Unfolding Cascading Disasters: Navigating Complex Risks and Systemic Vulnerabilities for Coordinated Disaster Response

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Systematic Review

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Abstract

Cascading disasters are multiple events that follow an ordered sequence that increases the occurrence rates of various events. These combined events compound the effects of single risks; consequently, priority is given to a multi-hazard system-oriented approach to mitigation, prevention, and management. Cascading disasters represent a significant challenge to conventional approaches to disaster risk management. As a result, there is a growing need for a unified view of risk. These events require a systemic cohesive and interconnected understanding. Therefore, this research seeks to offer a systematic review and a meta-analysis of the current literature on cascading disasters from a theoretical and empirical perspective. It aims to outline a critical understanding of how and why cascading events unfold and how the impacts of these events can be managed through a systematic, coordinated approach to disaster response. This study recognizes that systematic risk analysis, integrated disaster response techniques, and multi-sector coordination are fundamental components of an integrated disaster management framework in dealing with complicated, interconnected disasters across a range of settings. The research also identifies critical gaps in current disaster management policies and offers policy recommendations based on lessons learned from domestic and international case studies and best practices.

Keywords: *Cascading Disasters, Systemic Vulnerability, Complex Risk, Coordinated Disaster Response, Multi-hazard Risk Management.*

1. Introduction

The rising integration of systems globally makes societies more susceptible to cascading disasters. Events that start in one part of the world can quickly be felt elsewhere (Pescaroli *et al.*, 2021). Urbanization leads to ever-larger concentrations of people, making it more likely that any given event will affect health, life, and property on a devastating scale. Meanwhile, more and more risks tend to be concentrated in our global urban systems (Aliyu, 2015; Das, 2020b). Better urbanized, more interconnected, and far more at risk than any society in history, our present world may face systematic breakdowns of unfathomable depth and scale. These are the basic conditions that breed the appearance of cascading disasters on our horizons.

The common response to this prospect is to call for better disaster management. But what does that mean? Is it the same thing as "disaster risk reduction," so that we do not have to pay for managing the consequences of events? or is it more likely to be responding to the appearance of a series of disasters in public view, as in failing one "emergency response" system after another, and so likely to be examining the unfolding of events from the viewpoint of at least one of those systems that have failed? (Ayyub, 2011; Buzna *et al.*, 2007; Titus *et al.,* 2023;). In this connection, this research aims to fill this gap by bringing together the existing knowledge on cascading disasters, appraising the frameworks for integrated disaster response, and learning from international case studies.

1.1 Research Gap and Scope for Intervention

The current scholarly work on cascading disasters has concentrated very much on the developed world, especially high-income countries, such as the United States or countries in Western Europe (Mohan *et al.,* 2012), as Alexander & Pescaroli, (2019) pointed out, this produces a large and unfair knowledge divide as to how events that are expected to be unique – an earthquake or a tsunami – interact with each other as risks in the real world. Cutter, (2018) has pointed out that we know much less about how these interconnected risks compound one disaster after another in low-resource settings, such as those inhabited by the majority of the world's poor. The key vulnerabilities in those settings make them not only much more likely to experience extended periods of hardship but also—as recent history has shown—much more

likely to suffer huge losses in lives and livelihoods when disasters occur (Clark-Ginsberg *et al.*, 2021; Feng & Xiang-Yang, 2018; Kong & Sun, 2021).

Furthermore, current disaster response frameworks are mostly developed for individual or singular risks and do not encompass multi-hazard interactions. This highlights a critical gap in disaster management today—a need to rethink and rework our outdated, mostly CSRE path from hazard to risk to disaster. We need urgently to reassess the adaptive capacity of those frameworks toward collaborative disaster management capable of addressing, not with the usual platitudes, but in fact, the compounded risks we are beginning to talk about more and more. Kapucu *et al.* (2022) Reemphasized the need for this change.

In this connection, this research systematically sifts through the literature on cascading disasters to uncover and analyze the complex dynamics of these events and the current response frameworks' limitations. By wading through the case studies from several countries, this paper identifies best practices, flags areas where urgent intervention is needed, and brings to light the disaster management field's big challenges in an interconnected world.

2. Research Hypothesis, Research Questions, and Objectives

This research argues that a comprehensive, multi-hazard approach to cascading disasters can significantly enhance response effectiveness across affected sectors by eliminating the conditions that foster deep-seated vulnerabilities and by making inter-sectoral coordination across response organizations better and timelier. Realizing cascading risks as interrelated dynamics, the study aims to contribute to the development of disaster response frameworks that will avoid compounding impacts and enhance the sequential response to subsequent disasters. Thus, this study attempts to answer two questions: (i) What are the critical components of a multi-hazard disaster management framework that effectively addresses the complexities of cascading disasters? (ii) How can a coordinated multi-sector approach reduce cascading risks for vulnerable communities and infrastructure?

The research questions have been further translated into two central hypotheses to guide the research process: (i) multi-hazard disaster management frameworks with

robust inter-sectoral cooperation can substantially mitigate the intensity and length of cascading disaster effects (ii) There is a positive relationship between a multi-hazard, systemic approach and increased resilience in affected communities and infrastructures.

This research aims to identify structural components and interdependencies for a disaster management framework that minimizes cascading effects across systems and sectors. To meet the aims of the research, a systematic review and meta-analysis of the literature on cascading disasters will delineate the major themes, the incipient trends, and the inadequacies of both the literature and practical management that the literature reveals while proposing policy recommendations for integrating multi-hazard approaches.

3. Theoretical Framework, Research Approach and Methodology

3.1 Theoretical Framework

This research employs the Systemic Risk Theory and the Complex Adaptive Systems framework to analyze cascading disasters by emphasizing interconnectedness across systems and by providing emphasis on adaptive response strategies. These frameworks emphasize the interrelation among events; therefore, for efficient disaster management, understanding the relationship among systems i.e., environment, and infrastructure is important (Day, 2014; Kelman, 2018; Oktari *et al.,* 2020; Zakour & Gillespie, 2013). The complex adaptive systems theory identifies continued evolution and unpredictability of response under disruption, while systemic risk theory hints at the vulnerability of systems to high interconnection standards whereby even small changes may cascade into disruptions *(Comfort, 2005; Cutter et al.,* 2003 ; Helbing, 2013).

3.2 Research Approach and Methodology

The systematic review and meta-analysis of the study were conducted following the PRISMA framework. The PRISMA methodology guaranteed a thorough, systematic, and nonduplicated selection of studies for both previous literature reviews and new studies. These sources include academic works from disciplinary and interdisciplinary peer-reviewed publications and case studies, grey-and-white literature, and reports

from international disaster management organizations. Extraction of information centered on seemingly areas such as study design, themes addressed, and results in terms of cascading effects, response measures, and system weaknesses, with particular emphasis on cascading effects, response strategies, and systemic vulnerabilities.

Criteria for inclusion were limited to studies that concentrate on cascading disaster definitions, management practices, and theoretical frameworks, published between 1984 and 2024. Taking on board recent findings to recognize an emerging range of increasingly complex disasters influenced by climate change and the current methodology allowed us to highlight the reoccurring themes, gaps, and trends in the literature that could serve as a ground for policy recommendations.

The concept map (Figure 01) portrays the overall research process graphically. It depicts how each element of systemic risk to adaptive strategies enters the general objective of setting a more appropriate framework for preventing cascading risks.

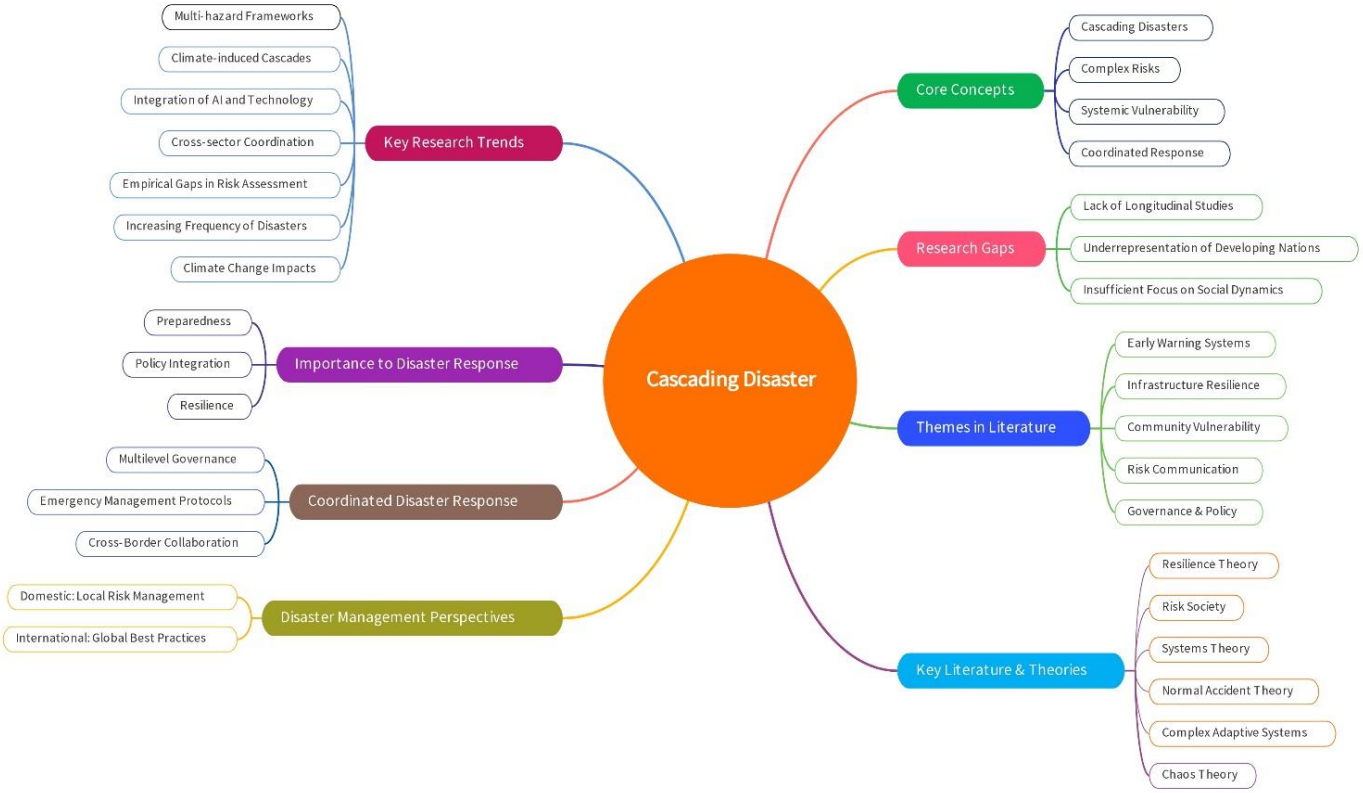

Figure 01: Concept Map Guiding the Research Process

(Source: Author's Preparation-Das,2024a)

The word clouds shown in Figure 02 illustrate the concepts and keywords more recognizable to cascading disaster literature, including systemic vulnerability, multi-hazard, and resilience. These keywords correspond to the multi-dimensional approach required for an analytical approach to addressing cascading disasters.

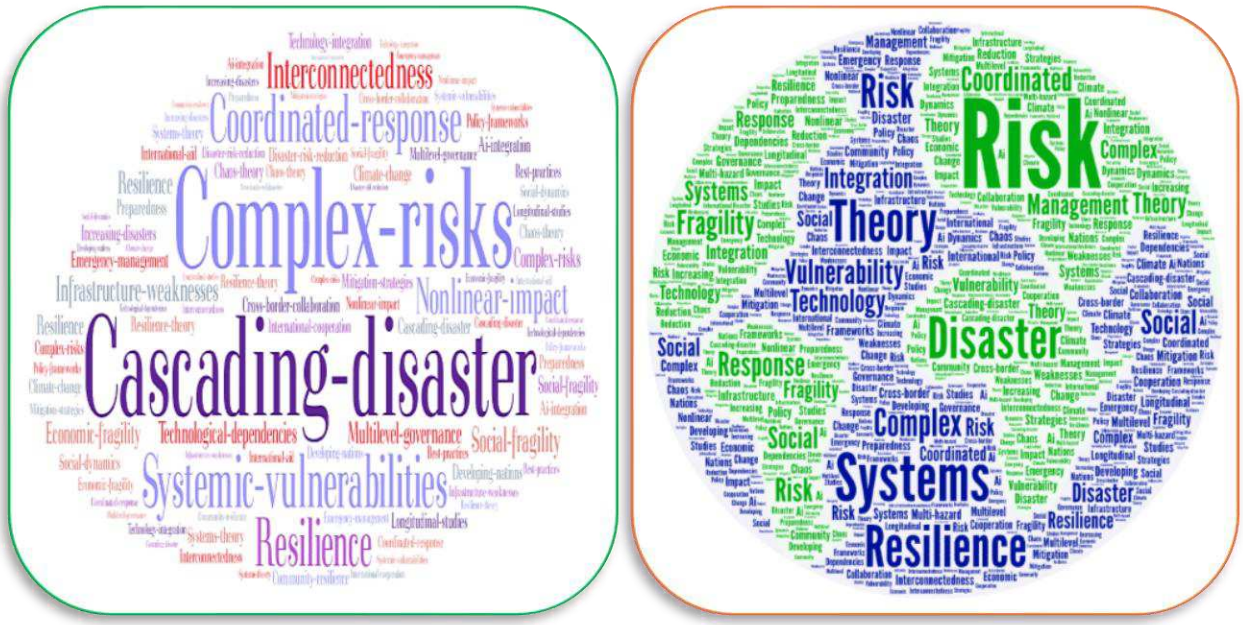

Figure 02: Key Concepts in Cascading Disaster Risk Management and Resilience Research

(Source: Author's Preparation-Das,2024b)

This systematic review and meta-analysis use both quantitative and qualitative synthesis to review the existing literature focusing on cascading disasters and response strategies. The methodology includes the phases as described in the PRISMA Framework (Figure 03).

Identification and Data Collection: The 'identification' step started by conducting a deep literature search on academic databases including Science Direct, JSTOR, Google Scholar, Web of Science, and so on. Specific keywords and terms such as Cascading Disasters, Systemic Vulnerability, Multi-hazard Risk Management, and Resilience were used. This effort resulted in 200 records from these databases and an additional 40 from various registers. Additionally, 25 more entries were gathered from websites, organizational reports, and citation searches. Studies from the previous version of the review were also included, adding 50 studies and 45 related reports to the dataset. This approach facilitated the inclusion of both traditional and recent impactful research appropriate to the aim and objectives of the study.

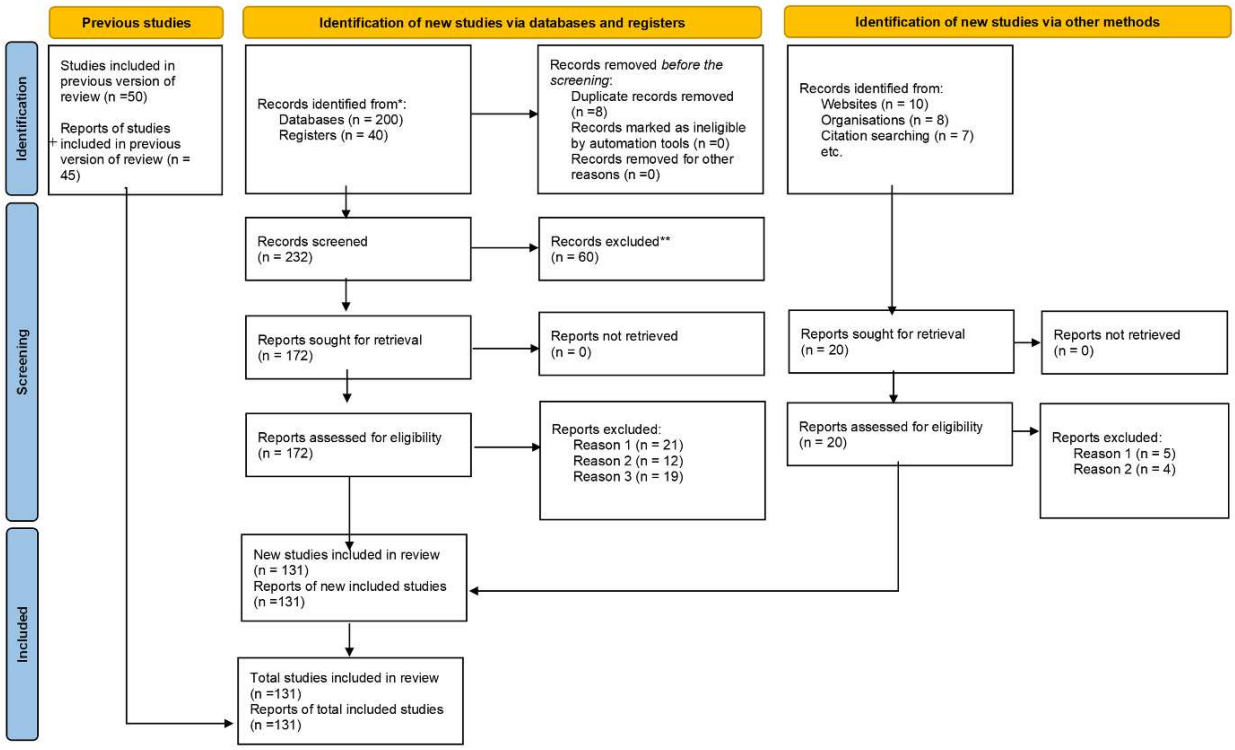

Figure 03: PRISMA Framework for Systematic Review & Meta-Analysis

(Source: Author's Preparation-Das,2024c)

Screening, Inclusion, and Exclusion Criteria: In the screening phase, duplicate records (n = 08) were removed, leaving 232 unique records for further evaluation. The titles and abstracts were scanned for their relevance; this resulted in the removal of 60 papers according to some guidelines like exploring one hazard or having inadequate actual data. The remaining 172 reports were then assessed in full text for eligibility. This phase aimed to find research on cascading disasters stressing their nature and managerial theories and approaches. Fifty-two of them were ultimately excluded on grounds such as the absence of a theoretical framework or minor relevance to cascading disasters.

Data Analysis and Synthesis of Outcome: The final inclusion phase resulted in 131 studies selected for qualitative synthesis, with 100 deemed suitable for quantitative analysis in the meta-analysis. Therefore, this research filled the gap in the previous review and presented a series of new studies on cascading disasters comprehensively. Thus, the integrative approach made it possible to define major trends, challenges, and opportunities for coping with systemic risks and multi-hazard risk management.

The analysis included a qualitative review of theoretical frameworks and a quantitative assessment.

4. Key Literature and Theories Associated with Cascading Disasters

The following sections will discuss relevant theoretical advancements concerning cascading disasters, key conceptual frameworks, indispensable disaster theories, and theoretical research studies. To promote easy understanding, the review categorizes sources into related sub-sections including Systemic Vulnerability, Risk Interdependency, Disaster Response Coordination, and Multi-Hazard Risk.

4.1 Key Concepts and Theoretical Foundations

Cascading disasters refer to a situation whereby several events occur in a sequence and very end up coalescing to make major calamities (Robinson *et al.,* 2021; Townend *et al.*, 2023). According to Alexander & Pescaroli (2019), 'cascading disasters' refer to sequences of interdependent failures in which a failure simply escalates to the next. Cascading disaster is hinged on the understanding of interlinked risks, thereby requiring the adopted strategies for responses to be multi-sectorial and adaptive.

Cascading disasters have a theoretical understanding arising from Systemic Risk Theory and Complex Adaptive Systems (CAS). Systemic Risk Theory postulates that interconnected systems like transportation, utilities, and health care reinforce vulnerability through interdependencies: disrupting one part can cause the entire system to fail. (Allen & Derr, 2016; Atun, 2014; Mitra & Shaw, 2023b). If CAS indicates resilience and adaptability according to Comfort (2005), disaster response frameworks would need to engage a built-in dynamic response continually to the complex and often unpredictable winding paths of cascading disasters.

Core Concepts

- **Cascading Disasters**: Cascading disasters are those disasters where the aftereffects of an initial disaster set off further disasters in a domino effect that intensifies and compounds the general impact (Mizrahi, 2020). For example, while an earthquake can cause collapsed buildings and other structures, it can also cause fires and chemical leaks and interrupt the emergency response as

well (Pescaroli *et al.*, 2018). Understanding these cause-and-effect patterns is important since cascading effects might overwhelm the response systems and multiply immense human and economic costs (Alexander, 2018).

- **Complex Risks**: In the context of cascading disasters, complex risks refer to interdependent hazards that complicate a disaster response. Complex risks and effects are overlapping, and multi-faceted, and they arise from interrelated societal, environmental, and technological systems, rendering it very difficult to foresee their effects (Gan *et al.,* 2024). The existence of complex risks means that a particular hazard may reverberate through various systems, where each has different vulnerabilities (Kasperson & Kasperson, 2001).
- **Systemic Vulnerability**: Systemic vulnerability hovers around cascading disarray among conjoined systems sometimes caused by the interconnectedness of critical components in infrastructure like power grids, water supply, and communication networks (Buldyrev *et al., 2010*). For instance, a power outage in one region can lead to water and health crises, which are on top of the calamity's consequences. (Mitra & Shaw, 2023a).
- **Coordinated Response**: Effective and efficient management of cascading disasters will have to involve multi-sectoral, multi-agency, and cross-jurisdictional efforts. Field studies bring out findings about joint emergency response protocols and mutual aid agreements aimed at meeting the difficult nature of cascading impacts (Bruneau *et al.*, 2003; Comfort, 2019).

4.2 Key Literature & Theories

- **Resilience Theory**: Resilience Theory gives an explanation and an explanatory framework for the adaptation and recovery of systems following cascading events. It illustrates how people and communities absorb and transform the forces of change associated with the role of flexible governance and social capital in developing resilience (Bruneau *et al.,* 2003; Chen *et al.*, 2021; Walker & Salt, 2006).
- **Risk Society**: Proposed by Ulrich Beck in 1992, risk society pertains to the different risks seen in the modern world that define societies – including risks coming from cascading failures. This view provides the rationale for the decision

to take a proactive approach to managing risks in uncertainty, commonplace in complex connected systems (Fakhruddin *et al.,* 2022; Park *et al.,* 2013; Suppasri *et al.,* 2021).

- **Systems Theory**: According to systems theory, such networks as modern infrastructures and societies create when one aspect detaches, it creates a negative domino effect throughout the networks (Meadows, 2008; Perrow, 2011). This link should be recognized in developing strategies for disaster response that will consider multiple effects.
- **Normal Accident Theory**: Normal accident theory put forward by Charles Perrow, (2011) insists on the fact that big accidents are inherent in complex systems mainly because of interconnection among sub-systems wherein the accidents may turn out to be big. This suggests that the organization must be aware of the weak areas in the system and that precautions should be taken to reduce the possibility of a failure affecting other areas (Kates, 1986; Sammarco, 2005; Sengupta & Jha, 2021).
- **Complex Adaptive Systems**: Disasters may be understood through a complex adaptive system approach whereby different components respond and adapt in real time (Holland, 1995). This perspective on the complex interactions among systems explains better how they respond to disturbances along with potential resilience and vulnerability amid cascading events (Baham *et al.,* 2017).
- **Chaos Theory:** The very essence of the chaos theory is quite distinct from other theories tendency which states that variations of initial conditions cause great, unpredictable changes in complex systems (Gleick, 1987). This indicates how unpredictable cascading disasters might be.

Table 1 extends a summary of some of the important works in the field of cascading disaster management, ranging from the conceptual foundation of systemic risk to empirical evidence that would later inform the development of best practices in response. These sources emphasize multi-hazard approaches, resilience planning, and integrated category response.

Table 1: Key Literature and Theories on Cascading Disaster

Author(s) & Year	Core Concepts/Theories	Findings/Contributions	Relevance to Cascading Disasters
(Alexander & Pescaroli, 2019)	Cascading Disasters Framework	Defines cascading disasters and multi-level response needs	Emphasizes coordinated response to risk amplification
(Alexander, 2018)	Emergency Planning	Advocates for comprehensive planning that includes multi-hazard scenarios.	Stresses preparedness for cascading events in emergency plans.
(Sun et al., 2024; Qiu et al., 2014; Wu et al., 2024)	Early Warning Systems	Proposes frameworks for community-engaged early warning systems.	Highlights the importance of timely warnings in mitigating cascading impacts.
(Braithwaite, 2024; Dizard, 2009)	Complex Catastrophes Model	Promotes cross-sectoral resilience planning	Essential for managing complex, cascading effects
(Beck, 1992)	Risk Society	Modern societies are increasingly defined by the risks they face.	Emphasizes the need for proactive risk management.
(Berkes & Ross 2013)	Resilience Theory	Highlights the importance of adaptive capacity and social capital.	Supports the development of resilient communities.
(Cutter, 2018)	Compound & Cascading Risk Theory	Highlights risk interdependencies in natural and human systems	Supports holistic management of interconnected risks
(Cutter et al., 2003)	Social Vulnerability	Identifies social factors that increase disaster vulnerability.	Points to critical social dimensions that affect cascading risks.
(Folke, 2006; Naqvi & Monasterolo, 2021)	Resilience Theory	Discusses the capacity of systems to absorb disturbances.	Relevant for understanding community resilience during disasters.

Author(s) & Year	Core Concepts/Theories	Findings/Contributions	Relevance to Cascading Disasters
(Kelman, 2018)	Cascading Disasters & Disaster Diplomacy	Links cascading disasters to disaster diplomacy efforts	Highlights how international cooperation can mitigate cascading impacts
(Ciplet & Roberts, 2017; Deubelli et al., 2022)	Multilevel Governance	Explores the importance of collaboration across government levels.	Critical for effective disaster response frameworks.
(Kruczkiewicz et al., 2021)	Multi-hazard Coordination Framework	Emphasizes integrated planning for compound risks	Highlights the need for coordinated response to simultaneous hazards
(Lindell & Perry, 2011)	Preparedness	Identifies strategies for proactive disaster preparedness.	Informs the development of effective preparedness measures.
(Meadows, 2008)	Systems Theory	Explains interconnectedness in modern infrastructures.	Important for understanding cascading effects in complex systems.
(Mileti, 1999)	Disaster Risk Assessment	Critiques traditional disaster management, advocating for proactive approaches.	Promotes a systemic view of interconnected hazards relevant to cascading disasters.
(López-Saavedra et al., 2021; Mitra et al., 2024)	Global Best Practices	Examines Japan's disaster response as a successful model.	Provides insights into effective disaster management strategies.
(Perrow, 2011b)	Normal Accident Theory	Argues that accidents are inevitable in complex systems.	Highlights vulnerabilities and the need for mitigation strategies.
(Perry & Lindell, 2003)	Preparedness and Resilience	Preparedness guidelines for emergency response	Highlights need for multi-level preparedness in cascading scenarios

Author(s) & Year	Core Concepts/Theories	Findings/Contributions	Relevance to Cascading Disasters
(Gong et al., 2023; Pescaroli & Alexander, 2015)	Toppling Dominos Metaphor	Analyzes disaster “domino” effects	Shows how initial failures trigger cascading impacts
(Pescaroli & Alexander, 2018)	Interconnected Risks	Develops a framework for analyzing interacting hazards.	Addresses complexities inherent in cascading disasters for better management.
(Gong et al., 2023; Huggins et al., 2020)	Infrastructure Interdependencies	Examines how critical infrastructure interdependencies amplify disaster impacts.	Emphasizes infrastructure's role in exacerbating cascading disaster effects.
(Gan et al., 2024; Mitra & Shaw, 2023a)	Disaster Research	Compiles theories and methodologies on cascading disaster dynamics.	Essential for understanding how cascading disasters evolve and manifest.
(Bruneau et al., 2003; UNDRR, 2015)	International Frameworks	Stresses the integration of disaster risk management into development.	Provides a guideline for addressing cascading disaster risks.
(UNDRR, 2021)	Disaster Risk Reduction	Highlights the need for reducing vulnerabilities to cascading disasters globally.	Guides strategies to diminish cascading risks in disaster management policies.
*(*Kelman, 2018b *; Kanteler & Bakouros, 2024)*	Cross-Border Collaboration	Discusses the importance of regional agreements in disaster response.	Relevant for managing transboundary cascading disasters.

(Source: Author’s Preparation,2024)

5. Key Themes, Trends, and Gaps in the Literature

5.1 Key Themes in Literature

- **Early Warning Systems**: Early warning systems sustain continuous monitoring and communication of information related to initial events, such systems are critically important in identifying and mitigating the risks of cascading disasters (Basher, 2006).
- **Infrastructure Resilience**: Research calls for designs of structures that can be able to withstand and recover from progressive effects. Essential to this process is resilient design, especially for critical sectors such as energy, water, and healthcare (Bruneau *et al.,* 2003; Yang *et al.,* 2023).
- **Community Vulnerability**: These caste communities, with disproportionate representations among low-income groups, girls, women, and the elderly, are the apparent import of the cascading disaster somewhere near the top of the chain, driven by limited resources and mobility (Alexander & Pescaroli, 2019; Cutter *et al.,* 2003).
- **Risk Communication**: What one needs to do is communicate correctly and at the right time not to let misinformation bubble over. It ensures that people understand the information provided and their response is quite rational (Mileti & Sorensen, 1990).
- **Interconnectedness and System Vulnerabilities**: Cascading disasters are the ones that expose the vulnerabilities in intertwined infrastructures; transportation, energy, and communication are the major ones posing vulnerabilities. Alexander & Pescaroli (2019) advocate for multi-sectoral approaches to manage these vulnerabilities, network interaction (Gill & Malamud, 2016) is discussed in connection with how the failures in one sector could lead to cascading failures in another.
- **Adaptation and Resilience in Disaster Response**: The CAS theory emphasizes the management of resistance as its primary principle. Comfort (2005) highlights that the major value of technology-driven solutions is to permit the kinds of adjustments that allow systems to adapt as disasters unfold: That

resilience must be shifted into real-time monitoring, flexible strategy, and collaboration among many agencies as pre-eminent tasks.

- **Multi-hazard Coordination**: The literature supports the development of multi-hazards in increasing order with the expectation of expanding the capacity of the disaster response. Further support is provided by Cutter (2018) who argues for multi-hazard approaches in which multiple sectors are coordinated to manage a set of interlinked hazards since isolated responses cannot mitigate the disproportionate effects of complex disaster chains.

5.2 Key Trends in Cascading Disaster Management Research

- **Multi-hazard Frameworks**: Multi-hazard frameworks include planning for several kinds of hazards simultaneously with an emphasis on how different hazards interact with one another. The multi-hazard approach allows social actors to prepare for combined and sequential occurrences in contrast to single scenarios (UNDRR, 2021). This concept has gained attention with researchers' recognition of the compounding impact of events such as hurricanes followed by flooding (Kappes *et al.,* 2012).
- **Climate-induced Cascades**: Climate change is inducing an increase in the frequency and intensity of natural disasters. Situations like wildfires that cause flooding due to deforestation—climate-induced cascades are on the rise (Field *et al.*, 2012). A clear understanding of these cascades greatly helps with the forecasting of the secondary impacts and in undertaking due mitigating responses.

  A powerful example of climate-induced cascades is the sequence of wildfires leading to catastrophic floods. Wildfires, particularly intense wildfires, can sometimes completely consume forests and grasslands. Vegetation degradation complicates the issue of soil stability and leads to a diminished soil’s water-holding capacity. When this natural barrier is gone, even light rainfall causes flash floods, or worse, detrimental mudslides because the burned, weakened soil will not support any pressure (Tedim *et al.*, 2020). For example, after the November 2018 California wildfires, heavy rains subsequently fell, with deleterious mudslides hammering Montecito, having afflicted burned-out areas.

The cascade illustrates how one disaster can lead to another, for instance, how a wildfire can amplify devastation and complicate disaster recovery (Stephen D. Wong, 2020).

- **Integration of AI and Technology**: AI and other emergent tools are changing risk evaluation and management in many ways while allowing timely enhancement of the predictive models. For instance, AI-driven analytics can identify patterns in climate data to anticipate cascading risks, meaning that the interventions can be made much sooner and more effectively (Clark-Ginsberg *et al.,* 2021; Das, 2021).
- **Cross-sector Coordination**: Recent research indicates the importance of the synergy of government and non-profit organizations with the private sector for efficient utilization of resources during complex emergencies. This approach ensures that resources and expertise are pooled effectively during complex disasters (Mileti, 1999; Hu *et al.,* 2022).
- **Shift Toward Resilience Across Multiple Hazards**: Scholars increasingly stress the need for resilience incorporating multiple interrelated hazards instead of single, isolated hazard responses (Cutter, 2018). These changes also mark another evolution toward integrating intersectoral risk and multiple-hazard assessments (Kachali *et al.*, 2018; Zuccaro *et al.,* 2020).
- **Development of Predictive Models**: The event evolutionary graph developed by Chen *et al.*, (2019) is a tool for real-time risk assessment. It partly empowers disaster managers to visualize cascading risks so that pre-emptive interventions and improved resource allocation can occur.

5.3 Research Gaps in the Existing Literature

- **Lack of Longitudinal Studies**: There is remarkable research work done on cascading disasters; however, none of the longitudinal studies account for the long-term impacts of such disasters. Consequently, only long-term interventions allow for identifying recovery paths, resilience, and adaptation in the process (Kanteler & Bakouros, 2024 ; T. J. Huggins *et al.*, 2020).Filling this gap reveals new possibilities for a broader or longer examination of cascading disasters over years or even decades.

- **Underrepresentation of Developing Nations**: Most of the studies have been carried out in high-income countries, thus rendering cascaded squalors unknown in developing ones. These countries face challenges that are order of magnitude greater owing to fewer resources and poor infrastructure, elements that multiply the effects of cascading dangers (Adelekan, 2010; Berariu *et al.,* 2015; Mohammed *et al.,* 2019).
- **Insufficient Focus on Social Dynamics**: The current ways of conducting research mainly overlook the social dynamics underlying disaster response, like community cohesion and social networks. They are crucial to revealing how the community responds to cascading disasters, and which might affect overall resilience (Perry & Lindell, 2003).
- **Lack of Empirical Validation**: Research work on cascading disasters primarily concentrates on well-researched developed nations. This very much leaves the findings' applicability level low for the under-researched less-resource areas. Most of the studies take cases from the United States and Japan, limiting the very issue of cascading disaster management in developing countries (Berariu *et al.,* 2015;Elvas *et al*., 2021; Nones & Pescaroli, 2016).
- **Insufficient Exploration of Governance Models**: Even though some see layered risk and CAS theories as giving support for cross-sectoral collaboration, little has been published about practical governance models that effectively base implicit support upon these theories. Comfort and Haase (2006) emphasize the communications enterprise but provide no actual governance structures adaptable to cascaded disasters.

Table 2 apprehends the vital findings along with the research gaps in cascading disaster management literature and demonstrates contributions that address issues like systemic vulnerabilities, cross-sector collaboration, and resource efficiency.

Table 2: Key Literature Findings and Research Gap Identified

Author(s) & Year	Research Gap Identified	Research Contribution	Associated Research Theme & Trend
(Alexander & Pescaroli, 2019)	Empirical validation in real-world settings as needed	Proposed a multi-layered response framework for cascading effects	Disaster response frameworks and resilience planning
(Berariu et al., 2015)	Focused on logistics, lacking broader governance insights	Analyzed resource allocation and identified bottlenecks	Resource management and operational efficiency
(Chen et al., 2019)	Limited application outside urban flooding scenarios	Developed a framework for mapping vulnerabilities and responses	Vulnerability assessment and rapid response strategies
(Ciplet & Roberts, 2017; Comfort, 2005; Schweizer & Renn, 2019)	Lacked cross-sector collaborative frameworks	Advocated for technological integration in disaster resilience	Technological innovation in emergency management
(Cutter, 2018)	Insufficient empirical data on implementation outcomes	Emphasized the need for resilience integration across hazards	Multi-hazard resilience and community adaptation
(Funabashi & Kitazawa, 2012)	Insights were mainly applicable to well-resourced nations	Reviewed Japan's comprehensive response to the tsunami and nuclear crisis	Crisis management in high-resource contexts
(Gill & Malamud, 2016)	Limited focus on comprehensive multi-sectoral policies	Examined multi-hazard interactions and systemic vulnerabilities	Systemic risk assessment and multi-hazard interactions
(Kapucu et al., 2022)	Required policy integration for cross-sector governance frameworks	Highlighted the importance of cross-agency coordination	Governance frameworks and inter-agency collaboration

(Source: Author's Preparation,2024)

6. Cascading Disasters: Complex Risks and Systemic Vulnerabilities in Coordinated Disaster Response

Cascading disasters consist of elemental failures in a system that flows through other systems and sectors when a driving hazard interrupts, impacting one or more critical systems, often going beyond just the immediate sectors (Alexander & Pescaroli, 2019). It shows us how modern systems, which include but are not limited to, the energy grid,

healthcare services, and transportation networks, very much interact with each other, making them vulnerable to complex risks and very prone to system-wide failures (Gill & Malamud, 2016). For instance, Hurricane Maria hit Puerto Rico paralyzed the power sector, and affected hospitals, water and electricity interests, and communications, making a natural disaster shift into a long-term humanitarian calamity with many sociopolitical consequences (Andrade *et al.,* 2022; Aranda et al., 2022). This example highlights the limitations of conventional sectoral disaster responses that are often insufficient in managing the cascading impacts of interconnected systems' failures (Kapucu *et al.*, 2022; Qie & Rong, 2022; Townend *et al.,* 2023; Uddin *et al.*, 2019; Uusikylä et al., 2020; Whitworth & May, 2006).

Coordinating sequential disasters entails a move from single-hazard risk strategies to complex multi-hazard solutions to the issues of systemic risks (Comfort & Haase, 2006). Scholars suggest the development of adaptive and cross-sectoral frameworks that can respond dynamically and variably across different thinking hazards intersecting with critical infrastructure and social systems (He & Cha, 2022). This need was further illustrated by the 2021 Texas winter storm, when the disruption of critical infrastructure certainly extended beyond that of heat and water systems to supply chains, manifesting how one system's vulnerability can enhance risk propagation across many other sectors (Clark-Ginsberg *et al.*, 2021). Hence, research calls for measures to promote resiliency, which include increased cooperation between agencies and research personnel making decisions based on a risk-scientific basis. It will prevent the aggravation of the effects of cascading events to strengthen the recovery capabilities in the disaster-affected areas *(Ahmed et al., 2019; Buchtmann et al.,* 2023; Helbing, 2013; Peng *et al.,* 2023).

6.1 Understanding Complex Risks in Cascading Disasters

Cascading disasters are complex—inherently, various hazards act in cohorts by making risks through direct and indirect interactions across interdependent systems of coupled hazards (Alexander, 2018). Cascading disasters, conversely, to stand-alone disaster events simulacra of failure-attack, calamity, or some other complex attack across interconnected systems of energy, transportation, water, and healthcare. The mitigation or aggravation of one another may characterize the interaction of these sectors with one another. Gill and Malamud (2016) convey the importance of “hazard

interactions." These actions are expected to compound the effects of initial disruption through a process of interconnected failures. The interaction of several factors like social vulnerabilities and structural weaknesses in ways not expected leads to complex risks that may surpass the traditional response capacities (Buchtmann *et al.*, 2023).

Research indicates that when complex risks manifest, they almost always insult the vulnerable areas that do not feature such resilient infrastructures capable of withstanding compounded effects. During the Fukushima Daiichi nuclear disaster, for example, an earthquake and subsequent tsunami provoked dysfunction in ligaments in the power supply system and created a failure cascade that paradoxically inhibited emergency operations and amplified public health risks (Funabashi & Kitazawa, 2012). This case demonstrated distinctly that if there is no sectoral cooperation and if separate systems fail, they can turn into a large systemic crisis causing immense socioeconomic damage (Helbing, 2013). Furthermore, Cutter (2018) argues that to understand cascading events, one must pay attention to the ways that some underlying vulnerabilities-such as old and antiquated infrastructure, or governmental systems that are not working well propagate localized hazards into general crises that indicate the necessity for multi-hazard risk-based approaches in risk management and disaster interventions.

6.2 Systemic Vulnerabilities in Disaster Response

Systemic vulnerabilities within critical infrastructure systems tremendously impact cascading disasters in their intensity and geographic scope (Federici & o'Brien, 2019). This systemic vulnerability encompasses the technical dependencies within systems, inadequate measures of preparedness, and the physical connectivity of systems (Huggins *et al.*, 2021). When these vulnerabilities are not redressed, they increase the likelihood of synchronization, and individual breakdowns can quickly assume larger-scale crises in society (Federici, 2020). The cold weather in Texas in February 2021 interrupted energy and water service, proving how a failure in one system threatens multiple, as the impacts became systemic (Clark-Ginsberg *et al.,* 2021).

The other networks that bedrock monopoly on systemic vulnerability is improving communication amongst sectors and coordination to alleviate compounded effects letting the sectors involved present development in individual spheres be assured.

According to several academics, coordinating frameworks will help mitigate risks to infrastructures that are mutually dependent upon one another. Empowering cross-connections among the partners reduces risks and enhances communication and responsiveness of cross-sectoral infrastructures (Amberson *et al.*, 2024). The impossibility of a cross-sectoral standard communication protocol is a persistent impediment to response coordination, concerning delays and longer recovery times. Kapucu *et al.* (2022) go further by proposing that the approach to disaster management is overseen by a "network governance" model of inter-organizational collaboration and transmission structures, flexibly structured so that they can dynamically be adjusted, to address cascading crises better through shared efforts.

6.3 Importance of Cascading Disasters to Disaster Response Planning

Cascading disaster is an essential theme to reflect on in current disaster response planning because it formulates the shortcomings of conventional single-hazard frameworks. Situations like the 2011 Tōhoku earthquake and later the COVID-19 pandemic, define the need for frameworks for coping with related risks (Funabashi & Kitazawa, 2012; Clark-Ginsberg *et al.,* 2021). Effective resilience will not address the immediate impact but go further to prepare for secondary and other hazards that result from the first one's activities. Mechanical preparation for this requires an integrated adaptive approach with cross-sectoral cooperation as well as real-time data sharing and engagement between relevant networks with established communication lines between the main actors involved (Quigley *et al.,* 2020; Quinn *et al.,* 2024; Rahaman *et al.,* 2020; Thomas, 2020).

- **Preparedness**: Comprehending cascade effects from disasters has obvious advantages for the design of preparedness measures. Understanding the chronology of hazards helps emergency responders build prevention-related measures that involve complex interconnection of the affected communities and systems. For instance, it is possible to integrate the probability of secondary disasters in plans of preparedness, such as floods in the event of an earthquake; efforts in staff training and development, in establishing communication networks that work in the context of a disaster (Khan *et al.,* 2023; Lindell & Perry, 2011 ; Lu *et al.,* 2018; Miller & Pescaroli, 2018).

- **Policy Integration:** Integrated policymaking is an important management approach that meets the complex risks of cascading disasters. Ideal disaster management should therefore call for a convergence of the health, the environment, and the infrastructure sectors for multi-hazard scenarios (Bisri & Lutfiananda, 2022; Santella *et al.,* 2009). These integrated disaster planning approaches are considered as important to the disaster risk management strategies that are enshrined in the Sendai Framework for Disaster Risk Reduction and which champion the spirit of formative cooperation to accrue the hazards into one framework (UNDRR, 2015). An integrated method allows discussions to be voiced from many angles and is, therefore, a more solid ground for disaster response.
- **Resilience**: Essentially, at the community, institutional, and infrastructural levels, developing the ability to build resilience is important in preventing cascading disasters. From the approach by Folke (2006), resilience may be understood as the ability of a specific system to withstand any type of interference and continue performing the core tasks. At this level, community resilience can be built through public consciousness programs where the members of the community are equipped and prepared for easy response to disaster occurrences. Policies targeted toward creating adaptive capability concerning modern challenges, including flexible governance structures, as well as investments in resilient infrastructure, will lead a very long way (Berkes & Ross, 2013). This will terminate the pursuit of creating resilient societies to withstand cascading disasters and recover from their effects.

6.4 Coordinated Disaster Response: Strategies, Challenges, and Paths to Success

6.4.1 Strategies and Challenges

Remarkably, the role of coordination during cascading disasters cannot be underestimated. It is inherently a multi-layer cross-system engagement. Hence a co-ordinated response action can support a more systematic, integrated approach to prevent and address second-order effects or cascades (Kapucu *et al.,* 2022). Inter-agency cooperation; a centralized communication framework;

and the planning of resilient infrastructure come to constitute the trio of more critical harmonized interventions for mitigating the effects of cascading failures (Chen *et al.,* 2024). Such a response network, however, requires overcoming structural, jurisdictional, and operational difficulties that generally hinder prompt response efforts (Comfort & Haase, 2006).

In making disaster responses successful or shortcomings, international case studies reveal that Hurricane Katrina, for instance, saw a lot less coordination among agencies prolonged their response duration, and aggravated losses; and this highlights the institutional limitations of segmented disaster response models (Comfort, 2005). The COVID-19 response also demonstrated how better cooperation, supply sharing, and data acquisition could enhance managing global affairs despite features such as resource scarcity and bureaucracy (Das *et al.,* 2021; Hagenlocher *et al.,* 2022; Quigley *et al.,* 2020; Rahaman *et al.,* 2020). Experts voice their opinion that systemic planning for cascading risk should encompass approaches that incorporate inter-organizational collaboration that favours vertical and horizontal cooperative governance for the preparedness of upsurging cascading events (He & Cha, 2022).

6.4.2 Pathways to Successful Disaster Response Efforts

Multilevel Governance

The coordinated response to disaster at different government levels is believed essential for effective disaster management. Multilevel governance is described as the coordination with local, regional, and national governments for resource mobilization, information exchange, and best practices swap (Ciplet & Roberts, 2017; Dougherty, et al., 2022; *Lawrence et al.,* 2020; MacGillivray & Richards, 2015).In this partnership, response efforts will reflect the peculiar needs of the affected areas and at the same time maintain the integrity of the national response the United States disaster response relations between government agencies and the private sector are covered in the National Response Framework (U.S. Department of Homeland Security, 2019).

Emergency Management Protocols

First responders have protocols that must be followed during cascading events. A well-established protocol like the Incident Command System provides support for the organization's management of incidents through the definition of roles, responsibilities, and communication structure of responders (FEMA, 2020). This framework provides an efficient approach towards a complicated disaster response system, in which structure is very important given that accuracy in coordination and response, especially in times of disaster determines success.

Cross-Border Collaboration

Cross-border collaboration in the management of cascading disasters affecting more than one country continues to rise. Different disasters like epidemics, weather disasters, and technology breakdowns, often affect different countries, which means that it is only reasonable, to work together to minimize the impact of such mishaps (Das, 2020a; Hu *et al.*, 2022; Kanteler & Bakouros, 2024; MacGillivray & Richards, 2015). The European Union (EU) funded instruments like the European Union Civil Protection Mechanism through the efficient grant enable its members to share information, knowledge, and resources, and to conduct training among member states to enhance disaster risk response in cascading events among the parties (Nones & Pescaroli, 2016 ; Suk *et al.,* 2020).

6.5 Resilience-Oriented Policy Approaches to Managing Cascading Disasters

Structurally stable policies should be able to meet challenges inherent to cascading disasters at present and in the future. Move towards new resilience-oriented policy frameworks will entail strategies that seek to prioritize adaptive capacities through cross-sectoral risk assessments, redundancy in critical systems, along people involvement in disaster planning (Buchtmann *et al.,* 2023). In the Hyogo Framework for Action, multi-hazard risk assessments must be integrated into disaster management, with countries required to adopt resilience-promoting policies working through both proactivity and responsive capacities (ANALYTICS, 2014).

Building resilience has increasingly turned towards policies that mandate disaster risk reduction strategies across core infrastructure sectors to enhance their ability to withstand cascade effects. Deubelli *et al.* (2022) suggest that resilience-enhancing policies should comprise high-threat standards of infrastructures, risky security checks and balances, and public-private partnerships that facilitate resource mobilization during calamity occurrences. Training programs for fostering interagency communication and networked disaster management are therefore necessary for developing an adaptive and resilient response system. Resilience policies promote readiness to lessen the risks of chain effects of disasters in both governmental and non-governmental organizations (Federici & o'Brien, 2019).

7. Case Studies and Best Practices

7.1 Key Practices in Cascading Disaster Management

Strategies for effective management of cascading disasters must be derived from experiences such as the Tōhoku earthquake of Japan in 2011 and Hurricane Katrina in the United States. These cases illustrate the role of multi-sectoral coordination, information-sharing, and variability in response structures in managing complex risks (Funabashi & Kitazawa, 2012; Comfort & Haase, 2006).

Domestic Disaster Management Perspective: Local Risk Management

Cascading disasters in turn call upon a domestic multi-level risk management regime; it has a paramount role in disaster mitigation at the community level. Community participatory planning exercises would go a long way toward including local needs and knowledge into disaster risk management strategies *(Das & Hossain, 2017; Quigley et al.,* 2020). Local governments should also support people in carrying drills, developing strategies, and establishing community response teams that contribute to the building of a constructive culture in this sphere.

International Disaster Management Perspective: Global Best Practices

International NGOs and World Organizations such as the United Nations and the World Bank have provided special instructions on how to prevent cascading

disasters. The essential features of the UN Sendai Framework are a multi-hazard approach and relevant disaster risk reduction as key elements to environmental failure in governance on all levels (UNDRR, 2015). Therefore, case studies such as Japan's reaction after the track of the 2011 earthquake and tsunami display the establishment of disaster risk reduction, which had been successfully put into national policy and local preparedness actions (Chen *et al.,* 2020; Mitra *et al.,* 2024; Wang *et al.,* 2022).

The response to Hurricane Katrina revealed major deficits in the disaster response network particularly in sharing and co-ordination amongst departments. As there was no coordinated response plan, there were weaknesses in the federal as well as the local government departments. Hurricane Katrina provided such lessons, starting with the need for reliable conventional communication and the integration of personnel from all federal, state, and local tiers, which subsequent enhancements have revised the federal disaster response policies (Comfort & Haase, 2006; Greenberg, 2020).

Disaster responses after the 2011 Tōhoku earthquake and tsunami proved that single-hazard disaster planning had come to its limitations (Holguín-Veras *et al.,* 2014). Funabashi and Kitazawa (2012) underscored the need for integrated responsive frameworks addressing multi-hazards, which include seismic activity, tsunami events, and nuclear melt-down. Consequently, Japan's response created; into remedy against future compounded disasters, the national resilience strategy, emphasizing cross-sector coordination and infrastructural strength.

The bushfire of 2019-2020 served to demonstrate the risks associated with cascading environmental events within Australia, whereby fire spreads to air quality and then hobbled the healthcare system. Formally, it eventually resulted in developing a Group National Resilience Taskforce in Australia which was essentially geared at risk evaluation, multi-hazard organizational coordination as well as adaptive planning through emergency services to enhance future preparedness towards cascading disasters (Buchtmann *et al.*, 2023).

8. Conclusion & Way Forward

Points raised in this literature review reflect the extreme challenges in managing cascading disasters and point out the limitations of traditional, single-event-focused response frameworks. The theoretical framework of systemic risk and CAS stresses the appropriate implementation of versatility, resilience, and integration in a disaster response framework. Such trends as predictive models and cross-sector alignment illustrated that there is a need for implementation avenues concerning cascading disaster management improvements. Still, empirical validation and the development of flexible governance frameworks remain in high need here.

Thus, improving capacities for responding to disasters in each country of the world will require multi-hazard resilience, prediction, and effective governance. The policy frameworks are based on adaptive activities that involve multiple sectors. These frameworks can be developed further to reach new forms of consequential disasters. Its development also contributes positively to the global disaster response and disaster risk reduction.

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