alternate failed components or pathways to maintain functionality	During and after disruption	Substitution-based
	Absorptive capacity	4, 12, 13	Buffers the impact using slack, reserves or protective systems	During disruption	Buffer-based
	Connectivity	7, 19, 24, 31, 40, 41	Maintains or restores network-wide access and service continuity	During and after disruption	Continuity-based
	Flexibility	4, 11, 12, 14, 15, 16, 24, 26, 30, 31, 32, 35	Reconfigures system structure or operations to adapt to disruption	During and after disruption	Adaptation-based
	System interdependency	4, 5, 6, 7, 8, 9, 11, 15, 19, 23, 24, 25, 26, 28, 34, 37	Manages cascading effects between interconnected infrastructure systems	Before and during disruption	Interdependency-awareness
Operational and functional capabilities	Rapidity	2, 3, 7, 12, 13, 20, 25, 31	Restores critical infrastructure functions as quickly as possible	After disruption	Time-sensitive awareness
	Recoverability	1, 12, 23, 25, 31, 33, 35, 39	Regains full infrastructure functionality over time	After disruption	Restoration-based
	Restorative capacity	4, 12, 13	Enables repair using available time, labor and material resources	After disruption	Operational capacity-based
	Detection and responsiveness	33, 40	Identifies system failures and enables prompt corrective action	During disruption	Awareness and response
	Monitoring and maintenance	36	Detects vulnerabilities early to prevent breakdowns	Before disruption	Preventive maintenance
Adaptive and management capacities	Resourcefulness	1, 3, 12, 13, 19, 20, 25, 31, 35	Mobilizes personnel, tools and resources effectively under stress	During and after disruption	Mobilization-based
	Adaptive capacity	4, 12, 13, 24, 29. 38	Reorganizes operations or applies alternative strategies during crises	During and after disruption	Dynamic response
	Scenario-based testing and planning	9, 16, 21, 31	Uses simulations to prepare for extreme disruption scenarios	Before disruption	Preparedness-based
	Automation and AI in decision-making	36	Supports real-time, data-informed decisions using intelligent technologies	During disruption	Technology-driven
	Efficient recovery	6, 12, 20	Restores infrastructure services efficiently by prioritizing actions	After disruption	Prioritization-based
Institutional and governance mechanisms	Governance and multi-agency coordination	17, 18, 34, 35, 36	Ensures coordinated decision-making and role clarity across institutions	Before and during disruption	Regulative and normative assessment
	Early warning and predictive analytics	12, 36	Forecasts failures and activates proactive responses	Before disruption	Proactive forecasting
	Situational awareness and communication	36	Shares real-time information for effective decision-making and coordination	During disruption	Information-centric
	Equity in service restoration	8, 10, 27, 30	Prioritizes vulnerable or critical populations during infrastructure recovery	After disruption	Equity-centric

Note(s): [1] Morshed *et al.*, 2021; [2] Twumasi-Boakye and Sobanjo, 2019; [3] Soltani-Sobh *et al.*, 2016; [4] Turnquist and Vugrin, 2013; [5] Chang *et al.*, 2014; [6] Singh *et al.*, 2018; [7] Rachunok and Nateghi, 2020; [8] Watson and Ahn, 2022; [9] Croope and McNeil, 2011; [10] Papadopoulos *et al.*, 2017; [11] Orengo Serra and Sanchez-Jauregui, 2022; [12] Mottahedi *et al.*, 2021; [13] Sun *et al.*, 2020; [14] Bhusiri *et al.*, 2021; [15] Kopanaki, 2022; [16] Gerges *et al.*, 2022; [17] Santos *et al.*, 2020; [18] Mostafavi and Inman, 2016; [19] Sathurshan *et al.*, 2022; [20] Esmalian *et al.*, 2022; [21] Nateghi, 2018; [22] McDaniels *et al.*, 2015; [23] Blagojević *et al.*, 2023; [24] Day, 2014; [25] Afrin and Yodo, 2019; [26] Cedergren *et al.*, 2018; [27] Dargin and Mostafavi, 2020; [28] Wang *et al.*, 2019; [29] Chester *et al.*, 2021; [30] Hecht *et al.*, 2019; [31] Liu *et al.*, 2022; [32] Murdock *et al.*, 2018; [33] Rehak *et al.*, 2018; [34] Tiedmann *et al.*, 2023; [35] Cantelmi *et al.*, 2021; [36] Habibi Rad *et al.*, 2021; [37] Bi *et al.*, 2023; [38] Cimellaro *et al.*, 2019; [39] Weir *et al.*, 2024; [40] Kuraganti *et al.*, 2020; [41] Dasuni *et al.*, 2025

Source(s): Authors' own work

Twumasi-Boakye and Sobanjo, 2019). Redundancy, meanwhile, emphasizes substitutability, allowing infrastructures to maintain functionality when primary systems fail. This can occur through preventive maintenance before disasters or reactive substitution during and after disasters (Morshed *et al.*, 2021). For example, a two-way multi-laned road can be flexibly converted into a one-way evacuation route during emergencies, while rerouting strategies can mitigate blocked transport corridors (Croope and McNeil, 2011). These features are essential because they provide the physical backbone upon which other resilience dimensions depend (Overstreet *et al.*, 2011).

The distinction between redundancy during and after disasters is critical. In slow-onset disasters (e.g. droughts, pandemics), substitution is more likely to occur during the event, while in sudden-onset disasters (e.g. earthquakes, floods), substitution takes place afterward. This temporal differentiation highlights the importance of proactive planning and flexible infrastructure design (Morshed *et al.*, 2021). For instance, modular bridges or temporary shelters can be deployed during floods, while permanent reconstruction follows afterward. Such strategies illustrate how structural resilience must be both anticipatory and reactive, aligning with system-of-systems theory that emphasizes interdependencies across infrastructures (Eusgeld *et al.*, 2011; Dasuni *et al.*, 2025).

4.4.2 Operational and functional capabilities

Operational and functional capabilities complement structural resilience by enabling rapid restoration of services after disruptions. Dimensions such as rapidity, recoverability and restorative capacity ensure that critical infrastructure functions are restored as quickly as possible, minimizing humanitarian suffering (Esmalian *et al.*, 2022; Liu *et al.*, 2022). Rapidity is characterized by the time to initiate restoration, restoration speed and clearance activities such as debris removal (Esmalian *et al.*, 2022). Recoverability ensures that infrastructures return to their original or improved state after disruption, reducing long-term vulnerability (Michel *et al.*, 2023). These capabilities are particularly vital in humanitarian contexts, where delays in restoring transport or communication systems can directly translate into loss of life and prolonged suffering (Tatham and Houghton, 2011; Leiras *et al.*, 2014).

The operational dimension also emphasizes the importance of logistics hubs and storage facilities, which enable pre-positioning of critical supplies and rapid deployment during crises (Balcik and Beamon, 2008; Duran *et al.*, 2013). When operational resilience is compromised, humanitarian supply chains face bottlenecks that hinder aid distribution and exacerbate human suffering (Shrivastav and Bag, 2024). Thus, operational resilience is not only about restoring physical assets but also about ensuring continuity of humanitarian logistics functions under extreme conditions.

4.4.3 Adaptive and management capacities

Adaptive and management capacities are equally critical for coping with uncertainty and dynamic disaster environments. Resourcefulness refers to the ability to mobilize and use resources effectively, including skilled professionals, financial capacity and efficient scheduling (Sathurshan *et al.*, 2022). Scenario planning further strengthens resilience by anticipating potential hazards and preparing contingency strategies (Nateghi, 2018). These adaptive capacities align with dynamic capability theory, which emphasizes the continuous reconfiguration of resources to sustain performance in uncertain environments (Christopher and Peck, 2004; Teece, 2007; Tomasini and Van Wassenhove, 2009).

Adaptive resilience also involves leveraging emerging technologies. Habibi Rad *et al.* (2021) argued that AI-based communication tools can improve situational awareness by extracting information from multiple sources and providing early warnings about potential hazards. IoT-enabled monitoring systems can track infrastructure performance in real time, allowing rapid adjustments during crises (Papadopoulos *et al.*, 2017). These technologies enhance flexibility and resourcefulness, but they also introduce new vulnerabilities due to their dependence on stable power and communication networks (Kopanaki, 2022). This "resilience paradox" underscores the need for balanced strategies that integrate digital innovation with redundancy and governance mechanisms.

4.4.4 Institutional and governance mechanisms

Institutional and governance mechanisms underpin the effectiveness of all other resilience strategies. Effective governance mechanisms address coordination, communication and equity-focused recovery through ensuring multi-agency collaboration, reducing duplication and delays in humanitarian operations (Papadopoulos *et al.*, 2017; Sonesson *et al.*, 2021). Communication systems, enhanced by emerging technologies such as AI and IoT, improve situational awareness and coordination among relief actors (Habibi Rad *et al.*, 2021). Equity-focused governance ensures that vulnerable populations are prioritized in recovery, reinforcing humanitarian principles (Aldrich, 2012; Dargin and Mostafavi, 2020). These institutional dimensions are critical because even the most robust infrastructures can fail without effective coordination and inclusive governance (Overstreet *et al.*, 2011; Kashav and Garg, 2025).

Institutional resilience also requires addressing systemic inefficiencies such as fragmented responsibilities and siloed decision-making. Previous studies showed that governance gaps often delay recovery and exacerbate vulnerabilities (Tatham and Houghton, 2011; Leiras *et al.*, 2014). By embedding resilience into governance frameworks, humanitarian organizations can ensure that technical and operational capacities are effectively mobilized. This integration highlights that resilience is not merely a technical attribute but a socio-institutional capability that requires inclusive and coordinated action (Mostafavi and Inman, 2016).

Taken together, the infrastructure resilience dimensions are mutually reinforcing. Structural robustness provides the foundation for operational continuity, adaptive capacities enable flexibility in reconfiguring logistics during crises and governance mechanisms ensure coordination across actors. This interrelationship reflects the dynamic capability view of resilience, where organizations must continuously integrate and reconfigure resources to sustain performance under uncertainty (Christopher and Peck, 2004; Tomasini and Van Wassenhove, 2009). By situating these insights within system-of-systems theory, this study advances both academic understanding and practical guidance for strengthening humanitarian logistics resilience (Eusgeld *et al.*, 2011; Ouyang, 2014).

5. Discussion

This study systematically reviewed 41 peer-reviewed articles to consolidate fragmented knowledge on infrastructure resilience within humanitarian logistics. This systematic review underscores the interconnectedness of infrastructure systems in humanitarian logistics and highlights how resilience dimensions mitigate cascading disruptions. Our analysis identified six infrastructure types, namely, transportation networks, utilities, communication and information systems, logistics and storage facilities, social and public services and production and supply systems. These types of infrastructure were found to be highly interdependent. For example, transportation networks depend on utilities for fuel and electricity, while communication systems require stable power and data connectivity (Grigoli *et al.*, 2024; Kashav and Garg, 2025). Failures in one sector often propagate across others, as seen during the 2012 Hurricane Sandy, where power outages disrupted transportation and health services simultaneously (Cimellaro *et al.*, 2019; Michel *et al.*, 2023). These findings reinforce the system-of-systems perspective, which emphasizes integrated resilience planning across multiple infrastructures (Eusgeld *et al.*, 2011; Ouyang, 2014; Mostafavi and Inman, 2016).

The analysis also determined six root causes of infrastructural vulnerabilities, including natural hazards, man-made disruptions, aging infrastructure, systemic interdependencies and communication failures, among others. It is important to note that certain types of infrastructure exhibit heightened vulnerability to particular modes of failure, with susceptibility often determined by their structural characteristics, operational demands and environmental exposure (Zarghami and Gunawan, 2020; van den Adel *et al.*, 2022). For example, roads and bridges are particularly susceptible to flooding and earthquakes, while communication networks are more vulnerable to cyberattacks and coordination breakdowns (Papadopoulos *et al.*, 2017; Dubey, 2019). Institutional rigidity, such as fragmented governance and funding shortages, exacerbates these vulnerabilities by limiting adaptive responses (Tatham and Houghton, 2011; Leiras *et al.*, 2014). These causal pathways highlight that infrastructure failures are not only triggered by external shocks but also embedded in chronic systemic deficiencies, extending supply chain resilience theories into the humanitarian infrastructure domain (Pettit *et al.*, 2010).

Four resilience dimensions emerged: structural and systematic features, operational and functional capabilities, adaptive and management capacities, as well as institutional and governance mechanisms. These dimensions are mutually reinforcing; structural robustness underpins operational continuity, adaptive capacities enable reconfiguration during crises and governance mechanisms ensure coordination across actors (Morshed *et al.*, 2021; Sathurshan *et al.*, 2022). For instance, redundancy in logistics hubs enhances operational rapidity, while adaptive scenario planning strengthens flexibility in resource allocation (Michel *et al.*, 2023). This interrelationship reflects the dynamic capability view of resilience, where organizations must continuously integrate and reconfigure resources to sustain performance under uncertainty (Christopher and Peck, 2004; Teece, 2007; Tomasini and Van Wassenhove, 2009).

Despite advances in technical resilience, governance and equity-focused strategies remain underexplored. Social capital and institutional trust play a pivotal role in recovery, as communities with stronger networks recover more effectively (Aldrich, 2012; Dargin and Mostafavi, 2020). Equity-focused resilience ensures that vulnerable populations are not excluded from recovery processes, reinforcing humanitarian principles (Overstreet *et al.*, 2011; Sonesson *et al.*, 2021). Linking resilience to governance theories highlights that infrastructure resilience is not merely about physical robustness but also about institutional agility and inclusivity, which are critical for equitable disaster recovery.

Emerging technologies such as AI, blockchain and IoT offer opportunities to enhance situational awareness and proactive resilience planning (Habibi Rad *et al.*, 2021; Younis *et al.*, 2026). However, these innovations also introduce new vulnerabilities, as their effectiveness depends on stable power and communication infrastructures (Kopanaki, 2022). This “resilience paradox” underscores the need for balanced strategies that integrate digital innovation with redundancy and governance mechanisms. Empirical evidence from the COVID-19 pandemic and recent climate disasters demonstrates how misalignment between technical and institutional systems amplifies cascading failures (Agarwal *et al.*, 2020; Ta’Amnha *et al.*, 2021; Bi *et al.*, 2023). Thus, resilience must be redefined as a dynamic, multi-layered capability evolving across preparedness, response and recovery phases.

Building on the categorization of infrastructure types, failure causes and resilience dimensions, this study integrates these elements into a comprehensive conceptual framework that is explicitly operationalized in Table 3, which positions infrastructure resilience as a system-of-systems capability evolving across preparedness, response and recovery phases. The framework strengthens system-of-systems theory by empirically demonstrating how functional interdependencies among transportation, utilities, information and social infrastructure generate cascading risks that must be managed holistically rather than asset by asset (Eusgeld *et al.*, 2011; Mostafavi and Inman, 2016). Simultaneously, the findings reinforce dynamic capability theory by showing that resilience depends on the continuous sensing, seizing and reconfiguring of infrastructure-related resources through adaptive management, governance coordination and learning mechanisms rather than static robustness alone (Teece, 2007; Shishodia *et al.*, 2023).

From a practical perspective, the review highlighted actionable strategies across disaster phases: in preparedness, investments in redundancy, modular infrastructure, preventive maintenance and scenario-based stress testing enhance absorptive capacity (Nateghi, 2018; Morshed *et al.*, 2021). For example, prior to the 2010 Haiti earthquake, limited redundancy in transport networks meant that collapsed roads and bridges immediately paralyzed aid delivery, underscoring the need for modular warehouses and anticipatory planning to sustain operations (Holguín-Veras *et al.*, 2012; Shakibaei *et al.*, 2024). During response, rapid restoration of transport access, deployment of mobile logistics hubs and real-time information sharing improve operational continuity, as evidenced in 2012 Hurricane Sandy, where widespread power outages and fuel shortages disrupted relief efforts; stronger interagency coordination and mobile hubs could have mitigated cascading failures across utilities and transport systems (Cimellaro *et al.*, 2019; Dargin and Mostafavi, 2020). Similarly, in the 2019 Cyclone Idai, damaged roads and communication breakdowns delayed humanitarian response, highlighting the importance of agile logistics and digital platforms for situational awareness (Chari *et al.*, 2021). In recovery, adaptive reconstruction, equity-oriented prioritization and cross-sector governance enable faster and more inclusive system recovery, as seen in the 2023 Turkey-Syria earthquake, where destroyed hospitals, utilities and transport networks required coordinated reconstruction strategies to restore critical services equitably across affected regions (Sonesson *et al.*, 2021; Ahmed, 2023). By situating these strategies within an integrated framework, the study provides a structured foundation for future empirical research to test resilience pathways, develop phase-specific metrics and examine how institutional and technical capabilities jointly shape humanitarian logistics performance under extreme disruption.

6. Theoretical and practical implications

This study makes four key theoretical contributions to the understanding of infrastructure resilience in humanitarian logistics. First, it examines the distribution of 41 reviewed papers across infrastructure types, failure causes and resilience dimensions. Through a synthetic analysis, the research connects these variables to explain why and how these variables interact. Particular attention is given to the interdependencies and causal pathways that emerge, offering novel insights that are not present in any single source. Second, the study operationalizes the system-of-systems and dynamic capability theories by mapping critical infrastructure interdependencies and integrating technical, operational and governance dimensions into a unified framework. Third, it bridges fragmented literature by connecting structural resilience (e.g. redundancy, robustness) with institutional mechanisms (e.g. coordination, equity). Fourth, it introduces a phase-based framework that conceptualizes resilience as a dynamic capability rather than a static attribute. The findings extend existing supply chain resilience models by highlighting interdependencies among infrastructure systems and introducing anticipatory strategies such as scenario-based planning and predictive analytics. These contributions provide conceptual clarity for future research, enabling scholars to explore resilience pathways, develop standardized metrics and examine socio-technical interactions that shape humanitarian logistics under complex disruptions.

Additionally, the findings of this study offer actionable guidance for humanitarian organizations, policymakers and infrastructure planners seeking to strengthen resilience in disaster contexts. Investments should prioritize adaptive and redundant infrastructure systems, such as modular warehouses, mobile clinics and alternative transport routes, to ensure continuity during disruptions. Enhancing cross-sector coordination and stakeholder engagement is critical to overcoming institutional silos and fragmented decision-making that often delay response efforts. Emerging technologies, including AI, IoT and predictive analytics, can improve situational awareness and enable proactive risk management, but their deployment must be supported by reliable power and communication networks. Furthermore, equity-focused recovery strategies should be integrated into resilience planning to ensure vulnerable populations receive timely assistance. Finally, proactive maintenance of aging infrastructure and scenario-based stress testing can help preempt systemic failures, enabling humanitarian supply chains to remain agile and effective under increasingly complex and uncertain conditions.

7. Conclusion

This study set out to address three interrelated research objectives concerning infrastructure resilience in humanitarian logistics. First, the review systematically classified the types of infrastructure critical to humanitarian logistics, identifying six core categories: transportation networks; utilities; communication and information systems; logistics and storage facilities; social and public services; as well as production and supply systems. The findings demonstrated that humanitarian performance is inherently dependent on the functionality and accessibility of these interconnected infrastructures rather than on isolated assets. Transportation and utilities emerged as particularly critical enablers, while communication, logistics hubs and social infrastructure play essential supporting roles across disaster phases. Importantly, the review highlighted that these infrastructure types form a tightly coupled system-of-systems, where disruptions in one category propagate rapidly across others, amplifying logistical breakdowns and humanitarian consequences.

Second, the study identified and analyzed the major causes of infrastructure failure affecting humanitarian logistics. Six dominant categories were synthesized: natural disasters, man-made disasters, aging and deteriorating infrastructure, systemic infrastructure interdependencies, communication and coordination failures and other contextual constraints such as funding shortages and institutional rigidity. The findings revealed that while hazards often act as triggering events, the scale and duration of disruption are largely shaped by chronic vulnerabilities embedded in infrastructure design, maintenance and governance arrangements.

Third, by synthesizing the literature on infrastructure resilience dimensions, the study integrated structural, operational, adaptive and institutional mechanisms into a unified resilience framework. This framework conceptualizes resilience as a dynamic, multi-layered capability that evolves across preparedness, response and recovery phases, rather than as a static attribute. By linking infrastructure types, failure causes and resilience dimensions, the framework informs both theory, by extending system-of-systems and dynamic capability perspectives and practice, by offering a structured foundation for designing phase-based, coordinated and equity-aware strategies to strengthen humanitarian logistics.

While this study provides a comprehensive synthesis of infrastructure resilience in humanitarian logistics, certain limitations must be acknowledged. The review was limited to peer-reviewed articles, excluding gray sources such as industry reports and policy documents that could offer valuable practical perspectives. Additionally, most analyzed studies focused on sudden-onset disasters, leaving gaps in understanding resilience strategies for slow-onset crises. Future research should address these gaps by incorporating diverse data sources, including practitioner perspectives, developing standardized resilience metrics for cross-study comparisons and exploring decentralized and climate-adaptive infrastructure solutions. Moreover, investigating the role of emerging technologies, such as blockchain for supply chain transparency and machine learning for predictive risk modeling, can advance anticipatory resilience frameworks and strengthen humanitarian systems against increasingly complex disruptions.

References

Abushaikha, I., Alqahtani, M.S., Bwaliez, O.M. and Bwaliez, O.M. (2026), “Cognitive supply chain management and risk management in pharmaceuticals: the mediating roles of forecasting, synchronization, and transparency”, *Logistics*, Vol. 10 No. 1, p. 11.

Abushaikha, I., Bwaliez, O.M., Yaseen, M.H., Hamadneh, S. and Darwish, T.K. (2025), “Leveraging animal feed supply chain capabilities through big data analytics: a qualitative study”, *International Journal of Quality & Reliability Management*, Vol. 42 No. 9, pp. 2605-2625.

Afrin, T. and Yodo, N. (2019), “Resilience-based recovery assessments of networked infrastructure systems under localized attacks”, *Infrastructures*, Vol. 4 No. 1, p. 11.

Agarwal, S., Kant, R. and Shankar, R. (2020), "Humanitarian supply chain management: a systematic literature review and directions for future research", *International Journal of Emergency Management*, Vol. 16 No. 2, pp. 111-151.

Ahmed, I. (2023), "Key building design and construction lessons from the 2023 Türkiye–Syria earthquakes", *Architecture*, Vol. 3 No. 1, pp. 104-106.

Aldrich, D.P. (2012), *Building Resilience: Social Capital in Post-Disaster Recovery*, University of Chicago Press.

Anand, P.B. (2009), "Infrastructure development in post-conflict reconstruction", *Making Peace Work*, Palgrave Macmillan UK, pp. 228-250.

Anjomshoae, A., Banomyong, R., Mohammed, F. and Kunz, N. (2022), "A systematic review of humanitarian supply chains performance measurement literature from 2007 to 2021", *International Journal of Disaster Risk Reduction*, Vol. 72, p. 102852.

Balcik, B. and Beamon, B.M. (2008), "Facility location in humanitarian relief", *International Journal of Logistics Research and Applications*, Vol. 11 No. 2, pp. 101-121.

Bhusiri, N., Banomyong, R., Julagasigorn, P., Varadejsatitwong, P. and Dhami, N. (2021), "A purchasing portfolio model for humanitarian supply chain resilience: perspectives from a development aid context", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 11 No. 4, pp. 639-660.

Bi, W., MacAskill, K. and Schooling, J. (2023), "Old wine in new bottles? Understanding infrastructure resilience: foundations, assessment, and limitations", *Transportation Research Part D: Transport and Environment*, Vol. 120, p. 103793.

Blagojević, N., Hefti, F., Henken, J., Didier, M. and Stojadinović, B. (2023), "Quantifying disaster resilience of a community with interdependent civil infrastructure systems", *Structure and Infrastructure Engineering*, Vol. 19 No. 12, pp. 1696-1710.

Bruneau, M., Chang, S.E., Eguchi, R.T., Lee, G.C., O'Rourke, T.D., Reinhorn, A.M., Shinozuka, M., Tierney, K., Wallace, W.A. and Von Winterfeldt, D. (2003), "A framework to quantitatively assess and enhance the seismic resilience of communities", *Earthquake Spectra*, Vol. 19 No. 4, pp. 733-752.

Cantelmi, R., Di Gravio, G. and Patriarca, R. (2021), "Reviewing qualitative research approaches in the context of critical infrastructure resilience", *Environment Systems and Decisions*, Vol. 41 No. 3, pp. 341-376.

Cedergren, A., Johansson, J. and Hassel, H. (2018), "Challenges to critical infrastructure resilience in an institutionally fragmented setting", *Safety Science*, Vol. 110, pp. 51-58.

Chang, S.E., McDaniels, T., Fox, J., Dhariwal, R. and Longstaff, H. (2014), "Toward disaster-resilient cities: characterizing resilience of infrastructure systems with expert judgments", *Risk Analysis*, Vol. 34 No. 3, pp. 416-434.

Chari, F., Ngcamu, B.S. and Novukela, C. (2021), "Supply chain risks in humanitarian relief operations: a case of cyclone Idai relief efforts in Zimbabwe", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 11 No. 1, pp. 29-45.

Chester, M., El Asmar, M., Hayes, S. and Desha, C. (2021), "Post-disaster infrastructure delivery for resilience", *Sustainability*, Vol. 13 No. 6, p. 3458.

Christopher, M. and Peck, H. (2004), "Building the resilient supply chain", *The International Journal of Logistics Management*, Vol. 15 No. 2, pp. 1-14.

Cimellaro, G.P., Crupi, P., Kim, H.U. and Agrawal, A. (2019), "Modeling interdependencies of critical infrastructures after hurricane sandy", *International Journal of Disaster Risk Reduction*, Vol. 38, p. 101191.

Croope, S.V. and McNeil, S. (2011), "Improving resilience of critical infrastructure systems postdisaster: recovery and mitigation", *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2234 No. 1, pp. 3-13.

Damoah, I.S. (2022), "Exploring critical success factors (CSFs) of humanitarian supply chain management (HSCM) in flood disaster management (FDM)", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 12 No. 1, pp. 129-153.

Daousis, S., Peladarinos, N., Cheimaras, V., Papageorgas, P., Piromalis, D.D. and Munteanu, R.A. (2024), "Overview of protocols and standards for wireless sensor networks in critical infrastructures", *Future Internet*, Vol. 16 No. 1, p. 33.

Dargin, J.S. and Mostafavi, A. (2020), "Human-centric infrastructure resilience: uncovering well-being risk disparity due to infrastructure disruptions in disasters", *Plos One*, Vol. 15 No. 6, p. e0234381.

Dasuni, K.A.L., Palliyaguru, R., Amaratunga, D. and Liyanawatta, T.N. (2025), "Redefining 'dependencies/interdependencies' of critical infrastructure: a systematic review of the existing knowledgebase", *Sustainable and Resilient Infrastructure*, Vol. 10 No. 2, pp. 202-222.

Day, J.M. (2014), "Fostering emergent resilience: the complex adaptive supply network of disaster relief", *International Journal of Production Research*, Vol. 52 No. 7, pp. 1970-1988.

Day, J.M., Melnyk, S.A., Larson, P.D., Davis, E.W. and Whybark, D.C. (2012), "Humanitarian and disaster relief supply chains: a matter of life and death", *Journal of Supply Chain Management*, Vol. 48 No. 2, pp. 21-36.

Denyer, D. and Tranfield, D. (2009), "Producing a systematic review", in Buchanan, D.A. and Bryman, A. (Eds), *The Sage Handbook of Organizational Research Methods*, Sage Publication, pp. 671-689.

Dubey, R. (2019), "Resilience and agility: the crucial properties of humanitarian supply chain", in *Handbook of Ripple Effects in the Supply Chain*, Springer International Publishing, Cham, pp. 287-308.

Duran, S., Gutierrez, M.A., Keskinocak, P. and Swann, J.L. (2013), "Pre-positioning of emergency items for CARE international", *Interfaces*, Vol. 41 No. 3, pp. 223-237.

Esmalian, A., Yuan, F., Rajput, A.A., Farahmand, H., Dong, S., Li, Q., Gao, X., Fan, C., Lee, C.-C., Hsu, C.-W., Patrascu, F.I. and Mostafavi, A. (2022), "Operationalizing resilience practices in transportation infrastructure planning and project development", *Transportation Research Part D: Transport and Environment*, Vol. 104, p. 103214.

Eusgeld, I., Nan, C. and Dietz, S. (2011), "'System-of-systems' approach for interdependent critical infrastructures", *Reliability Engineering & System Safety*, Vol. 96 No. 6, pp. 679-686.

Fekete, A., Bross, L., Krause, S., Neisser, F. and Tzavella, K. (2021), "Bridging gaps in minimum humanitarian standards and shelter planning by critical infrastructures", *Sustainability*, Vol. 13 No. 2, p. 849.

Gerges, F., Nassif, H., Herrington, T. and Boufadel, M.C. (2022), "A GIS-based approach for estimating community transportation exposure and capacity in the context of disaster resilience", *Sustainable Horizons*, Vol. 3, p. 100030.

Goetsch, D.L. and Davis, S. (2014), *Quality Management for Organizational Excellence: Introduction to Total Quality*, 7th ed., Pearson Education Limited, Essex, England.

Goncalves, S. and Chang, B. (2026), "Infrastructure resilience in the United States: a data-driven synthesis of disaster-related studies", *Sustainability*, Vol. 18 No. 5, p. 2549.

Grigoli, G.D.A., Silva Júnior, M.F.D. and Pedra, D.P. (2024), "Challenges and perspectives for humanitarian logistics: a comparative study between the democratic republic of Congo, the Central African Republic and the republic of South Sudan", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 14 No. 4, pp. 384-398.

Habibi Rad, M., Mojtahedi, M. and Ostwald, M.J. (2021), "Industry 4.0, disaster risk management and infrastructure resilience: a systematic review and bibliometric analysis", *Buildings*, Vol. 11 No. 9, p. 411.

Hecht, A.A., Biehl, E., Barnett, D.J. and Neff, R.A. (2019), "Urban food supply chain resilience for crises threatening food security: a qualitative study", *Journal of the Academy of Nutrition and Dietetics*, Vol. 119 No. 2, pp. 211-224.

Holguín-Veras, J., Jaller, M., Van Wassenhove, L.N., Pérez, N. and Wachtendorf, T. (2012), "On the unique features of post-disaster humanitarian logistics", *Journal of Operations Management*, Vol. 30 Nos 7-8, pp. 494-506.

Ilie, G. and Ciocoiu, C.N. (2010), "Application of fishbone diagram to determine the risk of an event with multiple causes", *Management Research and Practice*, Vol. 2No No. 1, pp. 1-20.

Imbriale, P. (2026), "The role of government in humanitarian logistics: a systematic review", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 16 No. 1, pp. 50-69.

Jaller, M., Calderón, C.A.G., Yushimito, W.F. and Díaz, I.D. S. (2015), "An investigation of the effects of critical infrastructure on urban mobility in the city of Medellín", *International Journal of Critical Infrastructures*, Vol. 11 No. 3, p. 213.

Kashav, V. and Garg, C.P. (2025), "Fortifying humanitarian supply chains: evaluating sustainability enablers for strengthened resilience of humanitarian supply chains during calamities and pandemics", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 15 No. 3, pp. 294-308.

Kopanaki, E. (2022), "Conceptualizing supply chain resilience: the role of complex IT infrastructures", *Systems*, Vol. 10 No. 2, p. 35.

Kuraganti, C.K., Robert, B.P., Gurrala, G., Joglekar, A., Puthuparambil, A.B., Sundaresan, R. and Tyagi, H. (2020), "A distributed hierarchy framework for enhancing cyber security of control center applications", *arXiv preprint arXiv:2010.04955*.

Leiras, A., de Brito, I., Jr, Peres, E.Q., Bertazzo, T.R. and Yoshizaki, H.T.Y. (2014), "Literature review of humanitarian logistics research: trends and challenges", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 4 No. 1, pp. 95-130.

Liu, Y., McNeil, S., Hackl, J. and Adey, B.T. (2022), "Prioritizing transportation network recovery using a resilience measure", *Sustainable and Resilient Infrastructure*, Vol. 7 No. 1, pp. 70-81.

McDaniels, T.L., Chang, S.E., Hawkins, D., Chew, G. and Longstaff, H. (2015), "Towards disaster-resilient cities: an approach for setting priorities in infrastructure mitigation efforts", *Environment Systems and Decisions*, Vol. 35 No. 2, pp. 252-263.

Michel, S., Gerbaix, S. and Bidan, M. (2023), "Dimensions and Sub-dimensions of emergency supply chain resilience: a case study of médecins sans frontières logistique during the COVID-19 pandemic", *Supply Chain Management: An International Journal*, Vol. 28 No. 5, pp. 939-953.

Mishra, V. and Mishra, M.P. (2023), "PRISMA for review of management literature–method, merits, and limitations–an academic review", in Rana, S., Singh, J. and Kathuria, S. (Eds), *Advancing Methodologies of Conducting Literature Review in Management Domain*, Emerald Publishing, pp. 125-136.

Moher, D., Liberati, A., Tetzlaff, J. and Altman, D.G. (2009), "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement", *BMJ*, Vol. 339 No. 1, p. e1000097.

Morshed, S.A., Arafat, M., Mokhtarimousavi, S., Khan, S.S. and Amine, K. (2021), "8R resilience model: a stakeholder-centered approach of disaster resilience for transportation infrastructure and network", *Transportation Engineering*, Vol. 4, p. 100058.

Mostafavi, A. and Inman, A. (2016), "Exploratory analysis of the pathway towards operationalizing resilience in transportation infrastructure management", *Built Environment Project and Asset Management*, Vol. 6 No. 1, pp. 106-118.

Mottahedi, A., Sereshki, F., Ataei, M., Nouri Qarahasanlou, A. and Barabadi, A. (2021), "The resilience of critical infrastructure systems: a systematic literature review", *Energies*, Vol. 14 No. 6, p. 1571.

Murdock, H.J., De Bruijn, K.M. and Gersonius, B. (2018), "Assessment of critical infrastructure resilience to flooding using a response curve approach", *Sustainability*, Vol. 10 No. 10, p. 3470.

Mutebi, H., Aryatujwika, W., Mayanja, S.S., Kyomuhangi, D. S. and Akashabaruhanga, A. (2025), "Humanitarian supply chain resilience: the role of localized logistics preparedness capacity and inter-organizational coordination capabilities", *Continuity & Resilience Review*, Vol. 7 No. 2, pp. 146-165.

Nasrazadani, H., Nogal, M., Adey, B.T. and Mitoulis, S.A. (2025), "Prioritizing simulation-based stress tests to assess the resilience of transport systems: a computation-free methodology", *Journal of Infrastructure Preservation and Resilience*, Vol. 6 No. 1, p. 16.

Nateghi, R. (2018), "Multi-dimensional infrastructure resilience modeling: an application to hurricane-prone electric power distribution systems", *IEEE Access*, Vol. 6, pp. 13478-13489.

Niewöhner, J. (2022), "Infrastructure", in *Oxford Research Encyclopedia of Anthropology*, Oxford University Press, doi: 10.1093/acrefore/9780190854584.013.128.

Orengo Serra, K.L. and Sanchez-Jauregui, M. (2022), "Food supply chain resilience model for critical infrastructure collapses due to natural disasters", *British Food Journal*, Vol. 124 No. 13, pp. 14-34.

Osei-Kyei, R., Tam, V., Ma, M. and Mashiri, F. (2021), "Critical review of the threats affecting the building of critical infrastructure resilience", *International Journal of Disaster Risk Reduction*, Vol. 60, p. 102316.

Ouyang, M. (2014), "Review on modeling and simulation of interdependent critical infrastructure systems", *Reliability Engineering & System Safety*, Vol. 121, pp. 43-60.

Overstreet, R.E., Hall, D., Hanna, J.B. and Rainer, R.K. (2011), "Research in humanitarian logistics", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 1 No. 2, pp. 114-131.

Paciarotti, C., Piotrowicz, W.D. and Fenton, G. (2021), "Humanitarian logistics and supply chain standards. Literature review and view from practice", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 11 No. 3, pp. 550-573.

Papadopoulos, T., Gunasekaran, A., Dubey, R., Altay, N., Childe, S.J. and Fosso-Wamba, S. (2017), "The role of big data in explaining disaster resilience in supply chains for sustainability", *Journal of Cleaner Production*, Vol. 142, pp. 1108-1118.

Pettit, T.J., Fiksel, J. and Croxton, K.L. (2010), "Ensuring supply chain resilience: development of a conceptual framework", *Journal of Business Logistics*, Vol. 31 No. 1, pp. 1-21.

Polater, A. (2020), "Airports' role as logistics centers in humanitarian supply chains: a surge capacity management perspective", *Journal of Air Transport Management*, Vol. 83, p. 101765.

Rachunok, B. and Nateghi, R. (2020), "The sensitivity of electric power infrastructure resilience to the spatial distribution of disaster impacts", *Reliability Engineering & System Safety*, Vol. 193, p. 106658.

Rehak, D., Senovsky, P. and Slivkova, S. (2018), "Resilience of critical infrastructure elements and its main factors", *Systems*, Vol. 6 No. 2, p. 21.

Rojas Trejos, C.A., Meisel, J.D. and Adarme Jaimes, W. (2023), "Humanitarian aid distribution logistics with accessibility constraints: a systematic literature review", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 13 No. 1, pp. 26-41.

Samawi, G.A., Mdanat, M.F., Bwaliez, O.M. and Wishah, R. (2026), "Industry 4.0 and Jordanian pharmaceuticals: systematic literature review of efficiency and sustainability", in Hamdan, R.K. (Eds), *Integrating Big Data and IoT for Enhanced Decision-Making Systems in Business*, Vol. 1, pp. 45-53. *Studies in Big Data*, Vol. 177 Springer Nature, Cham.

Santos, J., Yip, C., Thekdi, S. and Pagsuyoin, S. (2020), "Workforce/population, economy, infrastructure, geography, hierarchy, and time (WEIGHT): reflections on the plural dimensions of disaster resilience", *Risk Analysis*, Vol. 40 No. 1, pp. 43-67.

Sathurshan, M., Saja, A., Thamboo, J., Haraguchi, M. and Navaratnam, S. (2022), "Resilience of critical infrastructure systems: a systematic literature review of measurement frameworks", *Infrastructures*, Vol. 7 No. 5, p. 67.

Shakibaei, H., Moosavi, S.A., Aghsami, A. and Rabbani, M. (2024), "Designing a sustainable-resilient humanitarian supply chain for post-disaster relief process, an earthquake case study in Haiti", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 14 No. 4, pp. 349-368.

Shishodia, A., Sharma, R., Rajesh, R. and Munim, Z.H. (2023), "Supply chain resilience: a review, conceptual framework and future research", *The International Journal of Logistics Management*, Vol. 34 No. 4, pp. 879-908.

Shrivastav, S.K. and Bag, S. (2024), "Humanitarian supply chain management in the digital age: a hybrid review using published literature and social media data", *Benchmarking: An International Journal*, Vol. 31 No. 7, pp. 2267-2301.

Singh, R.K., Gupta, A. and Gunasekaran, A. (2018), "Analysing the interaction of factors for resilient humanitarian supply chain", *International Journal of Production Research*, Vol. 56 No. 21, pp. 6809-6827.

Soltani-Sobh, A., Heaslip, K., Scarlatos, P. and Kaisar, E. (2016), "Reliability based pre-positioning of recovery centers for resilient transportation infrastructure", *International Journal of Disaster Risk Reduction*, Vol. 19, pp. 324-333.

Sonesson, T.R., Johansson, J. and Cedergren, A. (2021), "Governance and interdependencies of critical infrastructures: exploring mechanisms for cross-sector resilience", *Safety Science*, Vol. 142, p. 105383.

Sun, W., Bocchini, P. and Davison, B.D. (2020), "Resilience metrics and measurement methods for transportation infrastructure: the state of the art", *Sustainable and Resilient Infrastructure*, Vol. 5 No. 3, pp. 168-199.

Ta'Amnha, M.A., Bwaliez, O.M., Magableh, I.K., Samawi, G. A. and Mdanat, M.F. (2021), "Board policy of humanitarian organizations towards creating and maintaining their employer brand during the COVID-19 pandemic", *Corporate Board Role Duties and Composition*, Vol. 17 No. 3, pp. 8-20.

Tatham, P. and Houghton, L. (2011), "The wicked problem of humanitarian logistics and disaster relief aid", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 1 No. 1, pp. 15-31.

Teece, D.J. (2007), "Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance", *Strategic Management Journal*, Vol. 28 No. 13, pp. 1319-1350.

Tiedmann, H.R., Spearing, L.A., Castellanos, S., Stephens, K. K., Sela, L. and Faust, K.M. (2023), "Tracking the post-disaster evolution of water infrastructure resilience: a study of the 2021 Texas winter storm", *Sustainable Cities and Society*, Vol. 91, p. 104417.

Tomasini, R.M. and Van Wassenhove, L.N. (2009), "From preparedness to partnerships: case study research on humanitarian logistics", *International Transactions in Operational Research*, Vol. 16 No. 5, pp. 549-559.

Turnquist, M. and Vugrin, E. (2013), "Design for resilience in infrastructure distribution networks", *Environment Systems & Decisions*, Vol. 33 No. 1, pp. 104-120.

Twumasi-Boakye, R. and Sobanjo, J. (2019), "Civil infrastructure resilience: state-of-the-art on transportation network systems", *Transportmetrica A: Transport Science*, Vol. 15 No. 2, pp. 455-484.

van den Adel, M.J., de Vries, T.A. and van Donk, D.P. (2022), “Resilience in interorganizational networks: dealing with day-to-day disruptions in critical infrastructures”, *Supply Chain Management: An International Journal*, Vol. 27 No. 7, pp. 64-78.

Van Wassenhove, L.N. (2006), “Humanitarian aid logistics: supply chain management in high gear”, *Journal of the Operational Research Society*, Vol. 57 No. 5, pp. 475-489.

Wang, J.W., Wang, H.F., Zhou, Y.M., Wang, Y. and Zhang, W.J. (2019), “On an integrated approach to resilient transportation systems in emergency situations”, *Natural Computing*, Vol. 18 No. 4, pp. 815-823.

Watson, G. and Ahn, J.E. (2022), “A systematic review: to increase transportation infrastructure resilience to flooding events”, *Applied Sciences*, Vol. 12 No. 23, p. 12331.

Weir, A.M., Wilson, T.M., Bebbington, M.S., Campbell-Smart, C., Williams, J.H. and Fairclough, R. (2024), “Quantifying systemic vulnerability of interdependent critical infrastructure networks: a case study for volcanic hazards”, *International Journal of Disaster Risk Reduction*, Vol. 114, p. 104997.

Younis, H., Bwaliez, O.M., Al-Okaily, M. and Tanveer, M.I. (2024), “Revolutionizing supply chain management: a critical meta-analysis of empowerment and constraint factors in blockchain technology adoption”, *Business Process Management Journal*, Vol. 30 No. 5, pp. 1472-1500.

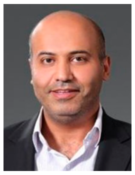
Younis, H., Shbikat, N., Bwaliez, O.M., Hazaimeh, I. and Sundarakani, B. (2026), “An overarching framework for the successful adoption of IoT in supply chains”, *Benchmarking: An International Journal*, Vol. 33 No. 4, pp. 1124-1153.

Zarghami, S.A. and Gunawan, I. (2020), “A fuzzy-based vulnerability assessment model for infrastructure networks incorporating reliability and centrality”, *Engineering, Construction and Architectural Management*, Vol. 27 No. 3, pp. 725-744.

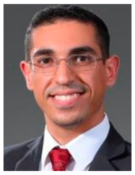
Further reading

Samawi, G.A., Bwaliez, O.M. and Mdanat, M.F. (2025), “Benchmarking Jordan’s trade role: a comparative analysis of logistics infrastructure, geopolitical position, and regional integration”, *Economies*, Vol. 13 No. 10, p. 282.

About the authors



Nizar Shbikat has a PhD in social and economic sciences from Kassel University, Germany, an MBA in logistics management from Dresden University of Technology, Germany, and a BSc in industrial engineering from the German Jordanian University, Jordan. Shbikat has taught several undergraduate and postgraduate courses in the field of logistics and supply chain management in Jordan and Germany. Besides teaching, he has research interests in sustainable supply chain management, institutional theory, as well as discrete and continuous event simulation.



Omar M. Bwaliez holds a PhD in operations and supply chain management from the University of Bedfordshire, UK, and has earned both a BSc and MSc in industrial engineering from the University of Jordan, Jordan. With over a decade of experience, Bwaliez has excelled in teaching, research, training and consultancy across various universities and companies in the Middle East and Europe. His scholarly contributions are highlighted by numerous publications and peer-reviewed articles in prestigious journals indexed by Scopus and Web of Science databases. Prior to his academic career, Bwaliez held key positions in the manufacturing sector in Jordan, including industrial engineer, business development engineer and quality assurance manager. Omar M. Bwaliez is the corresponding author and can be contacted at: omar.bwaliez@gju.edu.jo