A Survey of Natural Disaster Risk Assessment and Infrastructure Resilience

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Abstract

This survey paper provides a comprehensive evaluation of natural disaster risk assessment, focusing on the vulnerabilities of infrastructure systems to hazards such as typhoons, rainstorms, and earthquakes. It underscores the importance of integrating socio-economic dimensions into risk assessments to enhance governance and decision-making, thereby improving disaster preparedness and response. The paper highlights the role of advanced technologies, including AI and machine learning, in operational efficiency during crises, and emphasizes the need for data-driven approaches. Key findings reveal the significance of social support in disaster preparedness, particularly for vulnerable populations, and the critical interconnectedness of infrastructure sectors in achieving Sustainable Development Goals (SDGs). The survey explores power grid resilience strategies, advocating for adaptive approaches to diverse disruption sources and optimizing resource allocation under uncertainty to enhance disaster relief logistics. It also emphasizes the integration of social media data for improved risk communication and the necessity for enhanced disease surveillance systems to mitigate public health impacts during disasters. The paper concludes by advocating for continuous improvement in disaster risk assessment and resilience strategies, focusing on data integration, advanced technologies, and stakeholder collaboration to develop robust and adaptive measures for mitigating the impacts of natural disasters.

1 Introduction

1.1 Overview of Natural Disaster Risk Assessment

Natural disaster risk assessment is essential for understanding and mitigating threats from hazards such as typhoons, rainstorms, and earthquakes. These assessments identify vulnerabilities in infrastructures and communities, informing effective disaster management strategies. The increasing frequency and intensity of natural disasters, driven by climate change, highlight the need for scalable risk assessment tools that encompass both natural and socio-economic factors [1].

The primary aim of risk assessment is to reduce the adverse impacts of extreme weather events by quantifying potential risks and enabling tailored resilience strategies. Urban areas, facing heightened risks from rainstorms and floods, require improved assessment and emergency response strategies [2]. Evaluating infrastructure vulnerabilities allows stakeholders to prioritize resource allocation and develop targeted interventions, enhancing preparedness and response capabilities [3]. For example, the Zhengzhou '7.20' rainstorm disaster underscores the need to identify factors influencing disaster preparedness to improve overall readiness [4].

Traditional methods, such as field surveys, often lack scalability and accuracy, particularly at hyper-local levels [5]. Thus, innovative approaches leveraging advanced technologies and data analytics are increasingly necessary for precise and timely assessments. These assessments address immediate safety concerns after disasters [6] and inform long-term resilience strategies, including optimizing disaster relief management and emergency inventory pre-positioning [7].

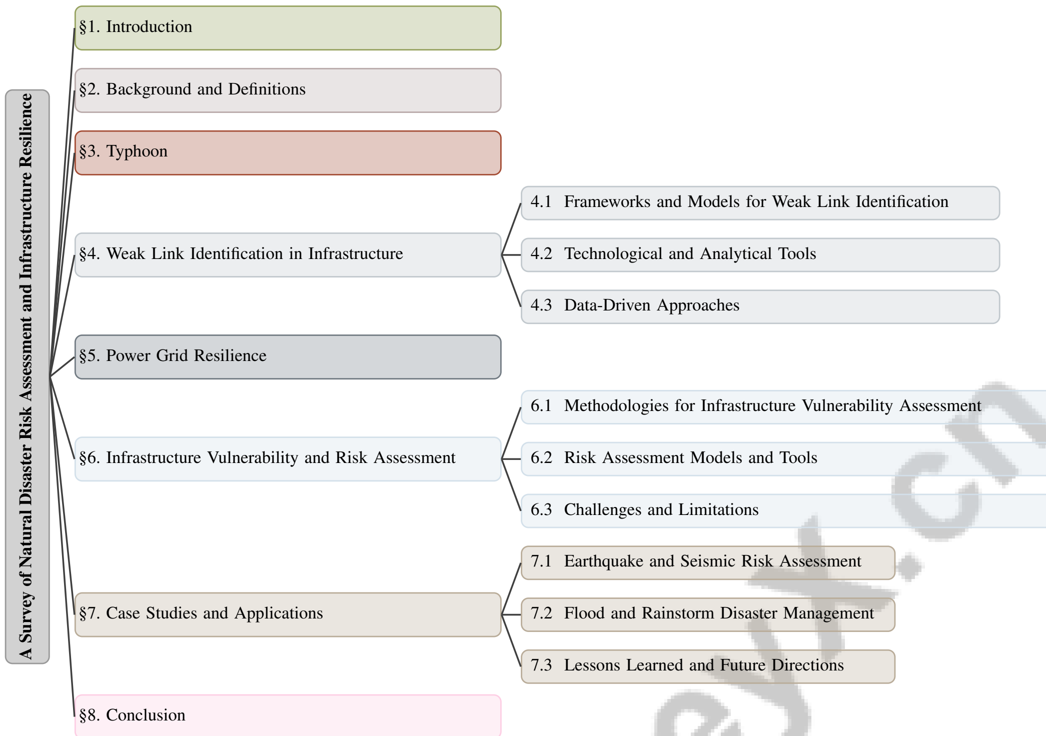

Figure 1: chapter structure

Integrating smart grid technologies and predictive analytics is vital for enhancing power system resilience against low-probability, high-impact disruptions like hurricanes and earthquakes. A comprehensive analysis of power system resilience across generation, networks, and loads is essential given their increasing vulnerability [8]. Additionally, addressing the resilience of integrated electricity and natural gas distribution systems during typhoons is crucial for maintaining essential services [9].

Effective disaster resilience assessments are critical for reducing casualties and property losses associated with natural disturbances, particularly short-term weather events like typhoons [3]. Accurate risk maps reflecting building vulnerabilities and potential seismic consequences are necessary, as demonstrated in assessments of residential buildings in Italy [10]. Understanding the impacts of extreme weather on power grid reliability is essential for maintaining services during disasters [11].

Furthermore, infrastructure's role in achieving Sustainable Development Goals (SDGs) and the interdependencies among various infrastructure sectors are vital in risk assessment, contributing to a comprehensive understanding of disaster risk reduction [12]. Integrating disaster and development studies informs policies for global disaster risk reduction, sustainable development, and climate change [13]. Utilizing social media data enhances insights into public awareness and responses to natural disasters, improving risk communication and management strategies. The vulnerability of critical infrastructure systems, such as power and water, during extreme weather emphasizes the need to address interdependencies and community social vulnerabilities [14]. Effective humanitarian logistics, particularly in optimizing location and allocation decisions during and after earthquakes, is also a crucial aspect of natural disaster risk assessment [15].

1.2 Structure of the Survey

This survey is organized to provide a comprehensive exploration of natural disaster risk assessment and infrastructure resilience, particularly in urban contexts. It begins with fundamental concepts and definitions related to natural disaster risk assessment, infrastructure vulnerability, and power grid resilience, establishing a foundation for subsequent discussions.

The survey then examines the specific characteristics and impacts of typhoons, rainstorms, and earthquakes, emphasizing the challenges these natural hazards pose to infrastructure and power grids.

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A focused analysis follows on identifying weak links within infrastructure systems, exploring various frameworks, models, and technological tools that detect vulnerabilities and enhance resilience.

Power grid resilience strategies, including the integration of smart grid technologies and predictive analytics, are analyzed to understand how technological innovations contribute to maintaining grid stability during natural disasters. Methodologies for assessing infrastructure vulnerability and disaster risk are discussed, addressing the tools and models employed in this domain, alongside their challenges and limitations.

A significant portion of the survey is dedicated to case studies and real-world applications, particularly urban disaster resilience assessments for rainstorm and flood disasters [16]. This section categorizes research into stages of risk assessment, including physical risk evaluation, socio-economic vulnerability analysis, and their integration into comprehensive risk management strategies [17]. These case studies offer valuable insights into successful strategies and lessons learned from past disasters.

Finally, the survey concludes with a synthesis of key findings and insights, discussing their implications for future research and the continuous improvement of disaster risk assessment and infrastructure resilience. This structured approach facilitates a nuanced analysis of the intricate relationship between natural disasters, particularly rainstorms and floods, and urban infrastructure systems. By integrating various assessment models that consider critical factors such as personnel safety, environmental conditions, and management practices, this methodology contributes to developing resilient urban environments capable of effectively responding to and recovering from catastrophic events, especially in light of increasing climate change impacts, as evidenced by recent disasters in cities like Beijing and Zhengzhou [16, 18, 19, 20, 2].The following sections are organized as shown in Figure 1.

2 Background and Definitions

2.1 Key Concepts in Natural Disaster Risk Assessment

Natural disaster risk assessment systematically evaluates hazards, vulnerabilities, and resilience capacities within socio-technical systems, including infrastructure and communities, to minimize adverse impacts and facilitate effective mitigation strategies. A crucial component is vulnerability analysis, particularly for water infrastructure exposed to diverse hazards [21]. Assessing vulnerabilities in interdependent infrastructure systems, such as Integrated Electricity and Gas Distribution Systems (IEGDSs), is vital to prevent outages and cascading failures during events like typhoons [9]. Urban lifeline systems' susceptibility to rainstorms necessitates resilience enhancement to mitigate economic losses and casualties from interconnected infrastructure failures [2]. The complexity of forecasting rainstorm-induced floods, especially in regions with intricate hydrogeological conditions, complicates risk assessment efforts [22].

A data-driven modeling approach to understanding interdependent urban infrastructure networks is essential for comprehending the complex interplay between systems and their collective resilience [23]. This approach is particularly relevant for assessing flood disaster risks in areas with heavy rainfall patterns, such as the Lijiang River Basin [24]. Inadequate community resilience assessment to urban floods hampers effective disaster risk management, highlighting the need for comprehensive frameworks integrating various vulnerability dimensions [25]. Community resilience is linked to resident engagement in disaster risk reduction (DRR) activities, enhancing a community's capacity to withstand and recover from disasters [26]. Understanding interdependencies and potential failure points within critical infrastructure systems is pivotal for ensuring urban resilience, especially under conditions of incomplete data [19, 27].

2.2 Importance of Weak Link Identification

Identifying weak links within infrastructure systems is crucial for enhancing resilience against natural disasters, as these vulnerabilities can undermine preparedness and response capabilities. The complexity of urban infrastructures, characterized by diverse topological structures and evolving states, presents challenges in effectively addressing vulnerabilities [23]. The intricate interactions among hazard factors, environmental vulnerabilities, and socioeconomic exposures necessitate a comprehensive understanding of these dynamics [28]. Uncertainties in natural hazard patterns, such as unpredictable typhoon paths, often lead to inadequate preparedness and recovery strategies [9]. The complexity of hydrological processes and the need for accurate meteorological data pose significant challenges in flood disaster assessments, as existing forecasting models often fail to address these complexities [22, 24].

Emergency management systems frequently struggle with the complexities and uncertainties inherent in urban lifeline systems, which can amplify the impact of rainstorm disasters [2]. Traditional methods often overlook interdependencies among resilience indicators, leading to incomplete evaluations and ineffective flood management [25]. This underscores the need for innovative approaches that dynamically capture failure propagation within interconnected infrastructure systems [27]. Identifying vulnerabilities in semi-centralized water infrastructures is critical for enhancing resilience, as existing methods often inadequately assess these systems [21]. Moreover, the lack of empirical data on community resilience, particularly in rural areas, challenges disaster risk reduction (DRR) efforts, necessitating targeted strategies to enhance resilience [26].

In recent years, the increasing frequency and severity of natural disasters have prompted significant academic inquiry into their impacts and the strategies for resilience and mitigation. Understanding the hierarchical structure of these disasters is crucial for effective response planning. As shown in Figure 2, this figure illustrates the hierarchical structure of natural disasters, categorizing them into three primary types: typhoon, rainstorm, and earthquake disasters. Each category is further divided into impacts and vulnerabilities, as well as resilience and mitigation strategies. This categorization not only highlights the key challenges associated with each type of disaster but also underscores the importance of tailored response measures to enhance community resilience. By integrating this framework, researchers and practitioners can better address the complexities of disaster management and improve preparedness efforts across different contexts.

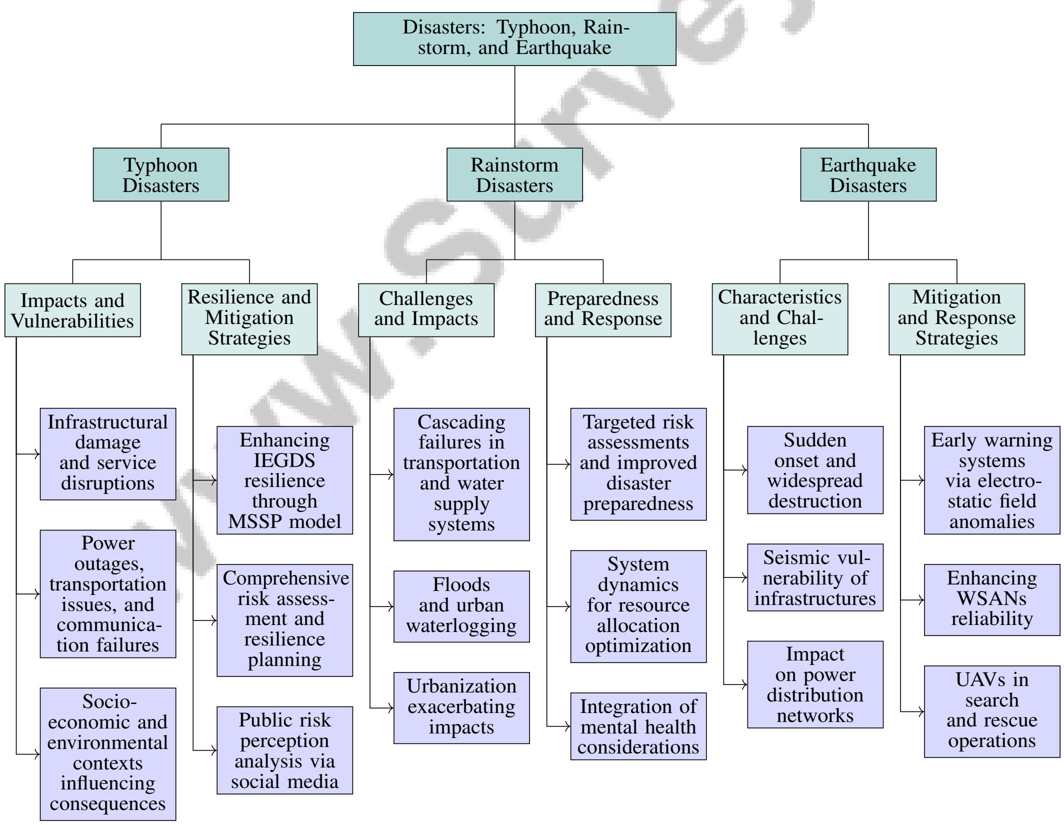


Figure 2: This figure illustrates the hierarchical structure of natural disasters, categorizing them into typhoon, rainstorm, and earthquake disasters. Each category is further divided into impacts and vulnerabilities, as well as resilience and mitigation strategies, highlighting key challenges and response measures.

3 Typhoon, Rainstorm, and Earthquake Disasters

3.1 Characteristics and Impacts of Typhoon Disasters

Typhoon disasters, marked by intense winds and heavy rainfall, cause significant infrastructural damage and service disruptions. Events like Typhoon Faxai in Chiba, Japan, highlight vulnerabilities in infrastructure and essential services [29]. These disasters lead to power outages, transportation issues, and communication failures, impeding emergency responses. Regional disaster system theory, integrating hazard intensity, environmental stability, and population vulnerability, provides a framework for understanding typhoon impacts [30]. This approach emphasizes the socio-economic and environmental contexts influencing typhoon consequences, which can prolong recovery and increase economic losses.

Enhancing the resilience of Integrated Electricity and Gas Distribution Systems (IEGDSs) is crucial for mitigating typhoon impacts. The Multi-Stage Stochastic Programming (MSSP) model addresses uncertainties in typhoon paths, improving IEGDS robustness [9]. Incorporating such uncertainties into resilience planning aids in maintaining critical services during and after typhoons. The necessity for comprehensive risk assessment and resilience planning is underscored by studies in Guangzhou and Beijing, which reveal the multifaceted nature of community resilience shaped by socio-economic, infrastructural, and natural factors. Localized data and modeling identify specific vulnerabilities and strengths, enabling targeted disaster preparedness and response strategies. Additionally, analyzing public risk perception through social media during events like Typhoon Lekima informs effective communication and risk management strategies, fostering resilience against future typhoon-related disasters [16, 3, 17, 30].

3.2 Characteristics and Impacts of Rainstorm Disasters

Rainstorm disasters challenge urban infrastructure due to their intensity, duration, and uneven distribution, causing cascading failures in transportation and water supply systems. These disasters can trigger floods, damaging infrastructure and causing traffic paralysis, necessitating improved emergency response strategies, urban planning, and drainage systems to mitigate impacts amid climate change and urbanization [16, 19, 2, 31, 32]. Urbanization exacerbates rainstorm impacts, as inadequate drainage and increased runoff in densely populated areas lead to severe urban waterlogging, disrupting transportation and emergency responses.

A comprehensive framework categorizing rainstorm events based on characteristics facilitates targeted risk assessments, improving disaster preparedness and response [33]. The social impacts, including public sentiment and behavior, are crucial in shaping community resilience and recovery [31]. Historical inadequacies in emergency responses to construction safety accidents caused by rainstorms necessitate new approaches using system dynamics for resource allocation optimization [34]. Advances in hydrological modeling reflect the need for sophisticated tools to predict and manage rainstorm impacts [22]. Psychological impacts, especially on adolescents, highlight the importance of integrating mental health considerations into disaster management strategies [35].

Figure 3 illustrates the key categories and subcategories of rainstorm disaster impacts, focusing on infrastructure challenges, social impacts, and assessment and modeling approaches, as derived from various research studies. This visual representation enhances our understanding of the multifaceted nature of rainstorm disasters and underscores the interconnectedness of the various impacts discussed.

3.3 Characteristics and Impacts of Earthquake Disasters

Earthquake disasters, characterized by sudden onset and potential for widespread destruction, significantly impact infrastructure and power grids. Seismic vulnerability of civil infrastructures, especially tall buildings, is a core concern in earthquake-prone areas, necessitating effective simulation models for predicting and mitigating damage [36]. Power distribution networks are particularly susceptible, leading to prolonged outages and service disruptions. Enhancing resilience in these networks requires comprehensive approaches addressing the unique challenges posed by earthquakes [37].

Atmospheric electrostatic field anomalies before earthquakes may serve as precursor signals, aiding early warning systems and disaster preparedness [38]. Formal models have improved disaster mitigation, particularly in enhancing Wireless Sensor and Actuator Networks (WSANs) reliability [39].

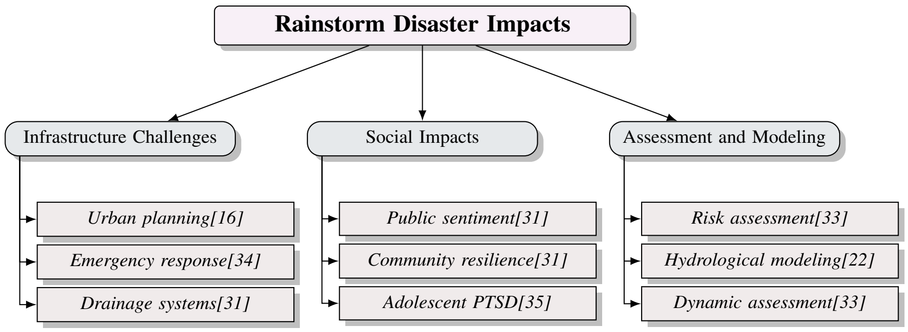


Figure 3: This figure illustrates the key categories and subcategories of rainstorm disaster impacts, focusing on infrastructure challenges, social impacts, and assessment and modeling approaches, as derived from various research studies.

Beyond physical infrastructure, earthquakes impact public health through post-disaster infectious disease outbreaks, necessitating integrated response strategies addressing both immediate and long-term health implications [40]. Efficient resource allocation during earthquake responses is critical, as existing algorithms often inadequately consider urgency and efficiency [41].

Unmanned Aerial Vehicles (UAVs) have proven effective in search and rescue operations in simulated earthquake sites, showcasing technological innovations' potential to enhance response efforts [42]. Optimizing earthquake response planning amidst unpredictable seismic events remains complex, requiring robust decision-making processes adaptable to dynamic disaster scenarios [43]. Predicting megathrust earthquakes and associated tsunamis is challenging due to noisy GPS data, necessitating advances in predictive modeling for improved forecast accuracy and preparedness [44]. A holistic approach integrating technological, structural, and health considerations is essential for effectively mitigating earthquake impacts.

4 Weak Link Identification in Infrastructure

4.1 Frameworks and Models for Weak Link Identification

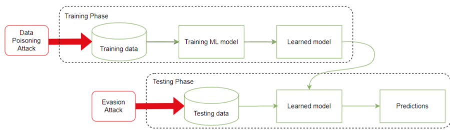
Method Name	Assessment Techniques	Interdisciplinary Approach	Community Resilience Domains
VASW[21]	Expert Discussions	Multiple Fields	Resource Recovery Centre
CREF[25]	Fuzzy Delphi Method	Multiple Fields Integration	Connection And Caring
IIVA[27]	Simulation-based Approach	Bayesian Network Analysis	-
3D-SVM[45]	K-fold Cross-validation	Machine Learning Techniques	-

Table 1: This table presents an overview of various frameworks and models employed for identifying weak links in infrastructure systems. It details the assessment techniques, interdisciplinary approaches, and community resilience domains associated with each method, highlighting their contributions to enhancing infrastructure resilience against natural disasters.

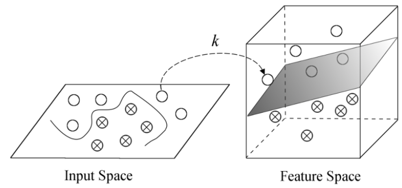
Identifying weak links in infrastructure is crucial for bolstering resilience against natural disasters. Various frameworks and models systematically evaluate vulnerabilities to facilitate effective mitigation strategies. The Vulnerability Assessment Methodology for Semi-Centralised Water Systems (VASW) classifies system components based on hazard susceptibility, integrating technical and social dimensions [21]. In urban lifeline systems, the fuzzy Delphi method (FDM) and analytic network process (ANP) provide a structured framework for assessing community resilience indicators, revealing infrastructure interdependencies and potential failure points during disasters [25]. Simulation approaches combined with Bayesian network analysis enhance the modeling of interdependencies and vulnerabilities, improving weak link identification accuracy [27].

The Communities Advancing Resilience Toolkit (CART) categorizes community resilience into five domains: Connection and Caring, Resources, Transformative Potential, Disaster Management, and Information and Communication, underscoring the need for comprehensive models incorporating diverse assessment techniques [26]. A multidisciplinary approach is essential for infrastructure resilience, leveraging advanced analytical tools, strategic planning models, and technologies like artificial intelligence. AI facilitates rapid data analysis for decision-making during emergencies, optimizes resource allocation for climate-related challenges, and strengthens cybersecurity. Quantitative models using large-scale outage data guide infrastructure enhancements, significantly reducing power outages during extreme weather [46, 20, 47].

Table 1 provides a comprehensive summary of the frameworks and models used in the identification of weak links within infrastructure systems, emphasizing their methodological diversity and interdisciplinary integration.



(a) Poisoning and Evasion Attacks in Machine Learning: A Comparative Analysis[48]



(b) Feature Space Visualization[45]

Figure 4: Examples of Frameworks and Models for Weak Link Identification

As shown in Figure 4, the frameworks and models for weak link identification are illustrated through two visualizations. The first, "Poisoning and Evasion Attacks in Machine Learning: A Comparative Analysis," highlights vulnerabilities in machine learning models, emphasizing the need to identify weak links in data processing pipelines. The second, "Feature Space Visualization," demonstrates data point organization into clusters, aiding in pattern and anomaly identification that may indicate weak links. Together, these frameworks and models provide a comprehensive approach to detecting and mitigating weak links within infrastructure systems, enhancing their resilience and reliability [48, 45].

4.2 Technological and Analytical Tools

Advanced technological and analytical tools significantly enhance weak link identification in infrastructure systems, crucial for assessing vulnerabilities and increasing resilience against natural disasters. Convolutional neural networks (CNNs) for text and image data exemplify cutting-edge technology in weak link identification, extracting critical information from diverse data sources [49]. Graph neural networks (GNNs) emerge as powerful tools for extracting topological features and optimizing vulnerable node selection within urban infrastructure. The method proposed by [23] employs GNNs and reinforcement learning, offering a robust framework for identifying and prioritizing weak links in complex urban networks.

In flood risk assessment, the Flood Risk Evaluation Model uses the Analytic Hierarchy Process (AHP) and entropy weight method to analyze hazard levels, environmental sensitivity, and vulnerability factors, systematically evaluating flood risks [24]. Understanding social vulnerability and interdependencies between power and water systems is crucial for infrastructure resilience. The STVA method, utilizing the Social Vulnerability Index (Sd-SVI), models these interdependencies, providing insights into socio-technical vulnerability dimensions [14].

Robust optimization models like ROM-HL enhance disaster response decision-making by adapting to unforeseen circumstances [15]. Combining the PageRank algorithm with a risk matrix offers a comprehensive understanding of disaster dynamics, evaluating node importance and assessing disaster chain risks [2].

Effective deployment of advanced technological and analytical tools is crucial for accurately identifying weak links in urban infrastructure systems. Leveraging real-world data to model interdependent networks and analyze vulnerabilities enhances understanding of potential cascade failures and disruption sources, contributing to designing resilient infrastructure capable of withstanding and adapting to various challenges [11, 23]. By employing advanced modeling techniques, machine learning algorithms, and decision-making frameworks, stakeholders can effectively assess and mitigate vulnerabilities, enhancing the resilience of critical infrastructure against natural disasters.

4.3 Data-Driven Approaches

Data-driven methodologies are pivotal in identifying and mitigating weak links within infrastructure systems, offering robust strategies for enhancing resilience against natural disasters. These approaches employ sophisticated statistical, analytical, and computational techniques, including artificial intelligence, to thoroughly understand vulnerabilities across sectors. This understanding informs strategic interventions, improving disaster response through rapid data analysis and optimizing resource allocation for climate resilience. They also facilitate robust crisis management and business continuity by anticipating disruptions and strengthening cybersecurity measures, supporting vulnerable populations, fostering social cohesion, and enhancing psychological resilience [50, 20].

Integrating simulation techniques with Bayesian network analysis provides a sophisticated method for assessing vulnerabilities in interdependent infrastructure systems, allowing detailed examinations of potential failure points and disruption propagation [27]. In flood risk management, risk mapping and vulnerability analysis techniques, such as fuzzy classification, yield valuable insights into the spatial distribution of risks and prioritize mitigation efforts [51].

Stochastic models, like the one proposed by [52], emphasize dynamic resource allocation in response to uncertain demand conditions and varying disaster severities, enhancing disaster response strategies' efficiency and effectiveness. In power grid resilience, data-driven methods capture complex interactions within grid systems, accounting for uncertainties in load demand and line parameters [53]. These methods contribute to developing adaptive and robust power systems capable of withstanding sequential and persistent natural disasters [8].

Participatory approaches integrating community-driven risk monitoring and legal rights awareness demonstrate the value of combining qualitative and quantitative data in enhancing community resilience [13]. Involving local populations in risk assessment processes ensures resilience strategies are contextually relevant and socially inclusive.

The systematic approach to emergency response optimization, particularly regarding rainstorm-induced construction safety incidents, exemplifies system dynamics models' application to analyze and improve response strategies [34]. These models focus on key influencing factors' interactions, providing a data-driven foundation for effective disaster management.

Data-driven approaches are essential for effectively identifying and addressing vulnerabilities in infrastructure systems, leveraging advanced techniques like graph neural networks and simulation-based assessments to analyze complex interdependencies and cascade failure risks. Utilizing real-world data, these methodologies enhance urban infrastructure resilience, inform resource allocation strategies, and improve emergency response capabilities, reducing the likelihood of system failures during adverse events [27, 48, 23, 54, 2]. By harnessing advanced modeling techniques, simulation tools, and participatory frameworks, stakeholders can enhance the resilience of critical infrastructure against a wide range of natural hazards.

5 Power Grid Resilience

5.1 Technological Innovations and Smart Grid Integration

Technological innovations and smart grid integration are crucial for enhancing power system resilience against natural disasters. AI-driven predictive analytics and real-time data processing significantly improve situational awareness and response capabilities, enabling adaptive management of power grids during extreme events [20]. Advanced models, such as the 4th-order model of synchronous machines, offer a comprehensive assessment of grid resilience by incorporating voltage dynamics, providing a more precise evaluation than traditional swing equations [55]. Machine learning and automation facilitate dynamic adjustments to unit commitments, enhancing grid stability through real-time fault prediction using hybrid models like CNN-RNN, CNN-GRU, and CNN-LSTM [56]. Decentralized learning frameworks, such as DLOLS, empower load centers to optimize load shedding independently, further strengthening grid resilience [57]. AI technologies also improve event identification and stability assessments using big data from platforms like FNET/GridEye [58]. The integration of renewable energy sources, particularly wind power, enhances restoration efficiency, while hardening transmission lines proves more effective than decentralized mini-grids in socially vulnerable areas [59, 14]. Advances in forecasting techniques using remote sensing and GIS are essential for predicting and managing disaster impacts on power grids [22]. These innovations and integrations are vital for developing resilient power systems capable of withstanding natural disasters, ensuring continued delivery of essential services.

5.2 Predictive Models and Analytics

Predictive models and analytics are essential for ensuring power grid reliability and resilience, especially during natural disasters like hurricanes. A three-dimensional Support Vector Machine (SVM) model accurately predicts operational states of grid components during hurricanes by incorporating a resilience index and forecasting hurricane paths and intensities [56, 45, 60]. This model enhances resource scheduling and resilience by maximizing the margin between classified states. AI algorithms improve data processing from wide-area measurement networks, enabling precise predictions and timely interventions [58]. Data-driven methods capturing customer outage dynamics provide insights into spatial and temporal patterns, informing strategic interventions to mitigate extreme weather impacts on grid reliability [46]. Integrating predictive models and analytics into grid management systems enhances resilience by employing advanced statistical techniques, AI algorithms, and data-driven insights, reducing disruptions and ensuring service continuity during extreme events. Real-time fault detection and predictive outage estimation enable quicker issue remediation, while large-scale outage data analysis facilitates targeted infrastructure improvements, empowering utilities to effectively prepare for and respond to catastrophic events [46, 56, 45, 58].

5.3 Optimization and Grid Hardening Strategies

Optimization and grid hardening strategies are vital for enhancing power system resilience against natural disasters. These strategies focus on reinforcing infrastructure and optimizing operations to ensure rapid recovery and service continuity. Addressing vulnerabilities to data poisoning attacks is critical for safeguarding grid operations [48]. Incorporating voltage dynamics into grid models offers nuanced stability analysis, revealing insights that traditional models may overlook, informing effective hardening strategies [55]. Hybrid machine learning models like CNN-GRU improve fault detection, enhancing grid resilience [56]. Scenario-based optimization models improve decision-making for substation hardening, particularly against flooding impacts [61]. AI applications on platforms like FNET/GridEye enhance situational awareness and resilience, outperforming conventional methods [58]. These strategies involve predictive analytics, co-optimizing economic and resilience objectives, and targeted infrastructure improvements based on historical outage data analysis. By addressing power generation, network, and load component characteristics, these strategies mitigate extreme weather risks, leading to a robust power system capable of withstanding and recovering from disruptions [62, 46, 8, 45]. Leveraging advanced modeling techniques, machine learning algorithms, and AI-driven applications enhances power system robustness and adaptability, ensuring continued operation in the face of natural hazards.

6 Infrastructure Vulnerability and Risk Assessment

Addressing infrastructure vulnerability requires a thorough understanding of assessment methodologies, which are crucial for effective risk evaluation and resilience strategy development. This section delves into various methodologies for assessing infrastructure vulnerability, highlighting their role in capturing system complexities and contextual vulnerabilities. These insights facilitate a comprehensive risk assessment framework by elucidating the interaction between infrastructure systems and the natural disasters that threaten them.

6.1 Methodologies for Infrastructure Vulnerability Assessment

Evaluating infrastructure vulnerability to natural disasters involves a multifaceted approach that incorporates diverse methodologies to assess risks and bolster resilience. Identifying contextual features is essential for understanding the unique vulnerabilities of different systems. The FePHFS-CoCoSo method exemplifies this by managing uncertainties in seismic risk assessments, providing a robust framework for seismic vulnerability understanding [43]. Real-time data integration into dynamic models, such as the MSSP method, enhances emergency response strategies by adapting to changing conditions [9]. Social dimensions also play a crucial role; social network analysis and social media insights improve information dissemination and resource allocation, enhancing community resilience [63, 49].

Case studies from cities like Barcelona, Beijing, and Mumbai illustrate the varied impacts of natural disasters on urban infrastructure, underscoring the need for tailored vulnerability assessments [64]. Advanced modeling techniques, such as the GNN-RL method, efficiently identify critical nodes in interdependent urban networks [23]. Flood risk assessments, utilizing models that analyze risk levels in urban lifeline systems during rainstorms, provide structured frameworks for targeted interventions [2]. However, comprehensive approaches that integrate the dynamic nature of urban flood disasters remain limited [32].

The framework proposed by [27] offers a flexible approach to vulnerability assessment, capturing complex indicator relationships for nuanced community resilience understanding [25]. These diverse methodologies, incorporating advanced modeling and machine learning, emphasize socio-technical approaches to understand the impacts of extreme weather on critical infrastructure. Techniques like the Tri-AHP method enhance infrastructure resilience against natural disasters through scientific and quantitative analyses [14, 2, 65]. Leveraging these methodologies strengthens disaster preparedness and response strategies, contributing to more resilient infrastructure systems.

6.2 Risk Assessment Models and Tools

Benchmark	Size	Domain	Task Format	Metric

Table 2: The table presents a comprehensive overview of representative benchmarks used in risk assessment models and tools. It details the size, domain, task format, and metrics employed to evaluate the performance and effectiveness of these models in predicting and mitigating disaster impacts.

Risk assessment models and tools are vital for evaluating natural disaster impacts, enabling robust disaster preparedness and response strategies. Table 2 provides a detailed overview of the representative benchmarks utilized in various risk assessment models and tools, highlighting their significance in enhancing disaster preparedness and response strategies. The 3D-Support Vector Machine (SVM) method optimizes prediction accuracy by distinguishing operational from damaged components, informing targeted interventions [60]. The Resilience Assessment Platform (RAP) and resilience metrics identify power grid resilience gaps, guiding investments for enhanced infrastructure [66]. Monte Carlo simulations offer comprehensive vulnerability metric analysis, informing risk mitigation strategies [53]. Basin stability and survivability measures contribute to effective resilience planning by analyzing power grid model performance under perturbations [55].

In urban settings, the Multi-Agent System (MAS) method evaluates evacuation strategies and survival rates during rainstorms, enhancing evacuation plans and resource allocation [67]. Risk optimization models, such as those in [52], prioritize interventions based on threat scenario probabilities and impacts. Integrating atmospheric electric field anomalies into models enhances earthquake prediction, providing valuable early warning tools [38].

The diverse range of risk assessment tools underscores the importance of advanced methodologies and technologies. AI-driven predictive maintenance and real-time monitoring improve infrastructure vulnerability understanding, informing strategic decision-making. These tools support robust infrastructure development, capable of withstanding natural disasters. AI technologies enhance disaster response through rapid data analysis, while social media applications provide situational awareness. Integrating disaster and development studies strengthens resilience frameworks, ensuring people-centric interventions for at-risk communities [50, 20, 46, 13]. Model performance is assessed using metrics like accuracy and F1-score, critical for evaluating the multimodal approach's effectiveness.

6.3 Challenges and Limitations

Infrastructure vulnerability and risk assessment face challenges that can limit their effectiveness. A key issue is the reliance on synthetic data and assumptions about interdependencies, which may not fully capture real-world complexities [27]. This can lead to inaccuracies, especially in diverse infrastructure systems. Another limitation is the neglect of long-term hazard probabilities and user

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behavior impacts on system performance, crucial for comprehensive resilience understanding but often overlooked [21].

Data availability and quality pose significant challenges, particularly in sparse or rapidly changing environments [21]. This affects the precision and reliability of risk assessments. The variability of natural disasters complicates adaptable emergency response strategy development, especially in urbanizing areas with evolving infrastructure [27]. High-quality data and sophisticated AI models require ongoing refinement for effective resilience strategies.

Addressing these challenges involves developing models that integrate diverse data sources, such as social media and environmental sensors, while accounting for system interdependencies and human factors. This comprehensive approach enhances predictive maintenance, disaster response, and resource allocation across sectors [20, 49, 13]. Overcoming these hurdles enhances the accuracy and effectiveness of vulnerability and risk assessments, contributing to more resilient infrastructure systems.

7 Case Studies and Applications

7.1 Earthquake and Seismic Risk Assessment

Earthquake risk assessment focuses on evaluating seismic impacts on infrastructure and communities to bolster resilience and enhance disaster management strategies. Case studies demonstrate the efficacy of diverse methodologies in this field. The Real-time Resiliency Management Tool (RT-RMT) exemplifies a data-driven approach that optimizes resource allocation and crew routing during emergencies, highlighting the integration of real-time data for operational efficiency [54]. Advanced simulation techniques refine predictive capabilities for structural resilience, informing engineering practices in earthquake-prone areas and yielding critical insights into structural integrity [36]. The National Risk Assessment (NRA) 2018 methodology effectively evaluates seismic risk in Italian residential buildings, providing insights into expected damage and societal impacts, underscoring the need for comprehensive risk assessments to guide policy and resource allocation [10].

Innovative initiatives, such as the Moroccan Solidarity Hackathon, leverage AI for creative earthquake solutions, demonstrating AI's potential in disaster preparedness and response [68]. Research suggesting stable negative atmospheric electrostatic field anomalies as earthquake precursors offers promising avenues for early warning systems [38]. Health impacts following earthquakes, including increased prevalence of diseases, highlight the need for integrated health and disaster response strategies [40]. The Earthquake Disaster-Based Resource Scheduling (EDBRS) Framework optimizes resource scheduling, reducing execution time and costs compared to existing algorithms [41].

Empirical evidence from Weibo data reveals correlations between public attention and disaster impacts, validating theoretical frameworks and emphasizing social media's role in disaster risk assessment [30]. A robust optimization model applied in Tehran demonstrates real-world effectiveness in disaster logistics, considering various scenarios, including earthquakes [15]. These case studies underscore the importance of integrating advanced technologies, data-driven approaches, and collaborative efforts to enhance resilience and mitigate seismic event impacts.

7.2 Flood and Rainstorm Disaster Management

Flood and rainstorm disaster management is essential in urban planning due to the significant threats these hazards pose to densely populated areas. The assessment of 13 metro stations in Chongqing, China, highlights the importance of evaluating critical infrastructure resilience during extreme weather events [18]. Studies indicate that extreme rainfall significantly contributes to urban waterlogging, necessitating improved forecasting methods and urban planning strategies to mitigate such impacts [69]. Integrating advanced forecasting techniques with robust urban planning is crucial for reducing urban vulnerability to rainstorm-induced flooding.

Social media platforms like Weibo offer valuable tools for analyzing public sentiment during rainstorm disasters, as demonstrated by data from the 2021 Zhengzhou rainstorm, which provides insights into public perceptions and informs effective communication strategies during emergencies [31]. Effective shelter planning and resource allocation are critical for enhancing infrastructure resilience. A Multi-Agent System (MAS) case study emphasizes strategic planning in optimizing resource distribution during rainstorm scenarios [67]. GIS-based studies identify high-risk flood areas, indicating the need for targeted flood prevention strategies and tailored interventions in vulnerable regions [24].

Flood and rainstorm disaster management requires a multifaceted approach integrating advanced technologies, data-driven insights, and strategic planning to enhance infrastructure resilience. By proactively addressing vulnerabilities associated with extreme weather events, stakeholders can devise targeted interventions that protect urban communities and critical infrastructure systems. This approach integrates social dimensions, ensuring interventions prioritize marginalized communities and lead to more effective emergency management strategies [14, 16, 13, 32].

7.3 Lessons Learned and Future Directions

Research into natural disaster risk assessment and infrastructure resilience has yielded valuable lessons for future research and practice. Community engagement in disaster risk reduction (DRR) is crucial, as active resident participation significantly enhances community resilience [26]. Strategies should foster community involvement and leverage local knowledge to improve disaster preparedness and response. Assessing vulnerabilities within infrastructure systems necessitates comparing centralized and semi-centralized systems to understand their strengths and weaknesses [21]. Future research should develop methodologies incorporating longer cause-and-effect chains for comprehensive vulnerability analysis.

Understanding critical risks within urban lifeline systems during rainstorm disasters emphasizes cascading effects, such as submerged houses and damaged roads leading to traffic disruptions. This underscores the necessity for comprehensive disaster management strategies addressing interdependencies and vulnerabilities within urban infrastructure systems. Recent studies have evolved urban resilience assessments to emphasize interconnected infrastructural, institutional, and environmental factors while often neglecting socio-economic dimensions. Modeling urban infrastructure as interdependent networks reveals vulnerabilities leading to cascading failures during extreme weather events. Integrated approaches considering these multifaceted relationships are essential for enhancing urban resilience and ensuring effective emergency response efforts [19, 16, 2, 23]. Future studies could explore adaptive strategies utilizing real-time data and predictive modeling to enhance urban flood management.

Integrating AI into resilience strategies presents a promising avenue for advancing disaster management. Empirical studies should evaluate AI-driven strategies' effectiveness across various sectors—such as disaster response, healthcare, and power grid management—while addressing ethical implications, including bias and accountability [20, 49, 58]. Enhancing real-time data acquisition systems and fostering stakeholder collaborations are critical for addressing gaps in current disaster management practices.

The relationship between human behavior and flood risks underscores the need for enhanced data collection on public and institutional responses to flooding events, alongside developing sophisticated models reflecting these interactions. Integrating insights from behavioral dynamics into flood disaster risk assessments can improve understanding of community reactions before, during, and after floods, leading to more effective flood risk management strategies [31, 70, 64]. Additionally, integrating health and well-being into disaster management strategies is essential for comprehensive risk reduction. Future research should focus on identifying barriers to effective DRR, enhancing community engagement, and ensuring health considerations are integrated into disaster management frameworks.

In multi-hazard resilience enhancement, future research should prioritize risk-based strategies incorporating AI and human factors in cyber-physical systems. Longitudinal studies are needed to track resilience improvements over time and adapt assessment frameworks for various disaster types beyond rainstorms and floods. Advancing disaster risk assessment and management can significantly benefit from improved data collection technologies, diverse modeling approaches, and mitigating uncertainties in meteorological predictions. These enhancements are crucial for addressing the interplay of physical vulnerabilities, socioeconomic factors, and human behavior dynamics influencing disaster resilience, particularly amid climate change and urbanization. By focusing on these areas, alignment with global frameworks like the Sendai Framework for DRR and the Sustainable Development Goals can lead to more effective disaster preparedness and response strategies [17, 16, 70, 13, 32].

Insights from various studies highlight the critical need to integrate advanced technologies, such as AI and multimodal deep learning, with data-driven insights and collaborative approaches. These strategies are vital for enhancing disaster resilience through improved predictive maintenance, real-time monitoring, and effective disaster response. Emphasizing a people-centric perspective, these lessons underline the importance of social relations and community engagement in DRR and sustainable development, ultimately fostering a robust and adaptable response to adverse conditions [50, 20, 49, 13]. By addressing identified gaps and leveraging innovative strategies, stakeholders can develop effective interventions to protect urban communities and critical infrastructure systems from the impacts of natural disasters.

8 Conclusion

The exploration of natural disaster risk assessment and infrastructure resilience highlights the multifaceted nature of these issues and the imperative for cohesive strategies. Incorporating socio-economic dimensions into risk evaluations is pivotal for enhancing governance frameworks and decision-making processes, thereby strengthening disaster readiness and response mechanisms. Advanced technologies and machine learning are instrumental in boosting operational efficiency during emergencies, underscoring the value of data-centric approaches.

Social support emerges as a vital component in disaster preparedness, particularly for at-risk groups, as it plays a crucial role in mitigating post-disaster mental health challenges. The interdependence of infrastructure sectors and the integration of sustainability principles are crucial for achieving Sustainable Development Goals and reinforcing resilience.

In the realm of power grid resilience, it is crucial to tailor strategies to various disruption sources to bolster overall system robustness. Models focusing on optimizing resource allocation under uncertainty demonstrate significant advancements in disaster relief logistics, effectively managing the repercussions of disasters. Addressing socio-economic factors alongside seismic risks is essential, advocating for enhanced governance and improved construction practices to mitigate future calamities.

The incorporation of social media data into disaster communication strategies offers valuable insights into public perceptions, enriching risk communication efforts. Additionally, the need for enhanced disease surveillance systems and targeted public health interventions is emphasized to alleviate the public health impacts of natural disasters.

This survey accentuates the ongoing necessity for advancements in disaster risk assessment and infrastructure resilience. Future research endeavors should aim to refine data integration, harness cutting-edge technologies, and promote collaboration among stakeholders to develop more robust and adaptive strategies for mitigating the effects of natural disasters. Tackling these challenges will contribute to the creation of more resilient communities and infrastructure systems capable of enduring the escalating frequency and severity of natural disasters.

AI-generated, for reference only.

References

[1] Giovanni Marin, Marco Modica, Susanna Paleari, and Roberto Zoboli. Assessing disaster risk by integrating natural and socio-economic dimensions: A decision-support tool. *Socio-Economic Planning Sciences*, 77:101032, 2021.

[2] Hai-xiang Guo, Xin-yu He, Xin-biao Lv, and Yang Wu. Risk analysis of rainstorm-urban lifeline system disaster chain based on the pagerank-risk matrix and complex network. *Natural Hazards*, 120(12):10583–10606, 2024.

[3] Jinglu Song, Bo Huang, and Rongrong Li. Assessing local resilience to typhoon disasters: A case study in nansha, guangzhou. *Plos one*, 13(3):e0190701, 2018.

[4] Linpei Zhai and Jae Eun Lee. Analyzing the disaster preparedness capability of local government using ahp: Zhengzhou 7.20 rainstorm disaster. *International journal of environmental research and public health*, 20(2):952, 2023.

[5] Md Nasir, Tina Sederholm, Anshu Sharma, Sundeep Reddy Mallu, Sumedh Ranjan Ghatage, Rahul Dodhia, and Juan Lavista Ferres. Dwelling type classification for disaster risk assessment using satellite imagery, 2022.

[6] Mona Khaffaf and Arshia Khaffaf. Resource planning for rescue operations, 2016.

[7] Wenjun Ni, Jia Shu, and Miao Song. Location and emergency inventory pre-positioning for disaster response operations: Min-max robust model and a case study of yushu earthquake. *Production and Operations Management*, 27(1):160–183, 2018.

[8] Chong Wang, Ping Ju, Feng Wu, Xueping Pan, and Zhaoyu Wang. A systematic review on power system resilience from the perspective of generation, network, and load. *Renewable and Sustainable Energy Reviews*, 167:112567, 2022.

[9] Zekai Wang, Tao Ding, Wenhao Jia, Can Huang, Chenggang Mu, Ming Qu, Mohammad Shahidehpour, Yongheng Yang, Frede Blaabjerg, Li Li, et al. Multi-stage stochastic programming for resilient integrated electricity and natural gas distribution systems against typhoon natural disaster attacks. *Renewable and Sustainable Energy Reviews*, 159:111784, 2022.

[10] Mauro Dolce, Andrea Prota, Barbara Borzi, Francesca da Porto, Sergio Lagomarsino, Guido Magenes, Claudio Moroni, Andrea Penna, Maria Polese, Elena Speranza, et al. Seismic risk assessment of residential buildings in italy. *Bulletin of Earthquake Engineering*, 19:2999–3032, 2021.

[11] Maureen S. Golan and Javad Mohammadi. Mapping disruption sources in the power grid and implications for resilience, 2022.

[12] nfrastructure for sustainable de.

[13] Andrew E Collins. Advancing the disaster and development paradigm. *International Journal of Disaster Risk Science*, 9:486–495, 2018.

[14] Juan P Montoya-Rincon, Said A Mejia-Manrique, Shams Azad, Masoud Ghandehari, Eric W Harmsen, Reza Khanbilvardi, and Jorge E Gonzalez-Cruz. A socio-technical approach for the assessment of critical infrastructure system vulnerability in extreme weather events. *Nature Energy*, 8(9):1002–1012, 2023.

[15] Meysam Fereiduni and Kamran Shahanaghi. A robust optimization model for distribution and evacuation in the disaster response phase. *Journal of Industrial Engineering International*, 13(1):117–141, 2017.

[16] Research article.

[17] Martha Liliana Carreño, Omar-Darío Cardona, Alex H Barbat, Dora Catalina Suarez, María del Pilar Perez, and Lizardo Narvaez. Holistic disaster risk evaluation for the urban risk management plan of manizales, colombia. *International Journal of Disaster Risk Science*, 8:258–269, 2017.

[18] Liudan Jiao, Yinghan Zhu, Xiaosen Huo, Ya Wu, and Yu Zhang. Resilience assessment of metro stations against rainstorm disaster based on cloud model: a case study in chongqing, china. *Natural Hazards*, 116(2):2311–2337, 2023.

[19] Ayyoob Sharifi. Urban resilience assessment: Mapping knowledge structure and trends. *Sustainability*, 12(15):5918, 2020.

[20] Nitin Rane, Saurabh Choudhary, and Jayesh Rane. Artificial intelligence for enhancing resilience. *Journal of Applied Artificial Intelligence*, 5(2):1–33, 2024.

[21] Martin Zimmermann, Martina Winker, and Engelbert Schramm. Vulnerability analysis of critical infrastructures in the case of a semi-centralised water reuse system in qingdao, china. *International Journal of Critical Infrastructure Protection*, 22:4–15, 2018.

[22] XIA Jun, WANG Huiyun, GAN Yaoyao, and ZHANG Liping. Research progress in forecasting methods of rainstorm and flood disaster in china. *Torrential Rain and Disasters*, 38(5):416–421, 2019.

[23] Jinzhu Mao, Liu Cao, Chen Gao, Huandong Wang, Hangyu Fan, Depeng Jin, and Yong Li. Detecting vulnerable nodes in urban infrastructure interdependent network, 2023.

[24] Li Ziwei, Tang Xiangling, Li Liju, Chu Yanqi, Wang Xingming, and Yang Dishan. Gis-based risk assessment of flood disaster in the lijiang river basin. *Scientific reports*, 13(1):6160, 2023.

[25] Ming Zhong, Kairong Lin, Guoping Tang, Qian Zhang, Yang Hong, and Xiaohong Chen. A framework to evaluate community resilience to urban floods: A case study in three communities. *Sustainability*, 12(4):1521, 2020.

[26] Ke Cui, Ziqiang Han, and Dongming Wang. Resilience of an earthquake-stricken rural community in southwest china: Correlation with disaster risk reduction efforts. *International journal of environmental research and public health*, 15(3):407, 2018.

[27] Prasangsha Ganguly and Sayanti Mukherjee. Iiva: A simulation based generalized framework for interdependent infrastructure vulnerability assessment, 2022.

[28] Risk assessment of typhoon disas.

[29] Takato Yasuno, Masazumi Amakata, and Masahiro Okano. Natural disaster classification using aerial photography explainable for typhoon damaged feature, 2020.

[30] Jiting Tang, Saini Yang, Yimeng Liu, Kezhen Yao, and Guofu Wang. Typhoon risk perception: A case study of typhoon lekima in china. *International Journal of Disaster Risk Science*, 13(2):261–274, 2022.

[31] Xin WAN, Xin-yu DING, Tian-tian ZHANG, and Ling-zhi LI. Research on social impacts of rainstorm disaster considering infrastructure disruption: An analysis of sentimental and behavioral evolution from a public perspective. *Journal of Natural Resources*, 38(11):2919–2932, 2023.

[32] Wen Li, Rengui Jiang, Jiancang Xie, Yong Zhao, Jiwei Zhu, and Siyu Yang. Emergency management decision of urban rainstorm and flood disasters based on similar cases analysis. *Natural Hazards*, 116(1):753–768, 2023.

[33] WANG Fen, HONG Guoping, ZHAO Xiaofang, HE Mingqiong, LIU Jing, LUO Jingfang, and DENG Kai. Research of rainstorm event disaster hazard assessment method-a case study of" 8·12" rainstorm event in xiaogan city. *Torrential Rain and Disasters*, 42(6):724–730, 2023.

[34] CHEN Wei, QIAO Zhi, WANG Weizhen, ZHANG Kailan, NIU Li, and DENG Cong. Sd model for emergency disposal of construction safety accident caused by rainstorm disaster. *China Safety Science Journal*, 27(6):169, 2017.

[35] Lijuan Quan, Rui Zhen, Benxian Yao, Xiao Zhou, and Dapeng Yu. The role of perceived severity of disaster, rumination, and trait resilience in the relationship between rainstorm-related experiences and ptsd amongst chinese adolescents following rainstorm disasters. *Archives of psychiatric nursing*, 31(5):507–515, 2017.

[36] Xinzheng Lu and Hong Guan. Earthquake disaster simulation of civil infrastructures. *(No Title)*, 2017.

[37] Mostafa Nazemi, Moein Moeini-Aghtaie, Mahmud Fotuhi-Firuzabad, and Payman Dehghanian. Energy storage planning for enhanced resilience of power distribution networks against earthquakes. *IEEE Transactions on Sustainable Energy*, 11(2):795–806, 2019.

[38] Tao Chen, Han Wu, Chi Wang, Xiaoxin Zhang, Xiaobin Jin, Qiming Ma, Jiyao Xu, Suping Duan, Zhaohai He, Hui Li, Saiguan Xiao, Xizhen Wang, Xuhui Shen, Quan Guo, Ilan Roth, Vladimir Makhmutov, Yong Liu, Jing Luo, Xiujie Jiang, Lei Dai, Xiaodong Peng, Xiong Hu, Lei Li, Chen Zeng, Jiajun Song, Fang Xiao, Jianguang Guo, Cong Wang, Hanyin Cui, Chao Li, and Qiang Sun. Hour-scale persistent negative anomaly of atmospheric electrostatic field near the epicenter before earthquake, 2019.

[39] Nazir Ahmad Zafar and Hamra Afzaal. Formal model of earthquake disaster mitigation and management system. *Complex Adaptive Systems Modeling*, 5:1–29, 2017.

[40] Maria Mavrouli, Spyridon Mavroulis, Efthymios Lekkas, and Athanassios Tsakris. The impact of earthquakes on public health: A narrative review of infectious diseases in the post-disaster period aiming to disaster risk reduction. *Microorganisms*, 11(2):419, 2023.

[41] Sukhpal Singh and Rishideep Singh. Earthquake disaster based efficient resource utilization technique in iaas cloud, 2014.

[42] Chao Huang, Wenhao Luo, and Rui Liu. Meta preference learning for fast user adaptation in human-supervisory multi-robot deployments, 2021.

[43] W Iqbal, T Yang, and Sh Ashraf. Optimizing earthquake response with fermatean probabilistic hesitant fuzzy sets: a decision support framework. *Journal of operational and strategic analytics*, 1(4):190–197, 2023.

[44] Fumihide Takeda. Tsunami and megathrust earthquake disaster prevention warnings: Real-time monitoring of the genesis processes with physical wavelets, 2023.

[45] Rozhin Eskandarpour, Amin Khodaei, and Ali Arab. Improving power grid resilience through predictive outage estimation. In *2017 North American Power Symposium (NAPS)*, pages 1–5. IEEE, 2017.

[46] Shixiang Zhu, Rui Yao, Yao Xie, Feng Qiu, Yueming, Qiu, and Xuan Wu. Quantifying grid resilience against extreme weather using large-scale customer power outage data, 2022.

[47] Pooria Dehghanian, Semih Aslan, and Payman Dehghanian. Maintaining electric system safety through an enhanced network resilience. *IEEE Transactions on Industry Applications*, 54(5):4927–4937, 2018.

[48] Nora Agah, Javad Mohammadi, Alex Aved, David Ferris, Erika Ardiles Cruz, and Philip Morrone. Data poisoning: An overlooked threat to power grid resilience, 2024.

[49] Ferda Ofli, Firoj Alam, and Muhammad Imran. Analysis of social media data using multimodal deep learning for disaster response. *arXiv preprint arXiv:2004.11838*, 2020.

[50] Cagri Toraman, Izzet Emre Kucukkaya, Oguzhan Ozcelik, and Umitcan Sahin. Tweets under the rubble: Detection of messages calling for help in earthquake disaster, 2023.

[51] Kiyong Park and Man-Hyung Lee. The development and application of the urban flood risk assessment model for reflecting upon urban planning elements. *Water*, 11(5):920, 2019.

[52] Kaveh Khalili-Damghani, Madjid Tavana, and Peiman Ghasemi. A stochastic bi-objective simulation–optimization model for cascade disaster location-allocation-distribution problems. *Annals of operations research*, 309(1):103–141, 2022.

[53] Roberto Rocchetta, Enrico Zio, and Edoardo Patelli. A power-flow emulator approach for resilience assessment of repairable power grids subject to weather-induced failures and data deficiency. *Applied energy*, 210:339–350, 2018.

[54] Hossein Noorazar, Anurag. k. Srivastava, K. Sadanandan Sajan, and Sanjeev Pannala. Data-driven operation of the resilient electric grid: A case of covid-19, 2020.

[55] Sabine Auer, Kirsten Kleis, Paul Schultz, Jürgen Kurths, and Frank Hellmann. The impact of model detail on power grid resilience measures, 2015.

[56] Fahad M Almasoudi. Enhancing power grid resilience through real-time fault detection and remediation using advanced hybrid machine learning models. *Sustainability*, 15(10):8348, 2023.

[57] Yuqi Zhou and Hao Zhu. Machine learning for scalable and optimal load shedding under power system contingency, 2025.

[58] Shutang You, Yilu Liu, Hongyu Li, Shengyuan Liu, Kaiqi Sun, Yinfeng Zhao, Huangqing Xiao, Jiaojiao Dong, Yu Su, Weikang Wang, and Yi Cui. Build smart grids on artificial intelligence – a real-world example, 2022.

[59] Jinshun Su, Payman Dehghanian, Mostafa Nazemi, and Bo Wang. Distributed wind power resources for enhanced power grid resilience. In *2019 North American Power Symposium (NAPS)*, pages 1–6. IEEE, 2019.

[60] Rozhin Eskandarpour, Amin Khodaei, and Ali Arab. Improving power grid resilience through predictive outage estimation, 2018.

[61] Ashutosh Shukla, Erhan Kutanoglu, and John J. Hasenbein. Scenario-based optimization models for power grid resilience to extreme flooding events, 2023.

[62] Rozhin Eskandarpour, Amin Khodaei, A. Paaso, and N. M. Abdullah. Artificial intelligence assisted power grid hardening in response to extreme weather events, 2018.

[63] Stefan Partelow. Social capital and community disaster resilience: post-earthquake tourism recovery on gili trawangan, indonesia. *Sustainability science*, 16(1):203–220, 2021.

[64] Michael Hammond, Albert S Chen, Jelena Batica, David Butler, Slobodan Djordjević, Philippe Gourbesville, Nataša Manojlović, Ole Mark, and William Veerbeek. A new flood risk assessment framework for evaluating the effectiveness of policies to improve urban flood resilience. *Urban water journal*, 15(5):427–436, 2018.

[65] Zuo Sun, Qingjie Qi, and Yingjie Liu. Vulnerability assessment of mine flooding disaster induced by rainstorm based on tri-ahp. *Sustainability*, 14(24):16731, 2022.

[66] Sandia report.

[67] Qing Yang, Ying Sun, Xingxing Liu, and Jinmei Wang. Mas-based evacuation simulation of an urban community during an urban rainstorm disaster in china. *Sustainability*, 12(2):546, 2020.

[68] Morocco Solidarity Hackathon. Leveraging ai for natural disaster management: takeaways from the moroccan earthquake. *arXiv preprint arXiv:2311.08999*, 2023.

[69] Hai-hong LI and Ji-dong WU. Rainstorm characteristics and its relationship with waterlogging disaster in shanghai during 2007-2016. *Journal of Natural Resources*, 33(12):2136–2148, 2018.

[70] Jeroen CJH Aerts, Wouter J Botzen, Keith C Clarke, Susan L Cutter, Jim W Hall, Bruno Merz, Erwann Michel-Kerjan, Jaroslav Mysiak, Swenja Surminski, and Howard Kunreuther. Integrating human behaviour dynamics into flood disaster risk assessment. *Nature climate change*, 8(3):193–199, 2018.

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