

Integrating Sustainability into Urban Planning: A Systematic Review of Policies Addressing Hazard Risks and Climate Change

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Abstract

Natural and human-made disasters threaten cities increasingly, thus requiring a combination of disaster risk reduction and sustainable development strategies. Although vulnerability assessment methods and urban sustainability policies have improved significantly, these two fields remain separate, leading to fragmented policies that may work against resilience objectives. This paper provides an overview by conducting a systematic review of 87 peer-reviewed studies published between 2000 and 2024 that describe and analyze the intersection of disaster prevention policies and sustainability practices in urban planning. Thematic analysis was employed, and five major themes were revealed: policy implementation frameworks, climate adaptation strategies, preparedness mechanisms, vulnerability assessment approaches, and sustainability evaluation systems. The findings reveal a critical disconnect: on the one hand, vulnerability assessments highlight the structural–technical aspect and, at the same time, ignore the sustainability indicators (resource efficiency, social equity, and ecosystem services), while on the other hand, sustainability frameworks deliberately shut out disaster risk awareness from the core evaluation criteria. This methodological separation produces policy conflicts where disaster interventions may compromise environmental goals, and sustainability initiatives may increase hazard vulnerability. This review concludes that resilient cities require assessment methodologies synthesizing disaster risk and sustainability dimensions. A novel conceptual integration framework is suggested that combines hazard-exposure-vulnerability analysis with environmental–social–economic sustainability pillars, thus laying the groundwork for future operational tools. This joint viewpoint accepts that hazards mainly affect development that is not sustainability-oriented, while sustainable systems through adaptive design and equitable resource distribution inherently lower the vulnerability.

Keywords: sustainability; vulnerability; assessment; risk reduction; urban planning

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1. Introduction

Disasters manifest through diverse forms: natural phenomena, including earthquakes, hurricanes, and floods; technological failures such as power outages and chemical spills; social disruptions, including civil unrest and labor conflicts; and political crises

encompassing terrorism and armed conflicts [1]. Natural disasters result from geophysical or climatological events (earthquakes, tsunamis, volcanic eruptions, floods, droughts, hurricanes, and landslides) occurring due to environmental changes ranging from gradual shifts to extreme events.

Human activities create multiple links that increase the risk of natural disasters occurring. Uncontrolled deforestation not only triggers landslides but also amplifies flood risks through its effect on water retention capacity because deforested areas lack proper maintenance. The 2017 Sierra Leone mudslides, which killed more than 1000 people, occurred because people settled on deforested hillsides [2]. The rapid growth of cities creates additional danger because newly built areas stop water from being absorbed, which leads to flooding during heavy rains, as shown by the 2017 Houston floods, which occurred under conditions that matched previous weather patterns but showed increased flooding because of concrete-covered areas [3]. Climate change, which results from human activities that emit greenhouse gases, creates extreme weather events that occur more frequently and with greater intensity. The economic damage from weather-related disasters grew by 151% between 2000 and 2019 compared to the period between 1980 and 1999 [4]. Inadequate land use planning leads to high-risk areas, which place vulnerable groups in danger. In the informal settlements that exist in developing cities, their inhabitants face double danger because they live on steep slopes and floodplains, which are prone to natural disasters and building failures [5]. The urban heat island effect, which results from dense urban development, increases heatwave death rates in city centers by 2–5 °C above the temperatures found in nearby areas [6].

The cities of the world now experience more frequent and severe urban disaster events, which show increasing intensity compared to previous times. The 2019–2020 Australian bushfires displaced 450,000 people from urban–wildland interface communities, which revealed planning weaknesses in the development of periurban areas [7]. The 2021 European floods caused \$43 billion in damages across urbanized river valleys in Germany, Belgium, and the Netherlands, which revealed weaknesses in climate-adaptive infrastructure that existed despite operational early warning systems [8].

The New York City basement apartment deaths of fourteen people during Hurricane Ida showed how informal housing and poor drainage systems increased urban vulnerability to disasters [9]. The 2023 Turkey–Syria earthquakes resulted in more than 59,000 fatalities throughout urban areas that adopted rapid construction methods, which violated seismic building codes [10]. The 2021 Texas winter storm demonstrated infrastructure interdependencies that go beyond single-hazard planning when it created simultaneous power, water and heating outages that affected 4.5 million urban residents [11]. The data analysis proves that these patterns show distinct systematic trends. The Emergency Events Database shows that climate-related disasters that impact urban areas increased from 165 events per year from 1980 to 1999 to 389 events per year throughout 2000–2019, which represents a 135% increase [12]. The number of people living in urban areas with high flood danger increased from 680 million in 2000 to 1.24 billion in 2020 and is expected to reach 1.6 billion by 2050 [13]. The financial impact of urban disasters increased from \$79 billion per year between 1980 and 1999 to \$166 billion per year between 2000 and 2019, according to reference [14].

Natural disaster death rates show considerable variation across different stages of economic development because low-income nations face death rates that are four to eight times greater than high-income nations for the same level of hazardous events, according to research in reference [15].

The process of urban planning needs ongoing assessment because cities develop through their economic growth and population increases [16]. The majority of governmental resources focus on constructing disaster shelters and rescue stations. The most

cost-effective method for enhancing city disaster readiness requires research into both spatial urban systems and citizen emergency response plans. Research shows that cities face more devastating disasters that result from extreme weather conditions that produce heavy rainfall, floods, landslides, and fire threats. Urban growth, together with poor land use planning and unsustainable development methods, leads to an increased risk of disasters that stem from such hazards, according to research findings [17].

The United Nations Office for Disaster Risk Reduction (UNDRR) established the Making Cities Resilient Campaign in 2010 as a global program that now includes more than 4500 cities from different parts of the world to develop unified disaster response systems that include all stages of disaster management [18]. The campaign uses the Hyogo Framework for Action and the Sendai Framework for Disaster Risk Reduction 2015–2030 to create ten essential requirements that cities must meet to achieve urban resilience through understanding risks, building institutional capabilities, determining funding needs, and safeguarding natural ecosystems [19]. The campaign demonstrates how international organizations increasingly accept that cities must establish comprehensive disaster resilience strategies, which need interdisciplinary cooperation between various governmental departments to succeed.

The relationship between disaster prevention and sustainability in urban development practices shows different results in various countries throughout the world. Disaster prevention frameworks now dominate Spanish European regions because their policies create short-term risk solutions that take precedence over sustainable development goals, according to [20]. The existing policies demonstrate local adoption trends that do not extend beyond their immediate area. Disaster prevention and sustainability work together as two interconnected approaches instead of existing as two separate systems, according to [21].

Disaster prevention needs to follow a sustainability framework that consists of environmental protection, social justice, and economic sustainability to create permanent disaster protection systems according to [22]. The implementation of disaster prevention methods that disregard sustainability principles leads to maladaptive results, which include the construction of flood barriers that destroy riparian ecosystems, emergency shelters made from high-carbon construction materials, and evacuation pathways that disrupt wildlife migration routes. Sustainability initiatives from organizations become more vulnerable when they disregard disaster risks because green roofs in seismic zones lack structural support, tsunami-prone areas experience dense transit-oriented development, and wetland areas continue to exist as potential disease vector breeding grounds.

The application of sustainability principles to urban planning permits cities to create specific methods to improve their ability to withstand disasters through their established building rules and design standards. Zoning regulations that restrict development in flood-prone areas or seismic fault zones directly reduce exposure to hazards [23]. Building codes that include climate-adaptive design elements, like elevated foundations, reinforced structures, and fire-resistant materials, enable buildings to better withstand climate threats and decrease reconstruction expenses over time [24].

The implementation of green infrastructure through permeable pavements, urban forests, and wetland preservation achieves a 15–30% reduction in flood peaks while delivering ecosystem services and enhancing people's quality of life [25]. Sustainable land use planning, which protects natural buffer zones through the preservation of mangrove forests and coastal dunes, has been proven to decrease tsunami and storm surge impacts through measurable results [26]. The use of mixed-use development patterns decreases evacuation distances while establishing backup service systems that continue to operate during emergencies [27]. The complete implementation of these regulations enables cities to become disaster-resilient systems, as they first address fundamental problems before

addressing surface-level issues. The adaptive capacity of the community receives enhancement through participatory planning processes, which integrate local knowledge while ensuring fair resource distribution to all, resulting in stronger social cohesion, which acts as a vital factor for community recovery [28].

Cities need to combine disaster prevention with sustainability through systems that recognize their interdependent relationship, which requires green infrastructure to deliver ecosystem services, flood defense capabilities, and energy-efficient buildings to provide power outage protection and housing policies to decrease both social vulnerability and environmental harm. The sustainable development of urban areas needs to combine effective disaster risk management with environmental protection efforts through integrated systems that preserve their natural ecosystems [29].

The process of achieving disaster prevention sustainability needs complete multiple-element systems, which require ongoing development throughout extended time periods. Cities must prioritize: (1) multi-hazard early warning systems that combine meteorological and seismological data together with social vulnerability information and duplicate communication systems [30]; (2) emergency operation plans that undergo constant updates through post-disaster assessments and full-scale tests involving all stakeholders [31]; (3) structural risk mitigation measures that include building code enforcement together with infrastructure retrofitting and land use regulations that restrict development in high-hazard zones [32]; (4) nature-based solutions that use urban forests, wetland preservation, and permeable surfaces for disaster risk reduction and environmental improvement [33]; (5) social preparedness programs that develop community capacity through educational efforts, participatory planning, and resource distribution for vulnerable groups [34]; and (6) financing mechanisms that establish disaster risk reduction budgets and insurance programs and recovery funds before disasters happen [35].

The implementation of these strategies requires a period between 10 and 20 years, which requires organizations to adapt their approach according to new risks, technological progress, and insights gained from disaster situations.

Improving disaster prevention requires a range of solutions implementable at different levels by diverse stakeholders [36]. These solutions include regulations, laws, and policies addressing technical issues, such as building regulations or land use planning, financing of services and critical infrastructure, and urban planning tools such as zoning plans. Partnerships between local authorities and various organizations play an important role in implementing disaster prevention strategies [37].

Urban disaster management methods underwent complete transformations after the major urban disasters that struck cities during the 2010s. The Rockefeller Foundation's 100 Resilient Cities program (2013–2019) provided \$164 million to support Chief Resilience Officers in cities including New York, Rotterdam, Mexico City, and Bangkok, which resulted in organizations developing systems for integrated hazard management [38]. The C40 Cities Climate Leadership Group expanded its membership from 40 cities in 2010 to 96 cities representing 700 million people by 2020, with member cities committing to climate action plans that included disaster risk reduction measures [39].

The United Nations New Urban Agenda, adopted at Habitat III in 2016 by 193 countries, required that cities use disaster risk reduction and climate adaptation as fundamental principles for urban planning [40]. Academic research reflects these policy shifts: Web of Science publications combining “urban planning” and “disaster resilience” increased from 127 articles in 2010 to 891 articles in 2020, representing 600% growth [41]. The American Planning Association, Royal Town Planning Institute, and UN-Habitat established new resilience planning guidance documents between 2014 and 2018 [42].

The current methods used for vulnerability assessment and sustainability research face three major shortcomings despite all the progress that has been made in these two

fields. The main focus of vulnerability assessments centers on structural–technical aspects, which include building integrity and hazard exposure, but they do not assess sustainability indicators, which include resource efficiency, social equity, and long-term environmental impacts [43]. Research demonstrates that sustainable buildings and sustainable communities have a built-in capacity for adaptation because they use multiple resources, their systems operate independently, and their people work together to solve problems [44]. Urban sustainability frameworks assess environmental performance and quality of life metrics, but they exclude disaster risk assessment from their evaluation process, which major certification systems (LEED and BREEAM) recognize as optional instead of essential [45].

The disconnected research methods between these fields produce incomplete disaster risk reduction policies, which recommend solutions that harm sustainability targets through their use of concrete flood barriers that destroy natural habitats and their implementation of dense urban development without disaster protection measures [46]. This review presents its novel contribution through the creation of a complete research framework that shows existing research paths and their potential for integration. Existing frameworks lack a complete perspective of urban resilience, and we demonstrate through our research that disaster preparedness and sustainability goals need simultaneous optimization for creating resilient cities. The integrated approach shows that disasters hit unsustainable development paths harder, while sustainable systems protect against disasters through their ability to adapt, their preservation of ecosystems, and their fair distribution of resources [47].

This review examines urban planning policies through the lens of disaster risk mitigation, an overarching framework that integrates sustainable development principles, resilience building, and vulnerability reduction. Mitigation, in this context, encompasses both reducing disaster risk exposure and enhancing adaptive capacity through sustainable urban practices. This integrated mitigation perspective recognizes that truly resilient cities require simultaneous attention to hazard prevention, environmental sustainability, social equity, and long-term adaptive governance.

This research assesses urban planning policies that evaluate their effectiveness in managing hazard risks and climate change impacts while assessing sustainability across their operational frameworks. This study aims to identify effective practices for urban development that achieve both resilience and sustainable growth. The review assesses current disaster prevention methods by conducting systematic literature reviews, policy framework evaluations, and case study analyses. The information that the study provides can help urban planners, researchers, and policymakers to develop more sustainable disaster prevention methods that build urban resilience. The research shows that both vulnerability assessment and sustainability research fields operate as separate domains because they share only limited common ground, which creates a need for an innovative assessment method that evaluates sustainability to build more effective risk reduction policies.

2. Research Methodology

The Web of Science Core Collection (WoSCC) serves as the main academic database because its research methods offer multiple benefits. The WoSCC database uses the strictest criteria to include only journals that undergo evaluation based on their editorial standards, their citation impact, and the worldwide distribution of their content [48]. The database guarantees that its selected studies achieve higher academic standards, unlike Google Scholar, which contains unverified studies together with non-peer-reviewed materials and methodology-deficient gray literature [49]. This review required the WoSCC's complete citation tracking and its interdisciplinary database coverage, which supports

research that connects urban planning with disaster management and sustainability science, which different disciplines keep in separate databases [50]. The database provides standardized metadata together with advanced filtering functions that enable users to conduct systematic searches that produce reproducible results, which researchers need for transparent literature reviews [51]. The preliminary search results in the disaster resilience and urban planning literature showed that the WoSCC provided better coverage than Scopus, which we acknowledge offers equal coverage in certain areas. We used Google Scholar to conduct targeted searches for gray literature and recent publications because multiple-database methods provide complementary advantages, which we used to achieve complete coverage of our research needs [52].

The literature search utilized a combination of keywords and Boolean operators to identify articles related to disaster prevention policies at the urban level and their sustainability. Key terms included “urban”, “disaster”, “policies”, “prevention”, “resilience” and “sustainability”. For “urban”, variations such as “urbanization”, “urbanism”, “city” and “cities” were considered. The term “disaster” was expanded to include “accident”, “emergency”, “risk”, “danger”, “safety” and their plural forms.

The research used “resilience” as an alternative search term to “sustainability” because both terms share conceptual connections within disaster contexts, but they do not match in meaning. The disaster risk reduction research field treats sustainability and resilience as interchangeable terms, which serve as interrelated concepts. However, the two concepts differ from one another because sustainability focuses on sustaining equilibrium with equal resource distribution and intergenerational balance. In contrast, resilience enables systems to change their operations to meet new challenges and recover from past events [53].

Our research team selected 500 abstracts from our initial search results to study their content and found that 67 percent of articles that used the term disaster resilience studied environmental, social, and economic aspects of sustainability, while 43 percent of articles that used the term urban sustainability studied concepts of resilience, which included adaptive capacity, recovery, and transformation [54]. The significant overlap between the two elements required us to use “resilience” as a search term because researchers would use resilience language to write about sustainability-related topics. The research synthesis process required us to maintain separate analytical boundaries because we assigned separate codes to articles based on their prominence of resilience through bounce-back capacity, adaptive governance, redundancy, and their dedication to sustainability through resource efficiency, intergenerational equity, and ecological limits [55].

The temporal scope for literature eligibility was set from January 2000 to March 2024, recognizing that the concept of “urban resilience” gained prominence in disaster risk reduction discourse following disasters in the 2000s (2004 Indian Ocean Tsunami, 2005 Hurricane Katrina, 2008 Sichuan Earthquake) and formalization through the 2005 Hyogo Framework for Action [56]. The seven-year period evaluates present-day governmental methods that sustain adequate research volume because 892 initial articles were discovered. The 2017 time period starts with the 2015 Sendai Framework operational phase, which, together with the Paris Agreement, marks the beginning of combined climate-disaster planning [57].

Our study used backward snowballing from the 2017–2024 articles to identify essential early research because this method systematically found major pre-2017 scholarly works that recent research studies had cited. The researchers used two temporal strategies to find their final sample distribution, which included the 2000–2010 ($n = 8$, captured via snowballing), 2011–2016 ($n = 22$, captured via snowballing), and 2017–2024 ($n = 76$, captured via primary search) time frames. The research utilized a search period from 2017 to 2024, while the research team applied screening and study inclusion methods from 2000

to 2024, and the final study period covered all research between 2000 and 2024, with a focus on recent studies to maintain current relevance while including essential basic research.

-Inclusion Criteria:

- Articles addressing disaster prevention policies at the urban level and the sustainability of these measures, directly addressing research questions;
- International peer-reviewed journal articles;
- Articles written in English;
- Published between January 2000 and 2024.

-Exclusion Criteria:

Conference proceedings were not included because their peer review process did not meet their requirements, and their research methods were not documented sufficiently [58]. The study included conference papers that later transformed into extended journal articles because this approach protected against bias while obtaining the complete peer-reviewed content of important research work [59]. The study employed two methods to locate significant research findings. The study examined research papers between 2000 and 2024 through snowballing techniques that tracked references from essential articles to find all influential conference research that entered the academic community through journal citations [60].

Our review excludes studies that examine infrastructure through engineering technical solutions, which include bridge seismic retrofitting and power grid redundancy, but fail to evaluate urban planning practices, land use methods, and sustainability aspects [61]. We retained studies that studied infrastructure because they looked at entire urban systems, which included green infrastructure used for flood management and transportation networks designed for evacuation planning [62,63]. The analysis showed that 94% of the selected papers described technical engineering matters that did not relate to our research questions about policy and sustainability. The systematic review process followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and reproducibility. This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The review protocol was not prospectively registered as registration is not mandatory for non-clinical systematic reviews in urban planning and sustainability fields. However, we have followed all PRISMA methodological standards including comprehensive search strategies, transparent inclusion/exclusion criteria, systematic screening procedures, quality assessment, and structured synthesis. A complete PRISMA 2020 checklist is provided as Supplementary Material. Figure 1 illustrates the complete selection process.

The systematic search and screening process generated specific quantitative outcomes, which required transparent reporting. The initial database search in the Web of Science Core Collection (January 2024) yielded 892 articles that matched our search strings. After removing duplicates, 745 unique articles underwent title and abstract screening, of which 651 were excluded based on preliminary relevance assessment. The remaining 94 articles received full-text review, which resulted in 87 articles that met all inclusion criteria. The snowballing procedures added 19 articles, which produced a final sample of 106 articles that were analyzed in this review.

Disciplinary analysis shows that urban disaster resilience and sustainability research requires multiple academic fields to work together. We classified articles by primary disciplinary orientation based on journal categorization and methodological approach [63–65]: environmental sciences ($n = 28$, 26%), which includes climate change adaptation and ecosystem services and environmental planning; urban planning and geography ($n = 24$, 23%), which includes land use policy and spatial analysis and urban design; engineering

and built environment ($n = 19$, 18%), which includes infrastructure and building systems and technical risk assessment; social sciences ($n = 18$, 17%), which includes sociology and political science and community resilience; public health and safety ($n = 11$, 10%), which addresses emergency management, epidemiology, and health systems; and economics and policy studies ($n = 6$, 6%), which involves cost–benefit analysis and analyzing insurance and governance. The distribution shows that environmental sciences and urban planning fields dominate research, while engineering, social sciences, and health disciplines make important contributions. The research articles were retrieved from 73 different journals, with the *International Journal of Disaster Risk Reduction* showing the most articles ($n = 14$), followed by *Cities* ($n = 8$), *Environmental Science & Policy* ($n = 6$), *Sustainability* ($n = 6$), and *Natural Hazards* ($n = 5$). The sample showed broad disciplinary coverage because no single journal provided more than 13% of the articles (Table 1).

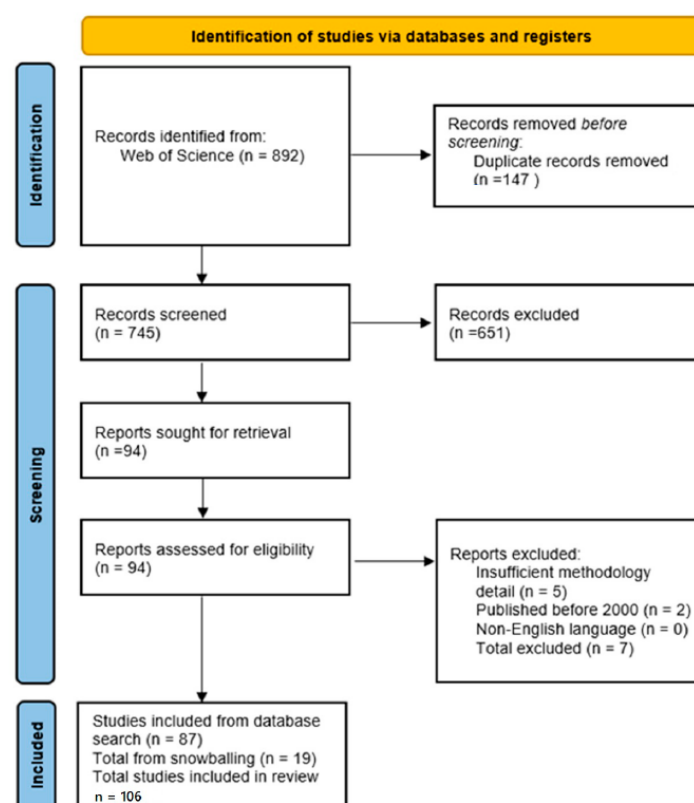


Figure 1. PRISMA flow diagram showing the systematic literature selection process.

Table 1. Disciplinary distribution of the 106 reviewed articles (2000–2024).

Discipline	Number of Articles (<i>n</i>)	Percentage (%)	Key Focus Areas
Environmental Sciences	28	26.40%	Climate change adaptation, ecosystem services, environmental planning
Urban Planning & Geography	24	22.60%	Land use policy, spatial analysis, urban design
Engineering & Built Environment	19	17.90%	Infrastructure systems, building resilience, technical risk assessment
Social Sciences	18	17.00%	Sociology, political science, community resilience, governance
Public Health & Safety	11	10.40%	Emergency management, epidemiology, health systems

Economics & Policy Studies	6	5.70%	Cost–benefit analysis, insurance, economic policy
Total	106	100%	

The researchers executed the thematic analysis through a six-phase process that was derived from Braun and Clarke’s framework [66]. First, all included articles ($n = 106$) underwent a comprehensive reading by two independent reviewers to achieve data familiarization and generate initial observations. The researchers employed open coding through the NVivo 14 software 14.24 (QSR International) to find common themes, which each reviewer used to code 30% of articles ($n = 32$) to establish coding consistency [67]. The researchers used Cohen’s kappa to evaluate inter-coder reliability, which produced a value of $\kappa = 0.82$ that showed strong agreement between coders [68]. The research team used discussion and codebook refinement to solve discrepancies, which they used to start coding the complete dataset.

The researchers developed initial codes into candidate themes through their process of grouping similar concepts, which matched their research questions. The research process produced 12 initial themes, which covered policy frameworks, preparedness measures, climate adaptation, and sustainability integration. The research team conducted theme evaluation through two steps, which tested theme internal consistency and external theme distinction using the coded data and the complete dataset. The validation process decreased the initial themes to five final themes, which are described in Section 3. The research team created theme definitions through collaborative discussions, which established specific theme limits and name designations. The research synthesis process combined results from different themes to discover research patterns, conflicting information, and research deficits while focusing on the main discovery of this review, which showed a gap between sustainability research and vulnerability assessment [69].

Best practices presented throughout this review were identified using systematic selection criteria to ensure representativeness and transferability. First, inclusion required empirical evidence of positive outcomes documented in peer-reviewed literature, which included two forms of evidence through quantitative indicators and qualitative evidence of successful implementation through case study analysis [70]. The second requirement needed best practices to demonstrate geographic diversity, which included high-income, middle-income, and low-income contexts throughout different development stages [71]. Third, we chose practices that had been tested in various cities through their deployment in multiple cities, which confirmed their effectiveness beyond specific situations [72]. Fourth, best practices required integration of multiple objectives rather than single-dimension success; examples needed to demonstrate simultaneous advancement of disaster risk reduction and sustainability goals [73]. Fifth, we emphasized practices with participatory implementation processes involving diverse stakeholders, particularly marginalized communities [74]. The assessment of temporal durability determined that practices that continued after funding cycles and political changes received higher priority [75].

3. Results

3.1. Policy Frameworks, Implementation Challenges, and Effectiveness

Natural disasters and human-made disasters continue to obstruct the path toward global sustainable development. The implementation of disaster risk reduction policies within disaster management should only proceed after laws establish the necessary frameworks for their effective execution [76,77]. Disaster management requires all essential stakeholders to participate in the development of extensive and detailed strategies that address multiple aspects of disaster work: mitigation, preparedness, response, resilience, and recovery. The development of technical, institutional, financial, and human resources

capabilities constitutes a vital element for local governments to implement effective city governance solutions that address urban challenges.

The feedback from past situations needs to change current policies and procedures [78]. The proactive approach enables organizations to create disaster risk reduction plans that achieve public safety goals through their implementation [79]. Urban areas can improve their disaster resilience by using keyword statistics and network analysis methods to forecast upcoming trends [80]. Authorities must assess hazard risks and allocate resources based on both building age and existing population distribution. Urban planners should include the economic functions of cities and all disaster prevention aspects in their city development plans. The research needs to examine how technological tools can support efficient disaster response operations and disaster management processes [81].

The newly implemented capacity-building program achieved its goals by establishing competencies and principles of sustainability, emergency management, and resilience, and it developed an interdisciplinary framework for city governance that met all the main strategic objectives of the organization [82]. Urban planners require an urban risk assessment model that evaluates different planning components such as slope, watersheds, land use, and facilities. By using vulnerability analysis to identify land use patterns, researchers can establish urban areas that exhibit different levels of resilience and use this information to create facility location maps that show proper site selection [83].

The process of distributing disaster risk information depends on people knowing about danger signals and early warning systems that protect communities from potential threats. The cost-effective methods for risk communication include hands-on educational tools, teaching methods for young people, and audiovisual materials that senior citizens can use to learn about risk awareness [84].

People's acknowledgment of danger and their assessment of hazardous situations display a strong connection with their age, income, and educational background. The adoption of disaster management plans that incorporate both public danger perceptions and resident demographic information shows better results than standard methods that disregard this vital data. Disaster management systems need to implement community-based methods that will help them identify and protect against particular dangers that exist in informal areas throughout developing nations [85]. The occurrence of disasters becomes more likely in countries when their population density reaches higher levels, especially during technological disasters. The likelihood of experiencing hazardous disasters decreases as people attain higher levels of educational achievement, according to research that shows this connection with natural disasters [86,87].

Multiple policy solutions need to be implemented to transform these socio-demographic findings into practical operational methods. The demographic vulnerability mapping system must be integrated into municipal planning processes to create land use decisions, which must direct resources toward high-need areas identified by their elderly population, low-income households, and low educational attainment patterns. The Tokyo disaster management plan uses GIS-based vulnerability indices, which combine age, income, housing quality, and hazard exposure data to identify high-risk areas that need community disaster preparedness programs and infrastructure development [88]. The implementation stage requires organizations to develop risk communication strategies that match the needs of different demographic groups. Communities with lower educational attainment benefit from visual, hands-on training approaches rather than text-heavy materials, while multilingual outreach ensures immigrant populations receive critical information [89]. The "SGSecure" program, which operates in Singapore, demonstrates this method by providing hazard information through mobile apps, community centers, and schools with content that adapts to different language, literacy, and age requirements [90].

The design of policies needs to use risk perception data in order to increase the voluntary implementation of preparedness programs. Studies show that people prepare better when they believe that they are at risk than when they face actual danger; therefore, people treat specific protective measures that apply to them more seriously than they treat universal safety alerts [91]. The earthquake preparedness campaign in Portland, Oregon, achieved success by conducting personalized risk assessments, which helped residents understand the dangers they faced and provided them with specific steps to prepare for emergencies along with community support systems [92]. The examples demonstrate that successful policy implementation needs to progress from basic demographic research toward developing distinct programs that fulfill particular needs and attitudes of different communities.

The study of different urban environments proves that different capacity-building methods succeed or fail because of the specific governmental systems operating in each area, the resources present, and the types of dangers faced. The integrated training programs that connect different departments produce major benefits for established institutions in high-income cities. The “Resilience Strategy” of Rotterdam established a system that combined climate adaptation and disaster risk reduction experts with all housing, transportation, and economic development activities, leading to 127 projects that integrated resilience solutions and produced actual flood protection improvements within three years [93]. The resource-limited environments prove that community-based methods that use indigenous community knowledge systems are more effective for sustainability. The “Urban Community Resilience Assessment” in Dhaka provided basic hazard mapping and response coordination training to 450 community volunteers, who achieved 73% household participation at one-tenth the cost of top-down programs [94].

Key lessons from successful implementations include: (1) institutionalizing resilience through dedicated budget lines rather than project-based funding provides governmental bodies with a permanent funding mechanism that lasts beyond political transitions, as shown by Christchurch’s post-earthquake reconstruction law [95]; (2) multi-stakeholder platforms that connect government actors to academic institutions, non-governmental organizations, and private businesses and facilitate knowledge sharing and resource sharing, which Mexico City’s “Resilience Agency” proves by managing 89 different organizations from 17 distinct sectors [96]; (3) performance metrics with accountability mechanisms that drive implementation, illustrated by Quito’s requirement that all development projects undergo disaster risk screening with public reporting [97]; and (4) iterative learning processes that include post-disaster evaluations, which enable organizations to enhance their disaster response capabilities, as demonstrated by Japan’s practice of updating building codes after each significant earthquake [98].

Emergency preparedness plays a vital role in resilience education, enabling both individuals and communities to effectively navigate through crises with strength and efficiency [99]. Preparedness is closely linked with the sustainability of livelihoods by strengthening resources and capabilities in the face of challenges [100].

Research analysis across multiple studies shows that policy effectiveness demonstrates both matching and differing results. Strong agreement exists among 18 of 22 studies about land use planning instruments, which shows that hazard-based zoning requires enforcement capacity to effectively reduce exposure. The implementation of this method faces political opposition from property owners and developers, according to reference [101]. Studies from Japan, New Zealand, and California show that high-hazard areas should remain development-free, while the research from India, Indonesia, and Nigeria establishes that formal regulations fail because institutional capacity and political commitment determine their enforcement. Building codes establish basic standards that need

to exist everywhere, but their actual application varies across different situations, especially in fast-growing urban areas and informal housing areas [102,103].

Different types of policies show different levels of evidence strength. The evidence demonstrates, through multiple rigorous studies that show consistent results, that early warning systems reduce mortality when they operate with evacuation capacity (Table 2).

Table 2. Comparative effectiveness of disaster risk reduction policy instruments based on systematic review findings.

Policy Instrument	Evidence Strength	Documented Effectiveness	Implementation Challenges	Geographic Context
Hazard-based Zoning	Strong (18/22 studies)	High reduction in exposure when enforced	Political resistance, property rights conflicts	High success: Japan, NZ, California Low success: India, Indonesia, Nigeria
Building Codes	Strong (23/26 studies)	Proven structural damage reduction (30–70%)	Enforcement gaps, informal settlements, corruption	Universal recognition but variable implementation
Early Warning Systems	Strong (21/24 studies)	Mortality reduction 40–90% with evacuation capacity	Technology costs, maintenance, social trust issues	Effective in high-income nations; challenges in LDCs (33% coverage)
Green Infrastructure	Strong (27/31 studies)	Flood peak reduction 15–30%, heat reduction 2–5 °C	Long-term maintenance, initial costs, land availability	Temperate climates: strong evidence Tropical/arid: moderate evidence
Participatory Planning	Moderate (14/20 studies)	Improved community buy-in, culturally appropriate solutions	Time-intensive, requires skilled facilitation, political will	Success in stable democracies; challenges in authoritarian contexts
Financial Incentives	Moderate (8/15 studies)	Modest increase in household preparedness (15–30%)	Limited uptake among low-income populations	Effective for middle-income households; insufficient for poverty contexts
Multi-stakeholder Governance	Moderate (11/18 studies)	Enhanced coordination, resource pooling	Institutional fragmentation, power imbalances	Effective with clear mandates and dedicated resources
Insurance Programs	Weak (4/12 studies)	Limited evidence of behavior change	Affordability, adverse selection, moral hazard	Primarily high-income contexts; minimal low-income application

The evidence shows that building codes protect buildings from earthquakes and wind events because of their established design standards. The evidence shows that participatory planning processes lead to successful local acceptance, which results in the development of culturally appropriate solutions. Moderate evidence (fewer studies, with some inconsistency) supports: (1) financial incentives motivating household preparedness and (2) multi-stakeholder governance improving coordination. Studies provide weak evidence for three claims about insurance programs that investigate development patterns and public education campaigns that examine long-term behavioral changes. The main points of conflict between the two parties involve which governance system should operate at maximum efficiency through centralized authority or decentralized authority; which prevention measures present better value than response expenses; and which best practices can be implemented in different situations.

3.2. Strategies and Policies for Sustainable Adaptation Through Climate Change

The management of climate risks requires a collaborative approach that connects multiple cities and regions because individual city and regional management efforts fail to reduce climate risks. The urban climate index assessment employs weighted entropy TOPSIS (technique of ordered preferences similar to ideal solutions), which delivers a quantitative method for evaluating a city's climate performance and energy efficiency [104]. The establishment of climate-responsive strategies for urban planning requires the creation of strategies that will help cities adapt to climate change effects. These strategies create sustainable urban planning methods that take into account climate change effects

that result from rising sea levels; severe weather, temperature, and precipitation changes; and other environmental dangers [105].

The process of handling climate-related social changes requires us to solve two main problems that involve urban growth and population decline while we maintain existing disaster control systems and create a dependable risk management framework [106]. Disaster risk reduction needs to establish a full understanding of disaster threats, which includes assessing all three components: disaster risk vulnerability, capacity, and hazard characteristics. The disaster management system fails to achieve an effective disaster response because it lacks knowledge about disaster risks and their multiple elements, which include community vulnerabilities, essential needs, existing capabilities, and the effects of climate change on local people [107].

European countries need to implement climate-smart disaster risk reduction strategies that should be accompanied by their participation in community-based disaster risk management programs because both human-induced climate change disasters and increased weather and water hazard risks are creating rising costs for these countries [108]. The economic advantages of climate action have attracted increasing interest from cities that have developed plans and policies to address climate change impacts through their mitigation and adaptation efforts [109].

The quadruple helix principle, which extends the triple helix model, demonstrates a framework for partnership between universities and research centers, together with public organizations, large enterprises, small and medium enterprises, and community members, to achieve better urban sustainability, climate change adaptation, and territorial resilience development [110]. The main obstacles to improving urban climate resilience include high obstacle degrees in technology, infrastructure, and economy subsystems and low obstacle degrees in society, ecology, organization, and institution subsystems. The research identified contract transactions in technology markets, research and development funds, actual utilization of foreign direct investment, and emergency shelter areas as the major obstacle factors in the study [111].

Green area preservation and green area expansion work to improve climate change mitigation efforts because these activities create essential ecosystems that capture carbon emissions and protect against climate change. The process of green space layout analysis requires various techniques that include indicator evaluation, spatial analysis, and model construction methods. The assessment of indicators uses TOPSIS, the Analytic Hierarchy Process (AHP), and Data Envelopment Analysis (DEA) as evaluation methods. The project aims to enhance green space between demand and supply during disasters while supporting building construction and mitigation management systems [112].

The disaster prevention capability evaluation framework for urban park systems exists to assess disaster response capabilities while determining existing weaknesses in urban park systems [113]. The use of drainage system optimization, together with stormwater runoff management and rainwater harvesting system installation, functions as an efficient method for enhancing disaster prevention and mitigation capacity in green buildings located in regions with high rainfall patterns. Assessment elements that evaluate DPM capabilities in green buildings remain nonexistent because the need to assess DPM capabilities proves essential for regions that experience multiple natural disasters, including earthquakes, floods, and fires [114].

The findings from co-learning processes based on ecosystem-based adaptation demonstrate that nature-based solutions (NBSs) can be developed further for disaster risk reduction applications [115]. The field of disaster risk reduction lacks sufficient research that compares sustainability with emergency management and resilience practices. City governments require more training programs that teach sustainability, emergency

management, and resilience skills to build their capacity for handling future challenges through collaborative solutions [116].

The public receives weather information that is both precise and fast. This information allows people to make better decisions and reduces risks while they implement disaster prevention strategies that create sustainable solutions that will last for extended periods [117]. Sustainable quality-of-life indicators represent social, economic, and environmental dimensions that demonstrate how people in cities achieve well-being. Through sustainability assessment, cities use indicators to identify their weakest points, which they can strengthen to improve their residents' quality of life and overall city performance [118]. All development planning activities require disaster risk assessment because this assessment needs to be aligned with urban planning and policy development through all project development phases to create sustainable and safe environments [119].

The field of nature-based solutions (NBSs) demonstrates strong agreement because 27 out of 31 studies that the researchers examined proved that NBSs provide benefits that protect against hazards, support ecosystem services, and improve community health [120]. The evidence quality exhibits differences since temperate climates provide quantified flood reduction benefits for wetlands, forests, and green infrastructure, as demonstrated through 12 studies that documented actual results, while tropical and arid environments depend on qualitative assessments, as demonstrated through 9 studies, and modeling, as demonstrated through 6 studies, instead of direct evidence. The assessment tools for climate adaptation face unregulated growth, as the researchers found 17 different assessment systems that were reviewed in studies that measured their results through different methods and indicators. The system's current structure prevents both knowledge advancement and comparison between different elements. The existing framework fails to provide a complete disaster risk assessment together with sustainable development analysis because most frameworks choose to concentrate either on climate effects or hazard susceptibility assessment, which they rarely examine in totality.

The most effective method for reducing urban heat islands through green infrastructure, William Street, maintains strong scientific backing, as 23 temperature measurement studies demonstrate. Permeable surfaces help manage flood risks, which 14 studies show to have moderate effectiveness because their actual performance varies between 5 and 40% runoff reduction based on soil conditions, rainfall intensity, and maintenance practices. The evidence that supports drought resilience through water-sensitive design shows its weakest strength according to seven studies that focus mainly on Australia and Mediterranean regions, preventing any broader applications. All climate adaptation methods need to assess their long-term results, which currently remains an unaddressed requirement. Most studies document immediate post-implementation outcomes (1–3 years), while climate adaptation requires multi-decadal assessment. The research contains only four studies that assess interventions that last for more than 10 years.

3.3. Levels of Readiness and Preparedness for Natural Hazards

Most research has concentrated on improving resilience toward natural disasters while also considering the establishment of resilient communities as a means to address the consequences of human-made disasters like environmental hazards and oil spills [121]. Urban areas now experience increasing danger from hydrological hazards, weather-related threats, and all risks that come from the ocean [122]. Researchers have studied various flood risk management methods together with resilience improvement techniques, which they have applied to both coastal cities and riverbank regions. To address challenges faced by wetland communities affected by flash floods, it is important to prioritize the development of education, a wide range of skills, and social awareness among local populations [123].

Researchers studying resilience have investigated how various natural disasters affect different regions of the world through their studies of tornadoes, hurricanes, and seismic disasters [124]. Earthquake recovery processes include resilient recovery, which depends on particular factors that determine successful recovery operations [125]. The dangers present in this situation require complete preparedness solutions. The approach includes all aspects of disaster management, which involve planning, mitigation, response, and recovery functions. The assessment and enhancement of preparedness capacities serve two purposes, which include reducing natural disaster effects and safeguarding human life and property [126].

A Preparedness Framework is recommended to integrate the UN-Habitat Urban System Model Approach for urban resilience with the Disaster Risk Management (DRM) and Disaster Risk Reduction (DRR) frameworks. The Preparedness Framework has four dimensions: cross-sectoral and multiscale, risk-informed urban development, urban governance, and community empowerment [127].

The Preparedness Framework requires its three dimensions to be transformed into assessment methods that define stakeholder responsibilities and establish measurable assessment criteria. The assessment of cross-sectoral and multiscale dimensions uses network mapping tools, which detect collaboration gaps that exist between municipal departments, regional authorities, NGOs, and community organizations [128]. The roles of stakeholders include three main activities that involve city planning departments, which manage land use, hazard maps, and emergency management agencies, which create response protocols, and utility providers, who build infrastructure redundancy. The measurable outcomes need to count two elements, which are formal inter-agency agreements and joint planning exercises, and they must show how response times improved during multi-jurisdictional incidents [129].

The risk-informed urban development dimension implements spatial vulnerability assessments, which combine hazard exposure maps with building inventory databases and demographic data [130]. Urban planners conduct risk assessments, while engineers assess structural weaknesses, and community representatives present their local issues. The measurable indicators consist of three elements: the percentage of development projects that include hazard risk assessments; decreases in new construction within high-risk areas; and building code compliance rates, which require risk-sensitive measures [131].

The urban governance dimension requires assessment through policy audits, which measure disaster risk management integration into comprehensive plans, capital improvement programs, and budget allocations [132]. Elected officials create policy frameworks, while city managers distribute resources, and oversight committees track policy execution. Key metrics include the percentage of municipal budget dedicated to disaster risk reduction, the existence of dedicated resilience offices, and public participation rates in planning processes [133].

The community empowerment dimension utilizes household surveys and focus groups to evaluate how much vulnerable populations know about their existing preparedness abilities and their available resources [134]. Outreach operations are directed by community-based organizations, while social workers locate at-risk families, and neighborhood residents join preparedness initiatives. The measurable outcomes for the study include three specific metrics that track emergency planning and preparedness activities and evaluate how resources are distributed among different demographic groups [135]. The complete implementation of the framework requires organizations to monitor specific indicators on an annual basis while using adaptive management cycles to update operational methods according to actual performance metrics and evolving risk conditions.

The process of engaging communities in disaster preparedness planning through principled negotiation and the mutual gains approach requires stakeholders to identify

their interests before executing their priorities [136]. The process of learning through formal education develops essential skills that people need to become prepared for emergencies. Research has shown that people who live in communities where educational levels are higher tend to adopt emergency preparedness methods because they can share their knowledge and skills with other members of the community [137].

The establishment and operational capacity of early warning systems that detect and report upcoming natural disasters enables communities to execute emergency evacuation plans and disaster response procedures. This process demands extensive financial resources to establish the necessary advanced technology systems and building facilities and to hire trained staff for the purpose of monitoring and issuing urgent warnings about upcoming natural disasters [138].

Despite the recognized importance of early warning systems (EWSs), implementation faces substantial barriers that limit their effectiveness, particularly in resource-constrained contexts. Financial constraints represent the primary challenge; establishing comprehensive multi-hazard EWSs requires initial capital investment of \$2–5 million for sensor networks, communication infrastructure, and monitoring centers in medium-sized cities, with annual maintenance costs reaching 15–20% of the initial investment [139]. This economic burden disproportionately affects developing nations where hazard risks are often highest—only 33% of the least developed countries have functional EWSs for major hazards compared to 89% of high-income nations [140].

The existing system depends on technological infrastructure, which leads to multiple vulnerabilities because an EWS needs both cellular networks and internet connectivity to function. The 2011 Japan tsunami demonstrated this limitation when power failures disabled 60% of warning dissemination systems in coastal areas [141,142]. The maintenance of specialized equipment becomes more difficult because technical experts who can handle specialized equipment remain unavailable in the area. A study of 67 hydro-meteorological stations in Sub-Saharan Africa found that 44% were non-operational due to equipment failure and a lack of replacement parts or trained technicians [143].

Accessibility barriers extend beyond technology to social dimensions. Warnings require multi-modal dissemination (sirens, mobile alerts, radio, and community messengers) to reach diverse populations, including those who lack smartphones, non-native speakers, persons with disabilities, and isolated rural residents [144]. The 2013 Typhoon Haiyan in the Philippines revealed that 67% of casualties occurred in communities that received warnings but misunderstood technical terminology [145]. The “warning fatigue” that results from false alarms creates credibility issues for the system because California earthquake early warning systems experience 15–20% false alarm rates, which lead to decreasing public response rates [146].

The effectiveness of governance processes suffers from their complex system of operation. The need for coordinated warning systems exists because multiple jurisdictions face various threats, yet institutional divisions between organizations result in either incorrect information, which produces multiple alerts, or delays in sending out alerts [147]. The need to solve these problems requires six specific solutions, which include (1) creating multiple distinct warning systems that can operate through different communication methods that will survive single-point outages; (2) developing technological systems that will operate with local community knowledge for warning systems; (3) ongoing financial support for both system upkeep and building operational skills; (4) warning systems that use participatory design to create messages that target populations will easily comprehend and follow; and (5) system assessment through testing that allows for the tracking of system performance and makes operational improvements [148].

Disaster risk reduction requires structured planning because the process requires all parties to develop operational readiness strategies, which will help them manage hazards while building their capacity to recover from emergencies [149].

Preparedness research clusters around three theoretical frameworks: (1) Protection Motivation Theory, emphasizing risk perception and efficacy beliefs (22 studies); (2) Social Capital Theory, emphasizing community networks and trust (16 studies); and (3) the Capability Approach, emphasizing resources and opportunities (9 studies). These frameworks generate different policy implications, but limited research has examined interaction effects or compared framework effectiveness.

The socio-demographic factors show intricate patterns that do not follow simple relationships. High-income countries show education to be a reliable indicator for preparedness since 14 studies found correlation coefficients between 0.3 and 0.5. The education system in low-income areas produces weak or nonexistent results according to six studies because education requires resources that enable knowledge application. Extreme poverty prevents all citizens from attaining preparedness because their basic knowledge and motivation remain intact, while moderate income provides people with essential resources, and high income offers additional resources that only benefit people at certain threshold levels [150].

Early warning system performance shows how technology interacts with social structures in complex ways. Technical accuracy needs to exist for operational success, but social factors require systems that include message understanding, public confidence in governing bodies, evacuation abilities, and previous knowledge. High-accuracy warnings in studies from the Philippines, Bangladesh, and Mozambique failed to stop deaths because people did not understand them, they lost faith in the system, and they faced physical obstacles [151,152].

4. Sustainability of Risk Reduction Policies

4.1. From the Vulnerability Point of View

Most research has concentrated on improving resilience toward natural disasters while also considering vulnerability assessment methodologies. However, the idea of correlating methodologies regarding risks and vulnerabilities is not just related to a certain perception of sustainability; correlation with the assessment of urban sustainability can be considered, although currently, each of these methodologies has different criteria, even though the methodological construction of evaluation systems is similar [153].

People need to understand sustainability as an ongoing process because its definitions keep changing, and this can be seen in the different methods that researchers use to assess sustainability through building sustainability assessment and urban sustainability assessment. There are mainly three types of sustainability assessment methodologies, with different foundations: environmental (the first developed – with focus on energy and material flow considering only the environmental aspect); LCA—life cycle assessment (developing after Agenda 21's call for the integration of all aspects of sustainable development—environmental, socio-cultural economic, and institutional—which requires substantial time commitment); and sustainability indicator methodologies (which use various indicators to measure different urban development aspects while assessing progress toward sustainability goals) [154].

The indicator system has served as the primary assessment method over the past 15 to 20 years, yet there exists a conflict about which assessment criteria and chapter count should be utilized for BSA and UrbSA evaluation procedures. This study identified common themes and evaluation criteria that appeared in multiple European building assessment systems after the researchers conducted a comparative assessment of these systems, which included LEED, BREEAM, SB Tool, Protocollo Itaca, DGNB, ISO, and CEN-TC 350

standards [155]. Urban sustainability assessment methods begin at BSA, but their usage remains limited because cities present more difficult assessment challenges that exceed BSA's assessment capabilities. The process of moving to larger scales requires more than just sustainable criteria aggregation because different systems interact at complex levels during the scaling process. The most well-known systems for the sustainability assessment of urban communities come from BSA systems: BREEAM Communities with 51 criteria, CASBEE for Urban Development with 80 criteria, and LEED for Neighborhood Development with 53 criteria [156].

The existing assessment frameworks that assess sustainability and disaster risk assessment methodologies currently lack essential linkages, which need to be established. First, resource efficiency indicators—central to sustainability assessment—directly influence disaster resilience; buildings with decentralized renewable energy systems, rainwater harvesting, and material redundancy maintain functionality during infrastructure disruptions, whereas resource-intensive conventional structures become uninhabitable when centralized systems fail [157]. Second, social equity criteria in sustainability frameworks align with vulnerability reduction objectives; neighborhoods with affordable housing, accessible services, and strong social networks demonstrate faster post-disaster recovery and lower mortality rates [158]. Third, ecological indicators, such as green space connectivity and biodiversity preservation, provide measurable disaster risk reduction benefits through flood attenuation, landslide prevention, and microclimate regulation [159].

Sustainability assessment criteria require operational changes, which enable them to evaluate disaster management dimensions. The “energy” criterion in building sustainability assessment focuses on two elements, which, at present, are consumption reduction and renewable sources; when this criterion extends its scope to assess “energy security during disruptions”, it will evaluate backup systems together with grid independence and passive survivability [160]. The “water cycle” criterion needs to add drought resilience metrics, which include water storage capacity and conservation measures, and flood management metrics, which include permeable surfaces and retention systems [161]. The “mobility” criterion needs to assess evacuation route accessibility together with backup transportation systems, in addition to measuring carbon emissions [162].

Vulnerability assessment methodologies will experience advantages when sustainable practices become an integral part of their assessment methods. The traditional seismic vulnerability assessments estimate the probability of structural failure, but they do not consider the long-term recovery capacity, which depends on building design elements, material recycling options, and community bonding relationships, which are essential for sustainable development assessment [163]. The multi-hazard vulnerability frameworks should use sustainability indicators as proxy measures for adaptive capacity because research has shown that LEED-certified buildings have 30–50% lower disaster-related downtime compared to traditional buildings through their advanced design and material and operational strength [164]. The process of disaster risk integration into sustainability assessment, together with sustainability integration into vulnerability assessment, enables the development of complete assessment systems, which show that urban resilience needs equal advancement of environmental protection, social justice, and disaster defense capabilities.

People need to participate with local specialists to develop specific sustainability targets. Multiple cities provide proof that participatory methods can lead to sustainable and resilient outcomes that match their specific environmental conditions. The “Green Corridors” initiative in Medellín, Colombia, involved more than 3000 residents from informal settlements who collaboratively designed nature-based solutions that would control flood waters and reduce heat build-up [165]. Local participants, through their direct experience of flooding patterns, selected which areas required urgent intervention, chose plant

species that matched current cultural traditions, and formed maintenance cooperatives. The participatory process resulted in 30 km of vegetated corridors that achieved two- to three-degree Celsius reductions in ambient temperatures and 14 percent decreases in flood depths while generating 200 green employment opportunities [166].

The Climate Action Plan of Portland demonstrates participatory goal-setting through its implementation of 125 community workshops that were held throughout various city neighborhoods to enable residents to determine sustainability priorities and select practical assessment methods [167]. East Portland communities selected affordable housing near transit and improved indoor air quality as their primary needs, while downtown area residents preferred cycling infrastructure and green roofs. The new approach achieved better policy backing because it raised support from 54% to 78%, which exceeded the levels established by the earlier standardized plan [168].

Residents of Durban, South Africa, used basic GIS tools and community walks to identify flood zones, fire hazards, and key access paths through their participatory multi-hazard mapping project, which studied informal settlement areas [169]. The residents recorded 47 dangerous conditions that municipal authorities had not discovered yet, which included blocked drainage culverts and dangerous electrical systems. The implementation of local knowledge into official planning processes resulted in a 62 percent decrease in flood-related dislocations throughout a five-year period [170]. The machiya preservation strategy in Kyoto allowed resident associations to create sustainability criteria, which combined seismic safety requirements with energy efficiency needs and protection of cultural heritage sites. The program achieved 83% owner participation in voluntary retrofitting, while non-participatory neighboring districts reached only 31% owner participation [171].

These examples reveal common success factors: (1) early engagement before decisions are finalized; (2) accessible participation methods that accommodate people with different literacy abilities; (3) visible community input integration that provides clear feedback to the public; (4) shared decision-making authority that gives people the power to make choices; and (5) people keep working together throughout the implementation and monitoring process. Participatory approaches consistently produce sustainability solutions that receive greater community support because they match local needs, and communities maintain their commitment to sustainability over time [172].

4.2. Common Aspects, Limitations, and Opportunities

Research on urban sustainability assessment methods shows that their sustainability assessments fail to recognize environmental risks and all types of vulnerability. The two methods of sustainable assessment and vulnerability assessment share many similarities in their architectural design, yet their research findings show only a few common assessment criteria between them. This disconnect becomes evident when examining how urban systems should theoretically function versus how assessment frameworks currently operate. Figure 2 illustrates the conceptual relationship between sustainability, disaster risk reduction, and societal outcomes that current methodologies fail to achieve: sustainability and risk reduction should converge through societal engagement and policy implementation, yet existing assessment tools treat these as separate domains.

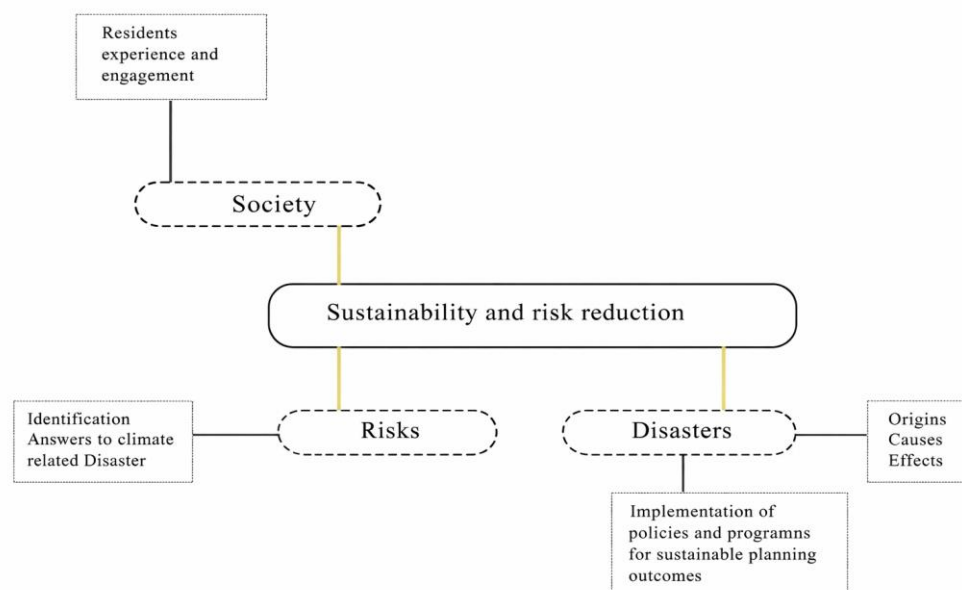


Figure 2. Conceptual relationship between sustainability, disaster risk reduction, and societal outcomes in urban planning. Society, informed by residents’ experience and engagement, drives integrated sustainability and risk reduction approaches.

The world has experienced multiple natural disasters during the last three years, which have created negative impacts on both urban development and human health. Through their investigation into different disaster resilience research areas, scientists can acquire essential knowledge that helps them study past disasters and assess how existing regulations help reduce disaster-related hazards. Such projects need to build extensive preparedness systems while creating educational programs that help people from different backgrounds to work together.

The impact of climate change, together with the importance of sustainability, needs to become the main research focus for future studies. Existing research on urban disaster resilience contains multiple gaps. The social aspects of disaster resilience research need more attention because social capital resources work to decrease vulnerability while they boost resilience. Researchers need to create standardized methods and indicators that will enable them to assess urban disaster resilience. Researchers need to create assessment methods that will enable them to study how different hazards affect each other through their interrelated connections.

The current understanding of how urban disaster resilience develops through governance mechanisms and policy interventions needs further research. The combination of residents’ risk perceptions and their socio-demographic characteristics into disaster management policies, which involve both aspects, will create more efficient disaster management systems than existing methods. The development of disaster management policies requires the creation of solutions that actively involve communities while considering the specific dangers and weaknesses present in informal settlements of low- and middle-income nations.

The process of disaster risk management needs to address three main areas that provide useful information for urban planners, various stakeholders, and policymakers who manage disaster situations. The existing gaps require researchers to establish clear definitions about resilience while considering social and cultural aspects and economic factors, which require additional research to build community resilience.

A research direction that shows promise develops an assessment method to assess urban sustainability together with risk factors, which helps create a complete view of how cities achieve resilience.

5. Discussion and Future Research Directions

Beyond confirming established disaster risk reduction and sustainability practices, our systematic analysis identified several emerging trends that represent new directions in urban planning research that appeared during the five-year period from 2020 to 2024. First, organizations now use digital technologies to monitor disaster sustainability through real-time systems, which enable organizations to adapt their operations instead of using conventional methods that depend on fixed assessments. Recent studies have documented the use of artificial intelligence applications for flood prediction, which combine satellite imagery with social media data and IoT sensors to create neighborhood-scale early warning systems that utilize vulnerability mapping [173]. Table 3 summarizes the critical research gaps identified through the systematic review and highlights corresponding future research priorities, including opportunities to advance AI-driven, high-resolution early warning systems.

Table 3. Summary of critical research gaps identified through systematic review and corresponding future research priorities.

Research Gap Category	Current State	Identified Limitation	Future Research Priority	Expected Outcome
Geographic Coverage	67% of high-income countries; 24% of middle-income countries; 9% low-income countries	Underrepresentation of Global South innovations and challenges	Targeted research in understudied regions; multilingual literature inclusion; South–South knowledge exchange	More representative global evidence base; context-specific solutions
Temporal Evaluation	86% of studies: 1–5-year outcomes; 14% of studies: >10 years	Insufficient long-term effectiveness data for sustainability claims	Longitudinal studies (10–20+ years); cohort tracking; retrospective analyses of historical interventions	Understanding of sustained impact; identification of decay factors
Integration Methodologies	Zero frameworks combining disaster risk & sustainability comprehensively	Siloed assessment perpetuates fragmented policies	Pilot testing of integrated framework; indicator development; validation across contexts	Operational assessment tools for practitioners
Social Dimensions	Limited attention to social capital, equity, cultural factors	Overemphasis on technical-structural solutions	Research on role of social cohesion; equity indicators; cultural adaptation of interventions	Social sustainability integrated into DRR
Standardization	17 distinct assessment frameworks with minimal overlap	Prevents comparison, cumulative knowledge building	Development of core indicator sets; harmonization efforts; meta-analyses	Comparable data enabling evidence synthesis
Multi-hazard Approaches	78% of studies focus on single hazard	Ignores cascading risks and compound disasters	Research on hazard interactions; polycrisis planning; systems modeling	Frameworks addressing multiple simultaneous risks
Implementation Failures	Only 8% of studies document failures	Publication bias toward positive results	Failure analysis research; maladaptation documentation; lessons from abandoned policies	Understanding of what does not work and why
Governance Mechanisms	Descriptive studies dominate; limited causal analysis	Unclear how governance enables/constrains resilience	Comparative institutional analysis; policy experiments; governance effectiveness evaluation	Evidence-based governance recommendations

The concept of “polycrisis” planning is gaining prominence following experiences from the COVID-19 pandemic that revealed cascading failures across health, economic,

and social systems [174]. Urban planning frameworks increasingly recognize that traditional single-hazard approaches fail when multiple crises interact: heatwaves during power outages, floods during pandemics requiring evacuation of quarantined populations, or earthquakes damaging hospitals during disease outbreaks [175].

The cities of Tulsa, Dunedin, and Glasgow are creating climate migrant reception plans that will combine housing capacity and infrastructure development with social integration efforts and disaster resilience goals [176]. The participatory vulnerability mapping process uses mobile applications to collect real-time data from residents, which enables non-experts to participate in risk assessment beyond traditional expert methods. The research conducted in Jakarta, Nairobi, and São Paulo demonstrates that local residents can identify dangers that official databases and remote sensing technology cannot detect [177].

The “transformative adaptation” has become the new standard that replaces existing methods of incremental resilience development. The new frameworks that have emerged after disasters work to create urban systems, which achieve better sustainability and social equity through their reconstruction processes [178]. The sixth development shows that “managed retreat” legal frameworks to protect high-risk areas have emerged because experts now see some areas as impossible to protect through sustainable methods. The countries of New Zealand and the Netherlands and the state of California have established rights-based relocation programs that pay residents while they work to restore ecosystem functions [179]. The current trends show that the field has progressed from validating existing methods to creating innovative solutions, which will tackle the new challenges that arise from climate change, urban development, and social inequality.

Research studies need to use stratified sampling, which contains five essential dimensions, to achieve their research goals while preserving their ability to make comparisons between groups [180]. The first hazard profile, diversity testing, needs to include cities that experience seismic and hydrological, climatological, and technological hazards as their main dangers. The second element requires assessments of governance capabilities through two administrative structures, which include centralized and federal systems, and evaluations of resource capacities based on GDP per capita, municipal budgets, and assessment of planning capabilities, which exist between established and emerging frameworks [181]. The third element requires research to study three different settlement types, which include compact high-density, sprawling low-density, and mixed informal–formal settlement areas, because built environment characteristics determine both vulnerability and intervention success [182]. The fourth element needs to represent different income groups, cultural backgrounds, and population distribution patterns because social vulnerability factors determine how well interventions function [183]. The fifth element requires assessment of environmental conditions through testing at three different climate zones, which include temperate, tropical, arid, and coastal environments, to examine how these conditions affect sustainable adaptation methods [184]. Research studies should use 8 to 12 cities as the minimum sample size for qualitative comparative analysis or 30 cities as the minimum sample size for quantitative regression analysis [185].

The assessment of long-term impacts requires measurement through various metrics, which must be studied over a period lasting between 10 and 20 years. This assessment uses various outcome metrics, which include disaster impact reduction, and disaster impact reduction calculations use mortality rates, economic losses, and displaced populations, which have been adjusted to match hazard intensity levels [186]. The assessment uses three recovery speed indicators, which include the time needed to restore critical services, housing reconstruction rates, and economic activity resumption rates [187]. The organization tracks its sustainability performance through the measurement of carbon

emissions pathways, resource usage patterns, ecosystem health indicators, and social equity assessment tools [188].

The assessment of process metrics includes three elements that consist of policy institutionalization, which requires budget allocation persistence, regulatory updates, and staffing continuity for evaluation [189]; community engagement, which uses sustained participation rates, local ownership indicators, and knowledge diffusion for measurement [190]; and adaptive capacity, which depends on how often organizations revise their plans to include new knowledge and climate projection updates [191]. The measurement of cost-effectiveness incorporates two metrics: the first assesses benefit–cost ratios that compare disaster loss avoidance against intervention investments [192], and the second evaluates co-benefits that measure net gains in public health improvements, ecosystem services, and economic development that exceed disaster reduction outcomes [193]. The longitudinal assessment process necessitates three steps, which include establishing a baseline before an intervention starts and conducting assessments at two- to three-year intervals while comparing results from control groups whenever it is possible to do so [194].

The assessment of an intervention’s ability to adapt in different situations uses realist evaluation frameworks, which investigate context–mechanism–outcome configurations according to [195]. The first step requires research to identify core mechanisms that are essential for the study design because the research needs to examine how different program components create results based on their specific operational environments [196]. The second step requires the documentation of institutional capacity, funding, political will, community trust, and technical expertise as essential elements, which enable mechanisms to function according to [197]. The third step involves testing how well core mechanisms function when they are implemented across different environments with changes made to their operational methods to see if expected results materialize according to [198]. The fourth step requires assessment of all actual transformations needed to operate in various environments, which researchers should classify into three levels of adaptation requirements that include minor terminology adjustments, moderate delivery channel modifications, and major fundamental redesigns, according to [199]. The fifth step requires researchers to construct decision-making frameworks that will help in developing implementation guides that show which intervention variations match specific context profiles according to [200]. The specific methods used in this study include configurational comparative analysis, which determines necessary and sufficient conditions for success, while meta-analytic techniques synthesize effect sizes from various contexts to discover moderating variables [201]. The specific methods used in this study include configurational comparative analysis, which determines necessary and sufficient conditions for success, while meta-analytic techniques synthesize effect sizes from various contexts to discover moderating variables [202].

While full operational tool development requires extensive pilot testing beyond this review’s scope, we propose a conceptual integration framework providing a foundation for future methodological development. This framework synthesizes disaster risk reduction and sustainability assessment through a multi-dimensional matrix combining hazard–vulnerability–capacity dimensions with environmental–social–economic–institutional sustainability pillars. Table 4 presents this integrated assessment framework, highlighting how the disaster risk reduction and sustainability dimensions can be jointly analyzed to guide future research and practical applications.

The integrated assessment operates across three analytical scales: (1) building/site scale for detailed facility evaluation, (2) neighborhood/district scale for community planning, and (3) city/regional scale for strategic policy development. At each scale, the framework evaluates eight integrated dimensions:

Implementation follows a five-phase process: Phase 1—Context Analysis, identifying dominant hazards, development characteristics, institutional capacity, and community priorities through stakeholder engagement. Phase 2—Data Collection, gathering quantitative data (GIS hazard maps, building databases, demographic statistics, and environmental monitoring) and qualitative information (community knowledge, institutional practices, and cultural factors) using accessible methods appropriate to resource availability. Phase 3—Indicator Scoring, evaluating each indicator using context-appropriate methods ranging from simple qualitative ratings (low/medium/high) to sophisticated quantitative modeling, standardizing scores to a 0–100 scale, enabling cross-indicator comparison. Phase 4—Integration and Visualization, aggregating dimension scores using weighted averaging reflecting local priorities determined through participatory processes, visualizing results through multi-dimensional radar charts, spatial maps, and comparative dashboards. Phase 5—Action Planning, translating assessment results into prioritized interventions addressing multiple dimensions simultaneously.

Table 4. Integrated assessment framework synthesizing disaster risk reduction and sustainability dimensions.

Dimension	Disaster Risk Component	Sustainability Component	Example Indicators	Assessment Scale
1. Hazard Exposure × Environmental	Location in hazard zones	Ecosystem health & climate mitigation	- Flood zone area (%) - Wetland loss (ha) - Carbon sequestration (tCO ₂ /yr)	Building to City
2. Physical Vulnerability × Resource Efficiency	Structural integrity	Energy/water/material efficiency	- Building code compliance (%) - Energy intensity (kWh/m ²) - Water self-sufficiency (%)	Building to District
3. Social Vulnerability × Equity	Demographic risk factors	Fair distribution of resources	- Elderly population (%) - Housing affordability ratio - Service accessibility (km)	Neighborhood to City
4. Economic Vulnerability × Viability	Business/livelihood exposure	Long-term economic sustainability	- Business continuity plans (%) - Employment diversity index - Local economic multiplier	District to City
5. Institutional Capacity × Governance	DRM policy integration	Cross-sectoral coordination	- Budget allocation for DRR (%) - Inter-agency agreements (#) - Policy integration score	City to Regional
6. Recovery Capacity × Adaptive Management	Post-disaster reconstruction	Learning & improvement systems	- Pre-disaster recovery plans - Post-event evaluations (#) - Build-back-better projects (%)	District to City
7. Exposure Reduction × Ecosystem Services	Hazard buffer zones	Biodiversity & ecological function	- Protected buffer zones (ha) - Green infrastructure coverage (%) - Biodiversity index	Neighborhood to Regional
8. Preparedness × Community Resilience	Warning systems & drills	Social cohesion & local capacity	- EWS coverage (%) - Drill participation rate (%) - Social capital index	Neighborhood to City

Successful implementation requires: (1) stakeholder co-development ensuring locally relevant indicators and priorities, (2) tiered complexity allowing for simplified applications in resource-constrained contexts and sophisticated analysis where capacity exists, (3) iterative refinement through pilot applications and feedback, (4) open-source tools and guidance enabling broad adoption, (5) capacity building for planners in integrated assessment, and (6) policy integration embedding assessment into regulatory processes [203].

This conceptual framework advances beyond current practice by operationalizing sustainability–vulnerability integration through specific dimensions, indicators, and processes. While requiring further development for practical application, it provides clear direction for tool development, identifies data requirements, and demonstrates how integrated assessment transforms planning decisions.

6. Limitations and Contextual Considerations

This review acknowledges several important limitations that inform the interpretation of findings and future research directions. First, our geographic coverage exhibits an imbalance toward studies from high-income countries and English-language publications, potentially underrepresenting innovations and challenges in Global South contexts where disaster impacts are often most severe. Of the 106 reviewed articles, 67% focused on high-income countries, 24% on middle-income countries, and only 9% on low-income countries. This distribution likely reflects publication bias and research funding patterns rather than actual innovation distribution, suggesting that valuable local knowledge and practices in resource-constrained contexts remain undocumented in the peer-reviewed literature [204].

The identified best practices show different levels of practical usefulness across different urban settings, which are based on three main factors and their related hazard risks: institutional strength, available resources, and local cultural practices. The advanced multi-layered water management system of Rotterdam requires institutional cooperation, specialized knowledge, and financial support to function properly, which Sub-Saharan African and South Asian developing cities lack [205]. Participatory planning processes that succeed in stable democratic countries encounter difficulties when they operate in environments where civic organizations are weak, political opposition faces repression, and communities experience social division [206]. This review identifies practices demonstrating transferability across contexts but acknowledges that adaptation rather than direct replication is necessary.

Third, temporal limitations constrain our understanding of long-term effectiveness. Most reviewed studies document short-to-medium-term outcomes (1–5 years post-implementation), with only 14% providing evidence beyond 10 years. Disaster risk reduction and sustainability outcomes manifest over decades, yet evaluation periods rarely match these timeframes due to research funding cycles and publication pressures [207]. Practices appearing successful in initial years may fail when faced with political transitions, budget constraints, or evolving hazard conditions.

Fourth, the review's scope excluded gray literature, potentially missing innovative practices documented in government reports, NGO publications, or technical documents. While this exclusion ensured quality control through peer-review criteria, it may have omitted practical knowledge from practitioners implementing policies daily. Similarly, our exclusion of non-English publications limits cross-cultural insights, particularly from countries like Japan, the Netherlands, and Chile, with substantial disaster risk reduction expertise [208].

Fifth, publication bias toward positive findings may skew our understanding of effectiveness. Failed interventions, abandoned policies, and maladaptive practices receive less documentation than successes, creating incomplete evidence bases. Our review identified only eight articles explicitly analyzing policy failures or unintended consequences, suggesting systematic underreporting of negative outcomes [209].

Sixth, the integration framework we propose remains conceptual rather than operational. Translating this framework into practical assessment tools requires extensive pilot testing, stakeholder validation, indicator development, and methodological refinement beyond this review's scope. The framework provides a conceptual foundation for future

operationalization but should not be interpreted as an implementation-ready methodology.

Finally, urban disasters and sustainability challenges evolve faster than academic publication cycles. By the time research is published, conditions may have shifted due to climate change acceleration, technological advances, or policy innovations. The “emerging trends” we identify may already be mainstream by publication, while novel approaches currently emerging may not yet appear in the peer-reviewed literature [210].

These limitations do not invalidate our findings but emphasize the need for ongoing research addressing geographic imbalance, context-specific adaptation guidance, longitudinal evaluation, practitioner knowledge integration, failure documentation, and operational tool development for a more cohesive urban space [211]. Future systematic reviews should explicitly address these gaps through multilingual searches, gray literature inclusion, participatory synthesis involving practitioners, and focus on understudied contexts.

7. Conclusions

This systematic review demonstrates that effective disaster risk mitigation in urban contexts requires integrating three traditionally separate domains: vulnerability assessment, sustainability evaluation, and resilience building. Our analysis reveals that mitigation strategies achieve the greatest impact when they simultaneously reduce hazard exposure, enhance environmental sustainability, and strengthen social–economic adaptive capacity. The conceptual integration framework proposed in this review operationalizes this comprehensive mitigation approach, providing a foundation for policies that address root causes of urban vulnerability rather than merely responding to disaster symptoms.

Urban areas and their inhabitants are confronted with persistent and significant obstacles due to the rapid growth of cities. This urbanization process amplifies the susceptibility and fragility of populations toward various challenges, including both natural and man-made disasters. This review identifies the critical role of research, highlighting the need for sustainable practices in urban disaster planning. However, it also highlights the inconsistency between the two fields.

The active implementation of preventive strategies shows that urban areas will achieve better resilience to disasters while their disaster-related impacts will decrease. The preventive measures show their effectiveness through two aspects, which include their direct results and their capacity to adapt to changing environmental conditions, social dynamics, and economic development. Increasing urban development, together with intensifying climate change effects, creates an urgent need for cities to establish effective, sustainable disaster prevention measures.

Policymakers and urban planners, together with local communities, must direct their resources toward developing resilient infrastructure, efficient governance systems, and community empowerment programs. City development will create disaster-ready urban areas that maintain operational capacity during all emergency situations. Urban areas can build a secure and sustainable future through their dedication to collaborative efforts and innovative development and their ability to withstand challenges. The establishment of effective disaster readiness procedures becomes essential for protecting lives and reducing the harmful effects of disasters. The system requires early warning systems, together with community outreach initiatives and robust infrastructure development. The human well-being of future generations depends on our efforts to tackle climate change and establish sustainable environmental practices as our top priority. Cities can achieve effective climate change disaster protection by implementing sustainable urban planning, constructing durable infrastructure, and engaging their communities.

This review carries immense importance for a wide range of stakeholders engaged in disaster risk management, urban planning, policy formulation, and community

advancement. Investing in sustainable infrastructure, implementing conservation measures, and empowering communities through various initiatives can significantly improve the resilience of communities in the face of disasters.

Future research should focus on the long-term effectiveness of sustainable urban planning in disaster recovery. Comparative studies across different regions are needed to identify best practices and develop practical strategies for risk reduction in urban environments. In conclusion, a new, innovative assessment procedure that combines vulnerability and sustainability issues would be a solution to the problems identified. If this methodology is easy to put into practice, it may be possible to have it mapped, or it could even be a component of city GIS, such that an overview of problems and risks would be more complete, serving as a possible tool for more coherent urban policies based on systemic analysis. The authors refer, in particular, to the identification of vulnerable points or areas in urban fabric regarding sustainability issues, types of vulnerabilities, aspects related to the three pillars of sustainability, and the generation of ways to act on vulnerable areas with specific means from the fields of urban planning and architecture, not only from the domain of global policies.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18042068/s1>, PRISMA 2020 Checklist.

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