

Review

Infrastructure Resilience in the United States: A Data-Driven Synthesis of Disaster-Related Studies

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Abstract

This study examines how research in the United States has addressed infrastructure resilience across different disaster contexts, situating the topic within broader discussions on climate-related risks and adaptation. Infrastructure resilience has gained increasing importance as communities face more frequent and severe natural hazards and as infrastructure systems become more complex and interconnected. A database of more than 7000 studies published over the past century by universities, research centers, and government agencies was compiled and organized, including supplemental works from regions such as Europe, Australia, Japan, Africa, and South America. The dataset provides a long-term perspective on the evolution of resilience-related research and reflects the scope of accessible literature indexed in major research repositories. Using systematic classification, each study was categorized by disaster type (i.e., floods, hurricanes, wildfires, heatwaves, and snowstorms) and by infrastructure system (i.e., transportation, water, energy, telecommunications, and buildings). A keyword-based relevance scoring method was applied to distinguish studies in which resilience is a central analytical focus from those in which it appears as a secondary or contextual concept. The results are presented through an interactive web-based platform that enables users to explore resilience research by state, year, disaster type, infrastructure category, and level of relevance. The analysis reveals a substantial increase in resilience-related publications in recent decades, with notable geographic and thematic concentrations. Transportation and water infrastructure dominates the literature, while energy systems, telecommunications, and digital infrastructure remain underrepresented. These findings highlight both progress and persistent gaps in infrastructure resilience research and support more integrated, system-oriented, and future-focused resilience planning.

Keywords: infrastructure resilience; disaster risk reduction; climate adaptation; transportation infrastructure; water and energy systems; telecommunications resilience; resilience mapping; data visualization



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1. Introduction

Resilience has been defined across multiple disciplines as the capacity of systems to withstand disturbances, adapt to changing conditions, and recover functionality following disruptive events. In infrastructure and urban systems research, resilience is commonly conceptualized through dimensions such as robustness, redundancy, resourcefulness, and rapid recovery, reflecting both engineering performance and socio-institutional adaptive capacity. Across fields including engineering, environmental science, planning, and risk

management, resilience is interpreted through different analytical lenses, leading to variation in evaluation methods and performance indicators [1,2].

In engineering-oriented studies, resilience is frequently quantified using performance-based frameworks, recovery-time metrics, probabilistic risk models, and system functionality curves. Planning and policy research often adopts index-based or composite indicator approaches incorporating social, institutional, and governance dimensions. Because of this disciplinary diversity, resilience measurement lacks a single standardized methodology.

In this study, infrastructure resilience is operationally defined as the ability of built infrastructure systems to resist, adapt to, and recover from natural disaster impacts while maintaining essential service functionality. This operational definition enables consistent classification across the large multi-source dataset and supports comparative analysis of long-term research trends, spatial distribution, and thematic emphasis in disaster-related infrastructure studies.

Growing attention reflects increasing recognition that modern societies depend heavily on interconnected infrastructure systems whose failure can lead to widespread economic losses, social disruption, and risks to public safety. As natural disasters become more frequent and more severe, there is a growing need to ensure that critical systems such as roads, bridges, water supply, electricity, buildings, and communication networks can withstand and recover from disruptive events [3,4]. These systems are essential not only for emergency response and post-disaster recovery, but also for maintaining everyday functionality and long-term sustainability of urban and regional environments. Resilience has therefore become a central idea in city planning, public policy, and academic research. It is increasingly viewed as a complement to sustainability, emphasizing the ability of infrastructure systems not only to reduce environmental impacts but also to adapt to, absorb, and rapidly recover from extreme events.

Many universities are now offering programs that include resilience as a subject or course content. These programs often combine knowledge from fields such as engineering, sustainability, and environmental science [2]. In addition, resilience-related education increasingly integrates concepts from risk management, climate adaptation, emergency planning, and systems engineering, reflecting the multidisciplinary nature of resilience challenges. As a result, faculty and students require access to a broad and well-organized body of existing research to understand historical trends, methodological approaches, and evolving priorities in infrastructure resilience studies. However, the rapid growth of publications across multiple disciplines and regions has made it increasingly difficult to obtain a comprehensive overview of the existing literature.

This study examines the research on infrastructure resilience conducted primarily in the United States, with supplemental international studies. We collected more than 7000 reports published over the past 102 years, including studies from the United States, Europe, Japan, Australia, Africa, and other regions. The long temporal coverage of the dataset allows for examination of how resilience-related research has evolved in response to changing hazards, technological advances, and policy priorities. All the data were organized into an interactive website that allows users to explore studies by disaster type, location, year, and type of infrastructure. By enabling flexible filtering and visualization, the platform supports both high-level trend analysis and targeted investigation of specific hazards or infrastructure sectors. This information can help faculty, students, and decision-makers understand what has already been studied and where there are gaps. Such insights are particularly valuable for guiding future research directions, curriculum development, and evidence-based policy decisions. It also supports universities, such as the University of New Haven, that aim to expand resilience-related content in their programs [5].

Beyond synthesizing an expanding academic literature, the motivation for this study is grounded in the growing societal and institutional significance of infrastructure resilience. Although numerous review studies have examined resilience concepts, sector-specific applications, or methodological developments, relatively few have systematically linked long-term research patterns with observed disaster frequency, hazard exposure, and national resilience priorities. Over the past century, the United States has experienced recurrent large-scale disaster events alongside increasing public investment in resilience research and infrastructure protection [2–4]. However, integrated longitudinal analyses that align research activity with real-world hazard dynamics remain limited.

By constructing a large-scale resilience research database and applying a structured classification framework across multiple infrastructure sectors and decades of publications, this study provides a data-driven foundation for identifying thematic concentration, geographic imbalances, and emerging gaps. The resulting synthesis extends beyond literature organization by enabling comparative trend analysis and supporting evidence-informed resilience planning and research prioritization.

2. Materials and Methods

This study employed a structured data-driven workflow to collect, process, and visualize publications related to infrastructure resilience. The workflow was designed to ensure consistency, reproducibility, and scalability, allowing the dataset to be expanded or updated as new publications become available. All scripts developed for data collection, extraction, cleaning, and visualization were written in Python 3.12 (2023) and are available to readers upon request. Python was selected due to its extensive ecosystem of libraries for web scraping, text processing, data analysis, and visualization, which are well suited for large and heterogeneous datasets. The full dataset and interactive visualizations are publicly accessible through the project website [5]. Providing open access to both the data and visualization tools supports transparency and enables reuse of the dataset for research, educational, and policy-related applications.

Data collection was conducted in Spring 2025. The data collection step involved automated retrieval of resilience-related studies from major research repositories widely used in infrastructure and transportation research, including the National Transportation Library Repository, Scimago Journal and Country Rank, and the Transportation Research Information Service (TRIS) [6–8]. These repositories were selected because they collectively cover peer-reviewed journal articles, technical reports, conference proceedings, and government-sponsored research relevant to infrastructure systems and resilience. A custom Python script was developed to query these databases using predefined keywords associated with infrastructure resilience and to download the resulting pages in HTML format for processing. The keyword set was iteratively refined to capture variations in terminology across disciplines while minimizing irrelevant results. This automated approach enabled the efficient retrieval of a large number of publications spanning multiple decades and geographic regions.

The use of keyword-based retrieval and classification follows established bibliometric research practices for analyzing large-scale scientific datasets through objective indicators such as keyword frequency, publication metadata, and thematic clustering. Such approaches are widely applied to map research trends and identify knowledge gaps when full-text analysis of thousands of records is impractical [9].

To minimize terminology bias and improve thematic coverage, an expanded keyword framework including more than fifty terms related to resilience concepts, hazard events, and infrastructure performance was employed. The complete list of keywords is provided

below. In addition to direct keyword matching, contextual filtering and combined keyword logic were applied to refine search results and reduce ambiguous classifications.

Following retrieval, iterative random sampling and limited manual verification were conducted to assess classification consistency and thematic alignment. Although this procedure improves reliability, some classification uncertainty may remain. Therefore, relevance categories should be interpreted as approximate thematic indicators rather than definitive measures. Despite these limitations, the dataset provides a consistent large-scale overview of research patterns, and the interactive platform enables independent verification and exploration of the results [5].

The keyword framework was organized into four thematic categories to ensure comprehensive coverage of resilience-related infrastructure research:

- (1) Resilience and Infrastructure Concepts: Adaptive capacity, built environment, climate adaptation, critical infrastructure protection, damage tolerance, fail-safe, infrastructure integrity, infrastructure resilience, infrastructure response, resilience, resilient infrastructure, restoration and resilience, robustness in response, and mitigation strategies.
- (2) Risk, Vulnerability, and Assessment: Investigating vulnerabilities, risk assessment, risk reduction, and vulnerability.
- (3) Disaster Response, Recovery, and Management: Case study, disaster, disaster recovery, disruption management, emergency, emergency planning, emergency response, lessons learned, recovery mechanisms, post-disaster reconstruction, and failure analysis.
- (4) Hazard and Disaster Events: Avalanche, blizzard, cold wave, cyclone, drought, dust storm, earthquake, flood, hailstorm, heatwave, hurricane, landslide, mudslide, sink-hole, storm surge, tornado, tsunami, typhoon, volcanic eruption, and wildfire.

These categories were used in combination through Boolean operators and contextual filtering to identify relevant studies and reduce retrieval bias.

In the data extraction step, a second Python script parsed the saved HTML files to extract publication titles, years, source links, and available descriptive metadata. Where available, additional attributes such as abstract text, publication outlet, and document type were also captured to support subsequent classification and filtering. The extracted data were compiled into a structured spreadsheet format. A data cleaning procedure was then implemented to standardize entries, resolve formatting inconsistencies, remove duplicates, and verify missing attributes prior to analysis [8]. Duplicate detection was performed using a combination of title matching, publication year comparison, and source verification to reduce redundancy across databases. This step was critical to ensure the reliability of summary statistics and visualizations derived from the dataset.

For studies in which the geographic location was not explicitly stated or identifiable in the metadata, original full-text documents were accessed manually or programmatically. This step was necessary because many older reports and technical documents do not include standardized location metadata. In cases where documents were provided as scanned files, Optical Character Recognition (OCR) was applied using Python's text extraction libraries. The resulting text was searched for geographic references to determine study origin or study area, and the identified information was added to the dataset [9]. When multiple geographic references were present, the primary study location was inferred based on the context of the analysis, such as the infrastructure system examined or the sponsoring agency. This process improved the completeness and spatial resolution of the dataset.

The final step involved visualization. The processed dataset was transformed into an interactive mapping interface, enabling users to filter studies by disaster type, location, year, and infrastructure system. This interactive functionality allows users to explore both broad patterns and specific subsets of the literature, supporting exploratory analysis as well as targeted inquiry. Additional dynamic charts were developed to display temporal and

spatial patterns. These visualizations were designed to highlight long-term trends, regional concentrations of research activity, and shifts in thematic focus over time. All visualizations were integrated into a publicly accessible web platform to support research, teaching, and decision-making [5].

In addition, random subsets of records were manually reviewed to verify classification consistency and reduce systematic bias.

3. Results

3.1. Classification by Resilience Relevance

A text-based keyword scoring method was applied to categorize each study by its degree of relevance to resilience. The classification framework was developed to distinguish between studies in which resilience constitutes a central analytical focus and those in which the term appears primarily in a contextual or descriptive manner. The categories were defined as follows:

- Strongly related: five or more resilience-related keywords;
- Moderately related: 3–4 keywords;
- Marginally related: 1–2 keywords.

This framework was designed to improve thematic consistency and reduce ambiguity in relevance classification. Studies with higher keyword frequencies typically engaged more deeply with resilience concepts, modeling frameworks, or assessment methodologies, while marginally related studies often referenced resilience in a limited contextual sense.

To improve classification reliability, random subsets of records were manually reviewed to verify consistency and reduce systematic bias. Although this procedure improved robustness, only a portion of the dataset was manually examined, and some classification uncertainty may remain. Therefore, the relevance categories should be interpreted as approximate thematic indicators rather than definitive measures of research focus.

Based on this method, 2578 studies were classified as marginally related, 1389 as moderately related, and 1907 as strongly related (Figure 1). These findings indicate that while resilience has become a widely adopted concept, comparatively fewer studies engage with it through quantitative metrics, modeling frameworks, or explicit assessment methodologies.

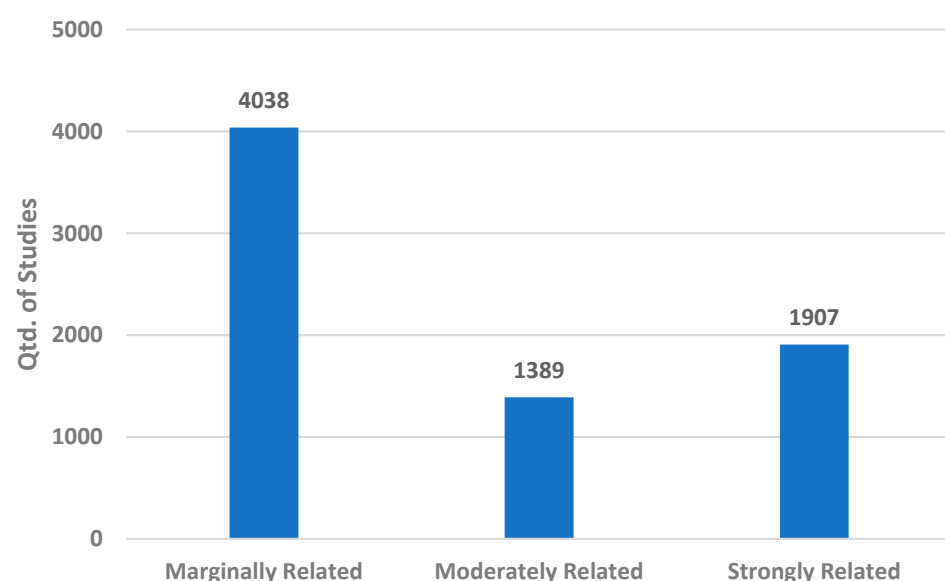


Figure 1. Classification of U.S. resilience-related research by level of relevance.

3.2. Distribution of Resilience Research by Jurisdiction

A total of 7152 resilience-related studies were identified in the dataset [5]. Of these, 4413 studies were conducted within the United States and constitute the analytical sample used in this study, while 2739 studies conducted in other regions, including Europe, Asia, Africa, Australia, and South America, were retained in the database but excluded from the present analysis and organized separately to support future global-scale research (Figure 1).

The predominance of U.S.-based studies highlights the significant contribution of domestic research institutions to the infrastructure resilience literature. In addition, many U.S. federal agencies and research programs have historically prioritized resilience-related research, particularly in transportation and public works sectors, contributing to higher publication output.

This pattern also reflects structural advantages in English-language publication and indexing practices, which tend to increase the visibility and accessibility of U.S.-based research outputs. As a result, the dataset represents a comprehensive overview of long-term trends and thematic emphases within the U.S. resilience literature, while acknowledging that global research activity may be underrepresented.

Despite this limitation, the compiled dataset provides a valuable basis for examining spatial and institutional patterns of resilience research and supports future expansion toward broader international analyses.

3.3. Disaster-Related Research Trends in the United States

A historical dataset of 181 major natural disasters occurring between 1816 and 2025 was compiled to compare research attention with real events [10]. This dataset included floods, earthquakes, hurricanes, wildfires, droughts, and other hazard types documented in federal and historical records. Although improved reporting in the digital era contributes to higher documentation of recent disasters, the data also aligns with scientific consensus that climate change is intensifying extreme weather events [3,4]. The comparison between disaster occurrence and research output provides insight into how empirical events influence academic research priorities over time.

3.3.1. Temporal Trends in Disaster-Related Research

The number of disaster-related studies increased substantially after 2000, as shown in Figure 2. While publication activity remained limited during earlier decades, a pronounced growth trend is observed beginning in the early 2000s and accelerating after 2015. Recent multi-year periods exhibit markedly higher publication volumes, reflecting increased public awareness of climate risks, expanded federal research funding, and the integration of resilience into national infrastructure policy frameworks. This trend indicates a gradual shift from reactive post-disaster studies toward more proactive planning and resilience-oriented research agendas.

3.3.2. Distribution of Studies by Disaster Type

Flood-related research in Figure 3 was the most prevalent (445 studies), followed by earthquakes (273) and cyclones (177). This distribution reflects the high frequency and widespread impacts of flooding across U.S. regions, as well as long-standing seismic research traditions in earthquake-prone areas. Research on heatwaves, droughts, and volcanic events was comparatively limited, despite their documented rise in frequency and severity [3,10]. The underrepresentation of these hazards suggests potential gaps in resilience research, particularly as climate-driven extremes increasingly affect infrastructure performance and public health.

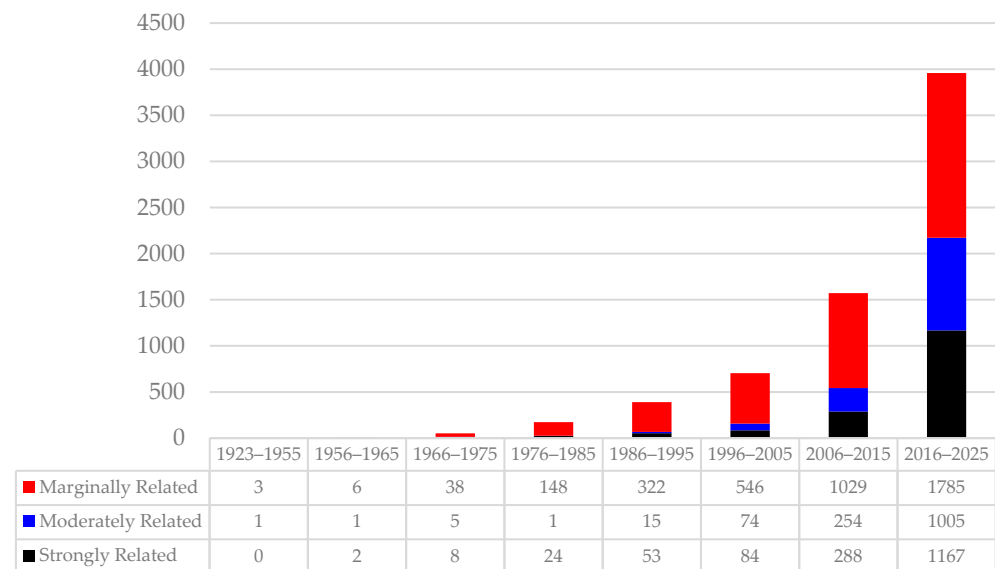


Figure 2. Number of disaster-related studies published per year in the United States.

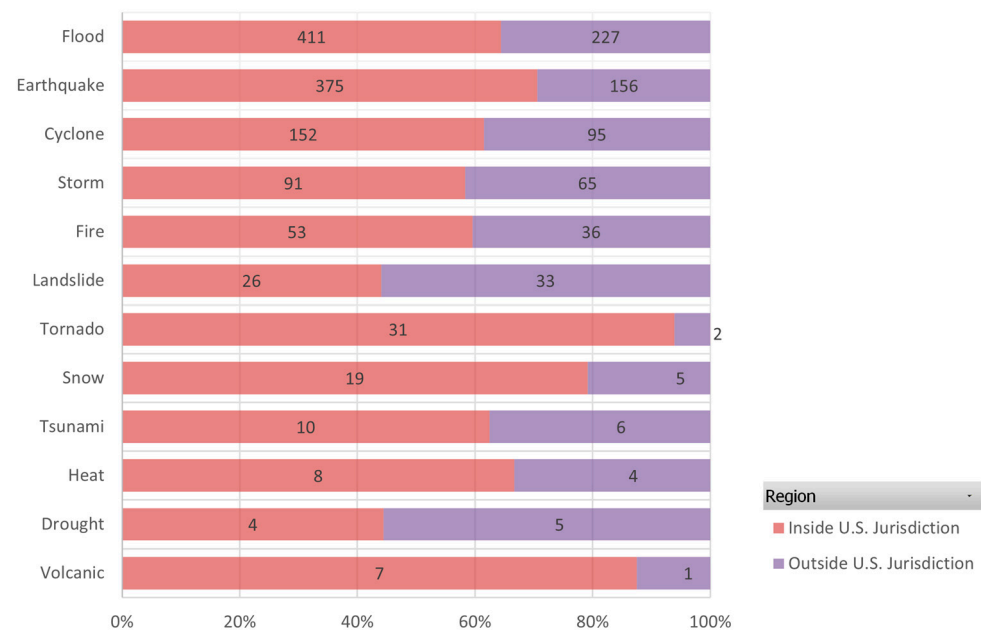


Figure 3. Distribution of U.S. resilience-related studies by disaster type.

3.4. Geographic and Institutional Distribution of U.S. Research

California, the District of Columbia, Washington, New York, and Texas had the highest concentration of resilience-related studies, while states such as South Dakota and New Hampshire had minimal representation (Table 1). States with higher research output are typically characterized by larger populations, greater infrastructure complexity, and the presence of major research universities and federal agencies. The uneven distribution suggests imbalances in research capacity, funding access, and academic networks [2,11]. Additionally, states with recurring exposure to natural hazards tend to attract sustained research attention, reinforcing geographic clustering of resilience scholarship. The total count in Table 1 includes studies classified as ‘Widespread,’ which represent national or multi-jurisdictional analyses and therefore exceed the count of studies assigned to individual states.

Table 1. Number of resilience-related research studies by U.S. state and territory.

State	No of Studies	State	No of Studies
Alabama	78	Montana	18
Alaska	70	Nebraska	18
American Samoa	1	Nevada	25
Arizona	59	New Hampshire	10
Arkansas	42	New Jersey	126
California	451	New Mexico	19
Colorado	74	New York	266
Connecticut	32	North Carolina	43
Delaware	19	North Dakota	20
District of Columbia	362	Ohio	64
Florida	212	Oklahoma	51
Georgia	75	Oregon	75
Hawaii	53	Pennsylvania	38
Idaho	32	Puerto Rico	10
Illinois	106	Rhode Island	12
Indiana	61	South Carolina	25
Iowa	58	South Dakota	6
Kansas	34	Tennessee	37
Kentucky	24	Texas	269
Louisiana	84	Utah	37
Maine	68	Vermont	24
Maryland	50	Virginia	88
Massachusetts	43	Washington	269
Michigan	50	West Virginia	1
Minnesota	97	Widespread *	604
Mississippi	67	Wisconsin	31
Missouri	43	Wyoming	31
Total		4562	

* Observed across many regions or jurisdictions.

3.5. Infrastructure Systems Addressed in the Literature

Transportation infrastructure was the most studied sector (over 3000 studies), followed by water systems (668 studies) and cross-sector emergency coordination networks. The dominance of transportation-related research reflects the critical role of roads, bridges, and transit systems in disaster response, evacuation, and economic continuity. Building structures appeared less frequently, while energy and telecommunications networks were least represented (12 and 7 studies respectively) (Figure 4). This imbalance indicates that certain infrastructure systems, particularly telecommunications and communication networks, remain underexplored despite their essential role in coordinating emergency response and supporting recovery operations. The lack of research on communication resilience is particularly notable given its critical role in emergency response and post-disaster recovery [2,11].

3.6. Public-Facing Interactive Resilience Map Platform

A web-based interactive platform was developed to visualize the dataset and support public access to the research (Figure 5). Users can filter studies by location, disaster type, infrastructure category, and level of resilience relevance. This functionality allows users to explore the literature from multiple perspectives and scales, ranging from national trends to localized case studies. The platform includes downloadable datasets to support teaching, planning, and further research [5]. By making resilience research accessible

beyond academic audiences, the platform supports knowledge transfer to practitioners, students, and decision-makers.

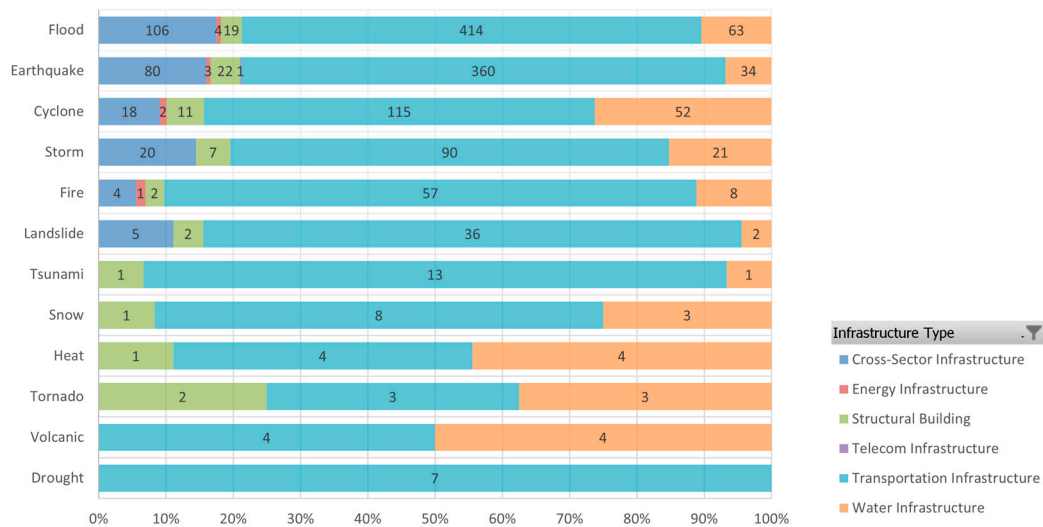


Figure 4. Distribution of resilience-related research by infrastructure system.

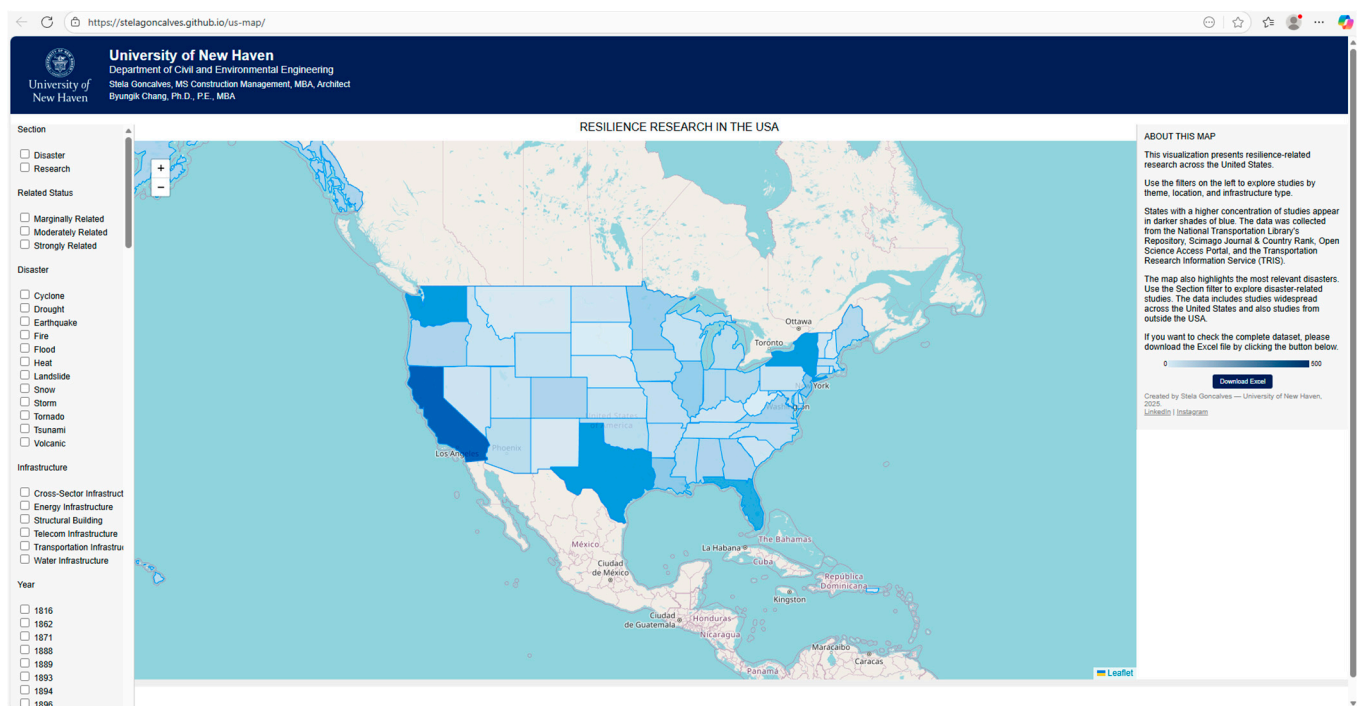


Figure 5. Interactive map showing the spatial distribution of resilience-related research studies in the United States (Website: <https://stelagoncalves.github.io/us-map/> (accessed on 31 December 2025)).

4. Discussion

The number of studies addressing infrastructure resilience in the United States has increased significantly in recent decades, reflecting growing recognition of climate-related risks and infrastructure vulnerabilities. This increase corresponds with heightened exposure to extreme weather events, aging infrastructure systems, and rising economic losses associated with infrastructure failures. Academic institutions have demonstrated growing interest in resilience-related themes, supported by improved analytical tools and wider access to datasets. Advances in data analytics, remote sensing, and computational modeling have enabled researchers to evaluate infrastructure performance under a broader

range of hazard scenarios than was previously possible. As a result, resilience has transitioned from a specialized topic to a central component in national discussions on safety, urban development, and climate adaptation. This evolution reflects not only changing risk conditions but also institutional shifts toward risk-informed infrastructure planning and performance-based policy frameworks.

Infrastructure resilience research is inherently interdisciplinary, integrating perspectives from engineering, environmental science, urban planning, social science, and public policy. Engineering studies primarily contribute system modeling, structural performance analysis, and failure-recovery assessment. Environmental and climate sciences provide hazard characterization and long-term risk projections, while planning and policy research addresses land-use strategies, governance mechanisms, and institutional preparedness. Social science research further contributes insights into community vulnerability, adaptive capacity, and stakeholder engagement. However, differences in methodological traditions, publication venues, and funding priorities across these disciplines may limit sustained collaboration and knowledge integration.

Effective resilience planning increasingly relies on the integration of these disciplinary perspectives, as infrastructure systems operate within complex socio-technical and environmental contexts. Interdisciplinary collaboration enables more comprehensive assessment frameworks, improves decision-making under uncertainty, and supports the development of adaptive and sustainable resilience strategies. The growing emphasis on cross-disciplinary research identified in this study reflects the recognition that isolated disciplinary approaches are insufficient for addressing large-scale disaster risks. Nevertheless, institutional barriers, including departmental boundaries and discipline-specific evaluation criteria, continue to constrain fully integrated resilience research.

The dataset reveals distinct patterns in research distribution. States with established research institutions and a history of documented disasters generally lead in publication volume. This trend suggests that research activity is influenced not only by hazard exposure but also by institutional capacity, funding availability, and proximity to policy-making bodies. Transportation infrastructure is the most examined sector, followed by water systems and public buildings. These sectors are directly associated with emergency response and the continuity of essential public services, as demonstrated in post-disaster transportation assessments conducted after major extreme events such as Hurricane Sandy [12]. In these cases, transportation system failures highlighted the cascading impacts of infrastructure disruptions on mobility, economic activity, and emergency operations. Subsequent mitigation measures, including flood-prevention strategies implemented in New York City subway systems, further illustrate how research findings have been translated into operational resilience actions [13]. However, the distribution of research focus is uneven. Certain domains are extensively studied, while others remain underexplored [2,11]. This uneven distribution reflects differences in data accessibility, institutional mandates, and sector-specific regulatory environments.

This imbalance creates opportunities for strategic advancement. Critical sectors such as energy and telecommunications, which are fundamental for response and recovery, are among the least represented in current research. Reliable access to electricity and communication networks is essential for emergency medical care, coordination, and dissemination of public information. Failures in these systems can undermine the functionality of otherwise resilient transportation and water infrastructure, illustrating the interconnected nature of modern infrastructure networks. The limited attention these sectors receive indicates a significant gap in the resilience research landscape [2,4]. Addressing this gap requires greater emphasis on cross-sectoral and systems-based approaches that account for interdependence among infrastructure networks. Structural barriers, including proprietary

data restrictions, cybersecurity concerns, and fragmented governance frameworks, further constrain empirical research in these sectors.

Similar structural imbalances in resilience research have been documented in the literature, where interdependence between critical infrastructure sectors complicate comprehensive analysis and bias research toward systems with more accessible data or standardized modeling frameworks [14–17]. Studies on interdependent networks highlight how cross-sector dependencies influence not only system performance under stress but also the feasibility of resilience evaluation and comparative assessment [18]. Moreover, adaptive governance and sustainability-oriented frameworks emphasize that institutional fragmentation, uneven data accessibility, and limited integration of policy and socio-technical perspectives can shape research priorities and hinder the development of unified resilience assessment models [19–21]. These findings suggest that sectoral disparities are driven not only by hazard exposure, but also by funding structures, regulatory environments, and methodological feasibility.

In addition, the findings emphasize that resilience is not solely a matter of constructing additional infrastructure or increasing regulatory requirements. It also involves reviewing, adapting, and improving existing systems. In many cases, retrofitting, operational modifications, and institutional reforms may offer more cost-effective resilience gains than large-scale capital investments. Flexible regulatory frameworks, updated building codes, and streamlined emergency protocols may better address contemporary hazards than rigid or outdated structures. This perspective aligns with recent shifts in resilience planning that prioritize adaptability, learning, and iterative improvement. Resilience therefore encompasses adaptability as much as structural robustness [1,2]. This approach supports long-term sustainability by emphasizing system learning and institutional capacity-building rather than short-term compliance.

A notably underdeveloped area in literature concerns cyber resilience. Many critical infrastructures, including power grids, hospital networks, satellite communications, aviation navigation systems, and water treatment facilities, are deeply interconnected with digital systems. The increasing integration of sensors, automated controls, and data-driven management systems has expanded the attack surface of critical infrastructure networks. A disruption caused by a cyberattack during or following a natural disaster could intensify vulnerabilities and slow recovery efforts. Yet, cyber risks remain marginal in current resilience research. This omission is particularly concerning given the growing frequency of cyber incidents targeting infrastructure systems worldwide. Expanding resilience research to incorporate digital infrastructure security and continuity planning therefore represents a key direction for future studies [2,4]. The limited integration of cybersecurity perspectives reflects disciplinary separation between infrastructure engineering and information systems research.

Although this study focuses on the United States, international technical documents similarly emphasize the importance of system-level resilience and network continuity in infrastructure planning, reinforcing the broader applicability of these findings [11]. Global frameworks increasingly highlight the need for integrated resilience strategies that address physical, operational, and digital dimensions of infrastructure performance. The patterns identified in the U.S. literature therefore provide insights that may inform resilience research and practice in other regions facing similar challenges. Comparative international studies may further clarify how governance structures influence resilience research priorities.

In summary, the progress achieved to date is considerable, reflecting strong institutional engagement and rising awareness of resilience challenges. However, future research must expand its scope to address underrepresented sectors and system interdependencies, particularly in energy, communications, and cybersecurity [2]. Greater integration

across disciplines and infrastructure sectors will be essential to develop comprehensive resilience strategies capable of addressing compound and cascading risks. Doing so will strengthen the foundation for building communities that are not only physically robust but also operationally and digitally resilient.

Several structural factors may also help explain the concentration of resilience research in transportation systems compared with the relative underrepresentation of energy and telecommunications sectors. Transportation infrastructure has historically benefited from sustained federal research funding programs, standardized national datasets, and well-established engineering evaluation frameworks, which facilitate quantitative resilience assessment and comparative studies [2,11]. In contrast, energy and telecommunications systems often involve privately operated networks, restricted operational data, and complex interdependencies that make large-scale empirical evaluation more difficult [2]. In addition, disciplinary research traditions within civil and transportation engineering have long emphasized transportation system performance, reinforcing sectoral research concentration over time [1]. These structural conditions suggest that the observed imbalance reflects not only research priorities but also differences in data accessibility, funding structures, and methodological feasibility across infrastructure sectors. These systemic conditions create path dependency in research investment and publication patterns.

The observed research gaps are not solely thematic but may reflect broader structural and institutional drivers. Geographic concentration of resilience research in certain regions likely corresponds to variations in research funding capacity, disaster exposure frequency, and national policy prioritization of infrastructure resilience. In addition, methodological barriers such as limited long-term performance data, inconsistent resilience metrics, and the absence of standardized evaluation frameworks may contribute to uneven research development across sectors. These limitations constrain comparative analysis and hinder cumulative knowledge development.

Disciplinary fragmentation further shapes resilience scholarship. Engineering studies often emphasize structural robustness and recovery time, whereas planning and social science research prioritize governance, adaptation, and community capacity. This divergence can limit integrative knowledge development and slow the emergence of unified resilience assessment models. Bridging these perspectives requires coordinated research agendas and shared analytical frameworks.

Addressing these gaps requires strengthened interdisciplinary collaboration, harmonized resilience indicators, and incorporation of emerging technologies such as data-driven modeling, AI-based risk forecasting, and digital twin platforms. Such advances can improve actionable sustainability outcomes by translating resilience theory into measurable infrastructure performance improvements. Institutional support for open data platforms and cross-sector partnerships will be critical for realizing these advances.

5. Conclusions

This study provides a comprehensive overview of infrastructure resilience research conducted over the past century, highlighting key patterns in thematic focus, geographic distribution, and institutional engagement. By synthesizing more than 7000 resilience-related studies into a unified, searchable dataset, this work offers one of the first large-scale, longitudinal, and systematically classified datasets linking disaster-related infrastructure research with hazard exposure and sectoral focus in the United States. The results show substantial growth in resilience-related publications, particularly in the last three decades, as universities and research organizations respond to increasing climate-related hazards and infrastructure vulnerabilities. This growth reflects both rising awareness of infrastructure risk and the increasing integration of resilience concepts into national policy and academic curricula.

However, the analysis also reveals significant imbalances. Transportation, water systems, and public buildings dominate literature, while critical sectors such as energy and telecommunications remain understudied, despite their essential role in emergency response and community recovery. These disparities suggest that research attention has not always aligned with the full spectrum of infrastructure dependencies required for effective disaster response and long-term resilience. By systematically identifying these sectoral gaps and spatial concentrations, this study provides an empirical basis for more balanced and targeted future research investment. Addressing these imbalances will be essential to developing more comprehensive and system-oriented resilience strategies.

Furthermore, the growing dependence of infrastructure systems on digital networks underscores the need to expand resilience research to include cyber risks. Strengthening the integration between physical and digital resilience is likely to become a central priority in the coming years, as modern infrastructure systems become increasingly interconnected. Cyber disruptions have the potential to amplify the impacts of physical damage, creating cascading failures across multiple sectors. Future research should therefore focus not only on traditional structural vulnerabilities but also on data security, communication continuity, and the interdependencies that shape modern infrastructure systems. This study highlights the need for integrated assessment frameworks that jointly consider physical, operational, and digital dimensions of resilience.

In addition to its research contributions, this study provides practical value through the development of a publicly accessible, interactive platform that enables users to explore resilience research by hazard type, location, infrastructure system, and relevance level. Unlike conventional literature reviews, the platform enables dynamic querying, visualization, and longitudinal comparison of resilience research patterns. This tool supports research, teaching, and decision-making by lowering barriers to accessing and synthesizing a rapidly expanding body of literature. It also offers a scalable framework that can be updated as new studies emerge, supporting ongoing assessment of resilience research trends.

This study is subject to limitations related to database coverage, English-language bias, and the use of keyword-based classification, which may influence the representation of global resilience research. Despite these limitations, the dataset provides a robust and transparent foundation for identifying broad trends, research gaps, and opportunities for future investigation. Continued refinement of data sources, classification methods, and international coverage will further enhance the utility of this framework.

Overall, this work contributes to advancing understanding of the evolving landscape of infrastructure resilience research by (1) establishing a large-scale, openly accessible resilience database, (2) applying a structured and reproducible classification methodology, and (3) linking long-term research trends with observed disaster patterns and sectoral vulnerabilities. By identifying both areas of strength and persistent gaps, the study supports more informed research agendas, educational initiatives, and evidence-based planning. By strengthening interdisciplinary integration and expanding attention to underrepresented sectors and digital infrastructure, future resilience research can better support sustainable, adaptive, and resilient communities.

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Conflicts of Interest: The authors declare no conflicts of interest.

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