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Towards Hazard-Resilience Cities: Comparative Research on Resilience-related Policies and Local Practices in Five Cities Worldwide

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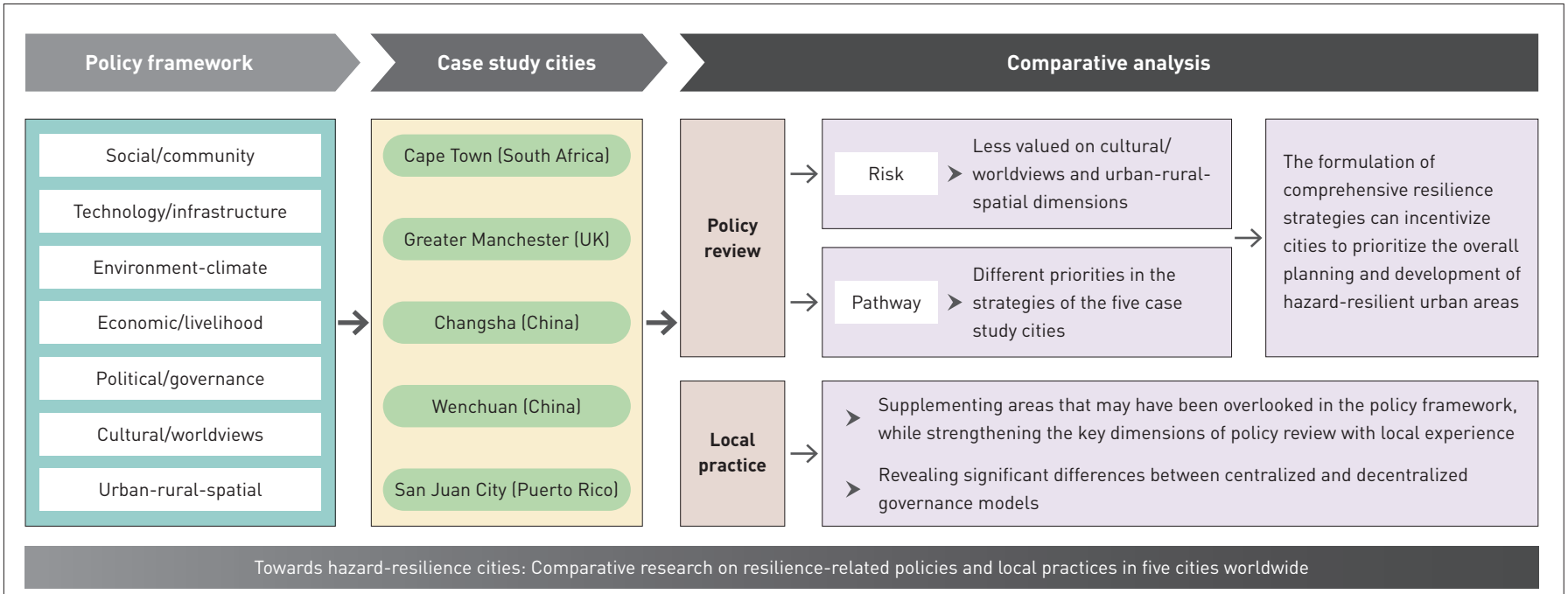
GRAPHICAL ABSTRACT



ABSTRACT

This study provides a comparative analysis of the journey toward hazard-resilience by examining the resilience-related policies and local practices in five exemplary cities worldwide: Cape Town (South Africa), Greater Manchester (UK), Changsha and Wenchuan (China), and San Juan City (Puerto Rico). Through a conceptual framework encompassing seven interrelated dimensions of the social-environmental system, this paper delves into how hazard risk is perceived and resilience is approached in both policy documents and local practices. Policy reviews reveal distinct strategies among cities. Cape Town employs diverse water-saving measures, addressing drought through water resilience. Greater Manchester focuses on human and organizational aspects in disaster risk reduction. Changsha and Wenchuan prioritize specific disaster response measures, while San Juan tackles environmental

and socio-economic challenges through multidimensional actions. Local practices illustrate the effectiveness of bottom-up resilience enhancement, with examples including home drilling in Cape Town and community engagement in Changsha. Despite these efforts, there is a common trend across cities of limited consideration for cultural/worldviews and urban-rural-spatial dimensions. Bridging this gap is crucial for effective risk management and disaster recovery. This study underscores the importance of aligning policy formulation with local practices, prioritizing targeted recovery plans, and expanding considerations to include the urban-rural-spatial dimension. Overall, this research contributes valuable insights to the development of hazard-resilient cities, offering policymakers and planners a foundation to prepare cities for future challenges and foster urban resilience.

KEYWORDS

Hazard Resilience; Policy Framework; Local Practice; Comparative Analysis; Resilience Pathway

HIGHLIGHTS

- Reveals varied hazard resilience strategies across five global cities: Cape Town, Greater Manchester, Changsha, Wenchuan, and San Juan City
- Examines nuanced local practices and underscores the effectiveness of bottom-up approaches
- Demonstrates that integrating top-down policies and grassroots efforts is crucial for effectively building urban resilience

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1 Research Background

In the context of urban studies and urban planning, future cities' development and prosperity is highly related to their capacity to adapt and recover from shocks and changes caused by diverse types of hazards[1][2]. Hence, resilience has emerged as a fundamental concept exemplified by frameworks like the Sendai Framework for Disaster Risk Reduction (2015–2030)[3]. Beyond the Sendai Framework, the United Nations also published several guidebooks outlining pathways to build hazard-resilient cities, such as the *City Resilience Action Planning Tool* and *How to Make Cities More Resilient: A Handbook for Local Government Leaders* (2012 and 2017 Versions)[4][5].

The substantial task of cities worldwide is to develop their hazard-resilience strategies and pathways. A notable piece of evidence is the project of 100 Resilient Cities (100RC) pioneered by the Rockefeller Foundation[6], which attracted more than 1,000 applications from cities aspiring to join the network①[7]. The governments of the selected cities were committed to fostering long-term thinking and enhancing decision-making processes related to hazard management and its underlying causes[8]. This reflects a growing acknowledgment of the intricate challenges posed by cascading and non-stationary risks within interconnected and increasingly globalized societies[9].

Although the globalized nature of initiatives like 100RC and the Sendai Framework helps align objectives for resilient future and develop resilience strategies at national level, it has sparked critiques regarding their effectiveness in enhancing local risk management and practice, particularly for lower-income countries[10]. These critiques underscore chronic governance issues often exacerbated by colonial legacies, different governance cultures and approaches, and economic challenges related to neoliberal economic models[7].

This paper takes a comprehensive approach to examining the development of urban resilience, both within and outside of global resilience initiatives, considering the complexity of resilience challenges that vary widely among cities and societies, intertwined with the unique governance, cultural, and economic contexts at local level. To critically assess how risk is defined and evaluated, and how resilience pathways are constructed within official governance structures and local practices, this study conducted case studies

① The Chinese cities/counties selected for the 100RC project include Deyang, Haiyan, Huangshi, and Yiwu.

and applied a theoretical lens rooted in the framework of social-environment systems. Such a comparative study helps enhance our understanding of the vulnerabilities in hazard-resilience strategies and enable necessary adjustments in practice.

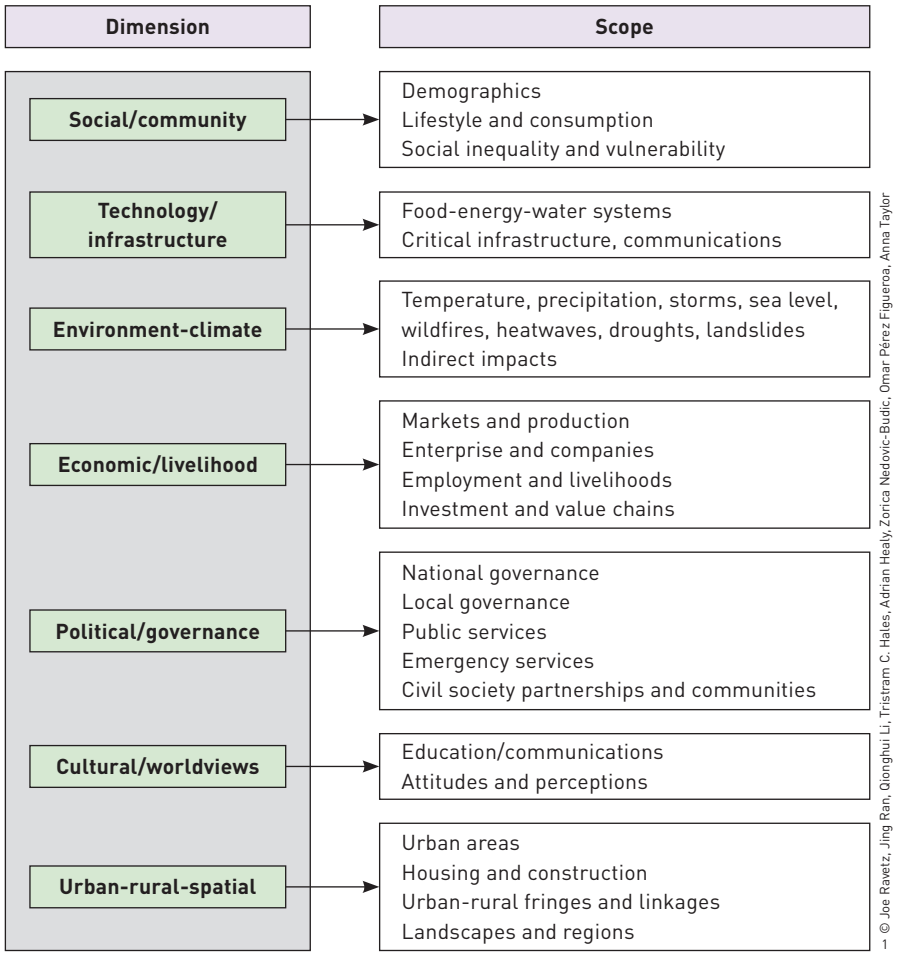
2 A Conceptual Framework for Hazard Risk and Urban Resilience

Resilience is generally understood as the ability of the system to reconstruct itself by altering non-core attributes in response to impacts or pressures, gradually adapting to new environments and surviving[11]. Risk, on the other hand, signifies the likelihood of system collapse or the inability to sustain itself due to such impacts or pressures. Internationally, cutting-edge strategies and policies for disaster prevention and reduction are mainly based on disaster risk assessment. One important reason for this trend is that risk theory provides a perspective of "managing disaster risk"[12] rather than "eliminating disaster risk," which has become the mainstream approach to disaster prevention and reduction both domestically and abroad. In this context, numerous countries have developed comprehensive risk evaluation frameworks to facilitate understanding of hazards, compare risks across cities or regions, and formulate policies and action plans for enhancing resilience. However, nuanced differences in focus exist from one locale to another. A detailed examination of these differences, alongside an integration of their commonalities, could yield significant insights.

This study drew inspiration from the Disaster Resilience of Place model proposed by Susan L. Cutter et al., which conceptualizes resilience from social, economic, institutional, infrastructure, ecological, and community competence[13]. Additionally, it integrated Christopher G. Burton's multi-dimensional explanation of resilience, which covers social, economic, institutional, infrastructure, community, and environmental aspects[14]. Building upon these foundations, the study further delineates each dimension and introduces a new dimension of urban-rural spatial, encompassing aspects such as city planning and urban landscapes, influence exposure levels, and spatial equity in disaster risk and resilience. Meanwhile, based on our previous research[15], a framework is developed to decompose the resilience of urban systems into seven closely interrelated dimensions: social/community, technology/infrastructure, environment-climate, economic/livelihood, political/governance, cultural/worldviews, and urban-rural-spatial (Fig. 1).

This framework holds three significant implications for comprehending disaster risk and proposing effective pathways for resilience construction. Firstly, it acknowledges that elements influencing disaster risk and resilience encompass both material factors and human factors. Thus, an examination of risks and enhancement of resilience should consider more than just the direct technical and climate concerns. It should also delve into the profound societal, cultural, and political facets under synergistic effects. For example, a seemingly straightforward material factor like a blocked drain leading to flooding is intertwined with human-related factors such as communication networks, maintenance programs, or working conditions, reflecting the cognitive capital or deeper intricacies involved[15].

Secondly, the seven dimensions offer insights into both risks and resilience pathways. For instance, the social/community dimension includes demographics, lifestyle and consumption, and social inequality and vulnerability of the urban system. From a risk perspective, this framework offers a lens through which to assess the exposure of individuals and organizations to risks, their susceptibility to damage, and the potential of amplifying socio-



1. The framework of the resilience of urban systems.

political risks. In terms of resilience pathways, it highlights the key role of stakeholders in addressing problems and the collective efforts to adapt to systemic changes. Similarly, the technology/infrastructure dimension addresses technical challenges related to the food-energy-water nexus, various critical infrastructure, and communication networks. Regarding the resilience pathways, it often includes transformative socio-technological innovations and essential technological solutions that mitigate risks.

Thirdly, theoretical exploration of hazard-resilience cities necessitates a top-level design view and systematic understanding of city mechanisms as complex social-environmental systems[16]. The seven dimensions of the framework are interconnected and jointly influence a city's capacity to withstand environmental, social, and economic risks. These dimensions reflect the influence of social systems on natural systems through policies and technological interventions, while the ecological, biophysical, and environmental components of systems subtly drive response dynamics[17]. Complex interactions between urban social and environmental systems play a pivotal role in determining both risk and resilience within cities[18]. To bolster risk-resilience, cities should extend their focus beyond the enhancement of individual dimensions to fortify their symbiotic relationships, recognizing the intricate web of cause-and-effect spanning climate impacts, ecosystems, socio-ecological systems, and socio-political systems. The proposed framework provides a lens for a refined comprehension of urban resilience, offering valuable insights for both research and practical applications in the improvement of risk-resilience.

3 Research Methodology

This study adopts the framework to examine the policies and local practices of five exemplary cities globally, assessing the inclusion of the seven dimensions outlined in the framework. Furthermore, the study investigates the variations and distinctiveness of each city in resilience-related policies and practices across diverse social, political, and cultural contexts.

3.1 Selection of Case Study Cities

This study selected five exemplary cities, namely Cape Town (South Africa), Greater Manchester (UK), Changsha and Wenchuan (China)②[19][20], and San Juan City (Puerto Rico), spanning Africa, Europe, Asia, and the Americas. These cities were carefully chosen for their representative population sizes, urban positioning, and disaster types (Table 1).

Cape Town, situated in the Western Cape Province of South Africa, is ranked as the country's second most populous city[21] with approximately 4.773 million residents[22]. It is the capital of South Africa and boasts the country's second largest municipal economy. Cape Town has faced severe water scarcity challenges, especially during the unprecedented drought from 2015 to 2019. In February 2018, the municipal water consumption even dropped from 800 million liters per day (ml/day) a year earlier and 1,200 ml/day in February 2015 to a new low of 500 ml/day[23]. In the same year, the city authorities' announcement of an impending "Day Zero"—a day when the city was projected to run out of water[24], which coincided with the highest levels of water restriction to delay "Day Zero" as long as possible.

Greater Manchester, a metropolitan region in the northwest of England, serves as the largest economic zone in the UK, excluding London, and home to nearly 3 million people across its 10 metropolitan boroughs[25]. To be a resilient place where everyone can "grow up, get on, and age well," Greater Manchester has developed its resilience strategy. Flood is one of the frequent natural hazards in this region, which has brought long-term troubles to the residents. The Boxing Day Floods in 2015 caused over 1,100 households in Greater Manchester to lose power, flooding dozens of city center businesses and forcing the evacuation of approximately 100 properties[26]. In July 2019, continuous heavy rainfall flooded streets, causing severe inconvenience to people's travel[27].

Changsha, the capital of Hunan Province in China with a population exceeding 5 million[28], is a key growth pole in the urban agglomeration along the middle reaches of the Yangtze River[29]. Although not having developed a separate resilience strategy, Changsha has explored many comprehensive disaster prevention plans and specific disaster prevention plans. The city is bisected by the Xiangjiang River, a major tributary of the Yangtze River, rendering it susceptible to flooding during the rainy season. In 2017, Changsha endured its longest, most widespread and severe rainfall in recorded history, causing a catastrophic flood that significantly impacted its residents[30]. Consequently, the Chinese government identified Changsha as one of 60 cities that have suffered severe waterlogging disasters in recent years[31].

② According to China's administrative division, Wenchuan is a county, which is an administration level between county-level city and town, covering 4,084 km^2, and has jurisdiction over 9 towns, 75 villages, and 8 communities. For an easier description, Wenchuan is regarded as a "city" in this study, same as the other four cities (source: Refs. [19][20]).

Table 1: Preliminary statistics of the five cities

City	Cape Town	Greater Manchester	Changsha	Wenchuan	San Juan City
Main natural hazards	Drought, gale-force wind, heat wave, storm	Flood, heatwave	Flood, earthquake, heatwave	Earthquake, mudslide, landslide, flash flood	Hurricane, storm, heatwave, flood, drought, landslide, ground subsidence, earthquake, tsunami
Population	4,772,846	2,911,700	5,205,100	84,668	319,837
Area (km^2)	2,461	1,277	1,200	4,084	103
Population density (per km^2)	1,939	2,280	4,338	21	3,150
Per capita GDP (USD)	5,528	36,507	18,783	14,296	25,695

NOTES

1. The population data of 2022 were respectively sourced from the Research Analytics, Policy and Strategy Department, City of Cape Town; the UK's Office for National Statistics; Ministry of Housing and Urban-Rural Development of the People's Republic of China; official website of Wenchuan County People's Government; and the Census Bureau of the United States.
2. The area data were respectively sourced from the Centre for the Sustainable, Healthy and Learning Cities and Neighborhoods of South Africa; the UK's Office for National Statistics; Ministry of Housing and Urban-Rural Development of the People's Republic of China; official website of Wenchuan County People's Government; and the Census Bureau of the United States.
3. The per capita GDP data were respectively sourced from the official website of Cape Town Government; the Statista website; Changsha Municipal Bureau of Statistics; Statistics Bureau of Aba Tibetan and Qiang Autonomous Prefecture; and the Census Bureau of the United States. All data were by the year of 2022, except for Greater Manchester by 2021.

Wenchuan County, nestled in the high mountain canyons on the northwest fringe of Sichuan Basin and along the seismic belt of Qinghai–Xizang Plateau, with an altitude difference of over 5,000 meters[19], is among the largest settlements of the Qiang ethnic group in China. Wenchuan has developed disaster emergency plans to tackle the challenges posed by frequent earthquakes and mountain floods. These disasters, along with secondary hazards triggered by earthquakes, form a typical geological and meteorological disaster sequence. In 2008, Wenchuan was struck by a catastrophic earthquake of magnitude 8.0[32], leading to nearly 30,000 aftershocks[33], severely affecting ten counties (cities)[34] and resulting in nearly 70,000 fatalities[35]. Following this catastrophe, in 2013, Wenchuan faced a severe mudslide, which damaged farmhouses on both sides of the ditch and buried roads and farmland under debris flow deposits[36][37].

San Juan City, situated on the island of Puerto Rico, finds itself in the hurricane-prone zone of the Caribbean Sea and boasts a unique and rich cultural heritage, a blend of Spanish, African, American, and Taíno indigenous traditions. San Juan City has developed a resilience strategy through the core project, ReImagina Puerto Rico, led by Resilient Puerto Rico Advisory Commission to promote the recovery and reconstruction of the city. Recurring hazards such as hurricanes, floods, and landslides threaten the infrastructure and the well-being of its residents[38]. Notably, in September 2017, Puerto Rico was hit by two Category 5 hurricanes, Irma and Maria, only 12 days apart[39]. These storms severely impacted the island's infrastructure, leaving many residents without access to water and electricity for months[40] and resulting in the loss of 4,645 lives[41].

The five selected cities enable the exploration of different strategies tailored to disaster risks faced by each city, emphasizing the diverse approaches required for comprehensive and single-risk scenarios. Additionally, this study reveals that in different cities with varying levels of understanding and emphasis on hazard-resilience capacity construction, and that the performance of such construction in each city varies in formulating strategic documents and local practices. The diverse geographical settings of these cities further highlight the significance of contextual and place-based considerations in developing resilience strategies.

3.2 Data Sources and Comparative Analysis

The analysis of case cities in this study focuses on two key questions: first, how these cities define and understand disaster risk; and second, how these case cities respond to typical disaster

risks. The former is explored through comprehensive risk assessments according to the seven outlined dimensions, and the latter is addressed by implementing resilience enhancement strategies and constructing resilience pathways. The primary data sources for this study comprise official policy documents related to risk-resilience, including strategies for resilience, water resource management, disaster reduction plans, and assessment reports (Table 2). In addition to formal policy documents, this study recognizes the significance of everyday responses to crises through years of observation, investigations, and research about the case study cities. These unofficial or informal pathways offer alternative perspectives on resilience, underscoring the significant role of local bottom-up experiences in orchestrating social-environmental systems, especially for situations where informal activities compensate for or challenge formal management. The evidence of informal resilience measures collected in this paper enrich the comprehensive construction of the resilience framework.

4 Risk Implication and Resilience Pathways in Policy Documents

The policy review started with extracting information related to risk (Table 3) and details regarding resilience pathways[42][43] (Table 4). By coding and analyzing policy materials based on the framework, this research unveils the varying focuses across five cities.

4.1 Policy Review of Cape Town

In the document for "Cape Town Resilience Strategy"[43], distinct risk definition or risk evaluation are not explicitly provided. However, another document encapsulates that "risk readiness should be incorporated into all aspects of government operations and disaster risk management could be better integrated into proactive decision-making before disaster events occur"[44]. Specifically, the factors resulting in drought risks in Cape Town cover all seven dimensions of the framework. For example, in the

Table 2: Data and policy sources about the case study cities

City	Data/policy	Source
Cape Town	· Cape Town Resilience Strategy (English Version) · The Water Resilience Profiles for Cape Town · Cape Town Water Strategy—We Shared Water Future	· Official website of City of Cape Town
Greater Manchester	· Greater Manchester Resilience Strategy 2020–2030 · Integrated Water Management Plan (Draft Plan, June 2023) · Local Flood Risk Management Strategy · UK Climate Change Risk Assessment 2022	· Greater Manchester Combined Authority · Manchester City Council · UK Department of Environment, Food and Rural Affairs
Changsha	· Expert Review Draft of the Special Plan of Territorial Space for Disaster Prevention, Reduction, and Emergency Response System of Changsha City (2021–2035) · Changsha Sponge City Construction Planning and Design Guidelines · Emergency Plan for Flood Control of Changsha (2022)	· Changsha Municipal Bureau of Emergency Management · Changsha Municipal Housing and Urban-Rural Development Bureau
Wenchuan	· Emergency Plan for Flood Control and Drought Relief of Wenchuan County · Emergency Plan for Sudden Geological Disasters of Wenchuan County (Revised in 2023) · Overall Plan for Post-Earthquake Recovery and Reconstruction of Wenchuan	· Flood Control and Drought Relief Office of Wenchuan County · Planning Group of Post-Wenchuan Earthquake Restoration and Reconstruction of the Earthquake Relief Headquarters under the State Council · Natural Resources Bureau of Wenchuan County
San Juan City	· ReImagina Puerto Rico Report (English Version) · San Juan County Hazard Mitigation Plan 2018 · San Juan County Pre-Disaster Hazard Mitigation Plan 2018	· Resilient Puerto Rico Advisory Commission · San Juan County

Table 3: Review on the risk implications in resilience-related policy documents

City	Dimension						
	Social/ community	Technology/ infrastructure	Environment-climate	Economic/ livelihood	Political/ governance	Cultural/ worldviews	Urban-rural-spatial
Cape Town	Trauma; poverty and inequality; food insecurity; unemployment; lack of social cohesion and community participation	Management of water infrastructure; unsafe municipalities	Climate change; protection of aquatic habitats and ecosystems	Impairment of urban investment image; absence of sustainable funding mechanisms or financial resources	Enforced land-use controls; strategy formulation; political leadership; coordination between government and other organizations; enforced water related regulations	Incorporation of local knowledge and culture into decision-making around water	The challenge of informal residential areas under rapid urbanization
Greater Manchester	Serious risk to life; loss of basic services	Risk of infrastructure failure	More devastating storms	Under-funding and vulnerability of economic	Distrust of government in water management	Apathy and skepticism on climate change	Poor housing design and conditions
Changsha	Current population density, personnel casualties	Establishment of monitoring and early warning systems; the planning of defense facilities such as reservoirs and flood control embankments	Rainfall and water regime trends	Direct economic loss	Construction of emergency system	—	Division of flood risk control areas from flood storage and detention areas
Wenchuan	Number of fatalities due to disasters; number of people affected by the disaster (relocated and transferred)	Monitoring water level; dam failure accidents of hydropower stations and reservoirs; the breach situation of important river embankments	Rainfall and duration	Direct economic loss potential economic loss	Construction of emergency system	—	Hazard zoning of geological hazards
San Juan City	Inequality; lack of authorization for social communities; weakened social structure; poverty; vulnerable groups	Aging infrastructure (power grid and water systems)	The impact of floods and wind; natural resource protection; sea level rise and changes of precipitation patterns led by climate change	Limited investment	Development of housing strategy portfolio; emergency services	Limited mental health services and disrupted education services; lack of communication and coordination among individuals, organizations, media, and government officials	Lack of affordable housing

NOTE
"—" indicates no mention of relevant implication among resilience-related policy documents.

Table 4: Review on the resilience pathways in resilience-related policy documents

City	Social/community
Cape Town	· Grow the number of neighborhood safety teams, and re-establish the Ceasefire Program · Celebrate diversity and build cohesion and inclusion through arts and community storytelling · Develop and deploy the Neighborhood Resilience Assessment, which evaluates the level of resilience at the neighborhood scale · Launch the "Be a Buddy" program, and change the mindset of residents, engineers, policy makers, and others who help build water sensitive cities · Establish mutual understanding between commercial farmers and citizens/community organizations around the connection between food, water, and livelihoods
Greater Manchester	· Build cohesive, healthy, and resilient communities, addressing hate extremism · Collaborate with the voluntary and faith sectors at local and national levels to enhance community resilience · Public and private investors work together to provide more innovative solutions
Changsha	—
Wenchuan	· Establish flood prevention and rescue teams · Hold different types of emergency drills
San Juan City	· Develop Resilient Community Centers, which provide a physical space for social, economic, health, and educational services to improve the provision of services during emergencies and disaster relief periods · Protect surface water consumers and individual well owners
City	**Technology/infrastructure**
Cape Town	· Create a live database of referral network · Utilize a screening tool to identify youth at risk · Develop "Build Back Better" protocols for infrastructure damaged in shock events · Deploy smart technology and predictive analytics · Enhance knowledge management and data use · Establish a data platform that provides basic information on each informal settlement · Develop a decision support system to enable effective management and optimization of resource · Design to achieve net zero thinking, promoting the connection of micro construction projects
Greater Manchester	· Use indicators and baseline assessments to measure resilience · Utilize academic knowledge to respond to opportunities and challenges brought by new technologies · Develop relevant digital tools to achieve data sharing
Changsha	· Establish a hydrological and meteorological monitoring and warning system, as well as a flood control dispatch system, to coordinate the control of flood storage spaces such as reservoirs, rivers and lakes, and other detention areas · Improve the hydrological information monitoring and forecasting warning system · Combining urban rainwater storage space to regulate floods, alleviate waterlogging, and regulate climate · Strengthen the construction of flood control infrastructure · Improve the municipal infrastructure system and security risk prevention and control system
Wenchuan	· Relevant departments are equipped with emergency communication facilities, emergency command systems, and flood prevention dedicated communication networks · Promptly repair the damaged highway projects and other infrastructure · Quickly repair the water damage projects that affect the safety of local flood control and urban-rural water supply · Strengthen the construction of group measurement and prevention monitoring systems, information transmission and release systems, emergency command and dispatch systems, and their supporting facilities · Strengthen basic surveying and mapping and build geographic information systems

(Continued)

Table 4: Review on the resilience pathways in resilience-related policy documents (Continued)

City	Technology/infrastructure
San Juan City	· Establish reliable and diversified backup energy systems · Update the Island's digital land cadaster · Conduct research and deployment of telecommunication infrastructure · Align reconstruction projects on water systems · Increase bandwidth adoption programs · Reconstruct decentralized wastewater systems for strengthening recovery capacities · Create integrated government data systems · Conduct mapping of flood areas · Improve roads and drainage systems
City	**Environment-climate**
Cape Town	· Revitalize urban rivers and their surrounding spaces to create livable urban waterways
Greater Manchester	· Protect and enhance the resilience value of natural environment · Maximize the utilization of multifunctional blue-green infrastructure · Reduce carbon emissions
Changsha	· Refine identification of risk control areas and flood storage and detention areas · Carry out ecological restoration of various elements, with a focus on promoting the governance of the Xiangjiang River Basin and the ecological restoration of mines in the Yangtze River Economic Belt
Wenchuan	· Strengthen ecological restoration and environmental governance, and promote coordinated development of population, resources, and environment.
San Juan City	· Protect existing drinking water sources and mitigate contamination · Restore and enhance coastal ecosystems · Conduct monitoring and management of aquifers
City	**Economic/livelihood**
Cape Town	· Protect water sources by supporting the Greater Cape Town Water Fund, and develop flood control capital project portfolio · Cultivate green economy · Offer support services to prevent existing businesses from closing down · Take future casting for just transitions in the rapidly changing global economy · Explore innovative insurance products for catastrophic shock events
Greater Manchester	· Utilize funds to enhance resilience, use resilience to promote economic development, and improve people's lives · Develop a portfolio manual to address water resource management challenges · Enterprises create opportunities and pathways for the jobs and skills required for integrated water management
Changsha	—
Wenchuan	· Arrange necessary funds for flood control and drought relief · Raise recovery and reconstruction funds through multiple channels and improve fund management and supervision mechanisms
San Juan City	· Invest in improving tangible infrastructure for education, healthcare, and labor training and skill certification · Optimize health care financing · Create loans, grants or subsidiary programs to support the improvement of housing · Improve fiscal stewardship of subsidies awarded · Develop and start the implementation of disaster resilience strategies for micro/small businesses

(Continued)

Table 4: Review on the resilience pathways in resilience-related policy documents (Continued)

City	Political/governance
Cape Town	· Strengthen partnerships, improve water governance and overall water resource resilience · Protect water sources through managed aquifer recharge · Develop ecological industrial parks using industrial symbiosis methods · Promote Cape Town as a resilient tourism and investment destination · Launch drilling data collection and owner awareness project · Encourage cross-societal support for Diversionary Programs and scale up the Live Well Challenge · Roll out the precinct management model to multiple areas and mainstream sustainable procurement in supply chain management, with resilience as the mainstream consideration for urban decision-making · Roll out simulations to prepare for shock events and determine progress towards attainment of improved water resilience · Transform governance structures into mainstream designs that are sensitive to water · Design and develop a method for jointly funding water infrastructure and services · Build trust in the government to ensure water supply · Develop an adaptive overall plan
Greater Manchester	· Coordinate and promote resilience building activities · Develop influencing resilience agendas and provide community support · Develop disaster response and recovery plans and provide multi-agency training and exercises · Provide information and guidance to the public · Break barriers to water resource management through cooperation · Propose good practices and suggestions to improve established policies and standards · Build a governance framework
Changsha	· Develop relevant flood control and drainage standards · Develop emergency plans and disposal measures for excessive floods · Build a security pattern for territorial space disaster prevention, reduction, and emergency response system · Designate flood risk control areas as disaster prevention space · Plan and construct emergency shelters for major floods · Build an emergency basic guarantee and emergency service system · Consider the design of flood discharge channels, flood control and water storage projects, the necessity of flood diversion areas, and the elevation design of planned area ground when developing prevention and control strategies · Coordinate with various departments to carry out flood prevention and disaster relief work, and ensure preventing and handling flood disasters
Wenchuan	· During disasters, the local government led a working group to guide flood control, drought relief, and disaster relief work on-site · Each government department shall promptly organize and coordinate the allocation of flood control and drought relief materials, and establish a sound disaster relief material reserve system and enhance reserve capacity · Carry out disaster monitoring and assessment, and timely report relevant flood, drought, disaster situation, and deployment of flood prevention and drought relief work · Strengthen hydrological forecasting, increase frequency of measurements, and closely monitor the changes and trends of flood and drought conditions · Post disaster resettlement of affected populations, maintenance of social security, and effective news promotion and public opinion response · Strengthen the construction of emergency rescue, rescue capabilities, and disaster relief command system · Improve various disaster prevention and emergency plans
San Juan City	· Develop a comprehensive resource plan and a master integrated Continuity of Operations Plan · Develop water efficiency plans and comprehensive water use plans, and manage water resource planning and new development to prevent groundwater overexploitation · Develop a public policy to promote the use of Nature-based Solutions · Improve the Puerto Rico's Dam Safety Program, and develop and implement Port Emergency Operations Plan · Develop strategies to increase the stock of affordable housing, emergency management agreements for housing, and feasible models for safeguarding the rights of informal housing · Force open space terminations with programs or guidelines

(Continued)

Table 4: Review on the resilience pathways in resilience-related policy documents (Continued)

City	Political/governance
San Juan City	· Require water transportation companies to submit annual reports · Carry out flood disaster warning · Strictly implement building codes
City	**Cultural/worldviews**
Cape Town	· Develop an anti-stigma, mental health public messaging campaign · Extend mental health training
Greater Manchester	· Create a culture of independence and inclusiveness
Changsha	—
Wenchuan	· Reshape a positive and optimistic spirit and promote the great spirit of earthquake relief
San Juan City	· Implement a communications campaign to build a culture of household emergency preparedness and awareness · Promote continuous public education
City	**Urban-rural-spatial**
Cape Town	· Remove alien invasive vegetation
Greater Manchester	—
Changsha	· Build mountain vegetation plans for the protection of mountain vegetation
Wenchuan	· Optimize urban spatial layout · Comprehensive consideration of multiple factors in planning zones
San Juan City	· Create community garden programs in rural and urban areas

NOTES

1. The Ceasefire Program is a project of the City of Cape Town's Violence Prevention through the collaboration between Urban Upgrading (VPUU) unit and the Department of Community Safety (DOCS), which was piloted in Hanover Park in January 2013. It is a social intervention plan aimed at guiding high-risk youth out of gang activities through community participation and social intervention (source: Refs. [42][43]).
2. Diversional Programs are a series of programs that help Cape Town people overcome pressures such as drug abuse, violence, and homelessness, avoid contact with the criminal justice system, and create alternative pathways to enhance social cohesion and reduce violence and trauma (source: Ref. [43]).
3. "—" means no mention of relevant resilience pathways among resilience-related documents.

dimension of economic/livelihood, Cape Town believes that "while the City has embarked on a journey to build resilience in the urban water system, the financing of required infrastructure and actions is not yet secure. The absence of sustainable funding mechanisms increases the risk and vulnerability of Cape Town to shocks and stresses."[44]

The response of Cape Town to severe drought has prompted a fundamental overhaul of its water management strategies. Since 2018, the city has invested substantially in enhancing groundwater resources and wastewater recycling efforts to supplement its surface water resources. Moreover, Cape Town remains committed to exploring diverse water supply solutions. Its resilience strategies encompass a broad spectrum of initiatives, focusing on social/community, technology/infrastructure, economic/livelihood,

and political/governance dimensions, while also significantly influencing environment-climate, cultural/worldviews, and urban-rural-spatial dimensions.

4.2 Policy Review of Greater Manchester

The Greater Manchester Resilience Strategy (2020–2030) builds on the insights gained from Preliminary Risk Assessment and previous civil contingency strategies, without directly defining risk. It operated on the understanding that "risks across the world can impact us within Greater Manchester" and "risks can now operate across borders"[25]. Acknowledging and comprehending these risks is crucial for strengthening and sustaining resilience. The flood risk assessment in GM considers various factors such as life and property, infrastructure failures, climate change, covering all the seven dimensions. Another relevant document notes that "Greater Manchester sits in a natural bowl. This results in a flashy response to rainfall events, in which water levels rise rapidly, and flood risk can come from areas upstream in the river catchments".[45] Therefore, water resource management is highlighted as a vital component of flood risk mitigation within the political/governance dimension. Notably, in the environment-climate dimension, climate change may affect floods and coastal changes, with observations indicating that "high rainfall illustrated how existing flood defences may be over-topped in future"[25].

The resilience pathways of GM focus on all six dimensions in the framework except the urban-urban-spatial dimension. The Greater Manchester Resilience Strategy (2020–2030) emphasizes the human and organizational aspects of disaster risk reduction and urban resilience as a system, putting forward five key resilience-enhancing priorities: communities, discovery, leadership, place, and responding[25]. These priorities advocate for a comprehensive "adaptive governance" model, which engages and empowers all stakeholders, as explored in subsequent discussion on "local practices." Building cohesive, healthy, and resilient communities, measuring resilience through indicators and baseline assessments, conserving the natural environment, and developing recovery plans are presented as effective methods mentioned in resilience strategies. Given the dual role of the city's peri-urban areas as sources of climate risks (especially regarding fluvial flooding) and contributors to climate adaptation functions (e.g., through natural flood management and biodiversity conservation), Greater Manchester values actions related to water resource management and climate adaptation. Other documents related to Greater Manchester's water management outline exemplary practices, including fostering cooperation to overcome water management challenges, leveraging multifunctional blue-green infrastructure, developing relevant digital tools, and embedding social and ecological values into investment portfolios.

4.3 Policy Review of Changsha

The disaster prevention and mitigation policies in Changsha categorize risk into 1) disaster risk, which is defined by hazard and frequency of occurrence, and 2) vulnerability, primarily assessed through built environment and population density[46]. Flood risks in Changsha are grouped into four levels: extremely high, high, medium, and low[46], with the risk assessment covering social/community, technology/infrastructure, environment-climate, economic/livelihood, political/governance and urban-rural-spatial dimensions, but lacking consideration on culture/worldviews dimensions.

The disaster reduction policies in Changsha place more emphasis on engineering solutions and emergency support, highlighting the resilience pathways in the dimensions of technology/infrastructure and political/governance. It pays less attention to the dimensions of social/community, economic/livelihood, and cultural/worldviews, and needs to strengthen the dimension of urban-rural-spatial to achieve disaster reduction goals. Changsha Municipal Government takes a leading role in disaster prevention, relief, and emergency management, concentrating on defining and coordinating the responsibilities of various governmental departments in disaster preparedness. From a spatial planning and layout perspective, the city strives to meet a broad spectrum of disaster response requirements, ensuring rapid disaster alerts and tiered infrastructure protection. Strategic initiatives—including the demarcation of flood risk control zones, the construction of hydrological and meteorological monitoring and early warning systems, the establishment of flood control dispatch systems, and the maintenance of emergency channels and urban lifeline projects—can help form a more secure emergency system in Changsha, to better achieve regional coordination and emergency rescue during floods.

4.4 Policy Review of Wenchuan

Among relevant policy documents, the risk indicators of Wenchuan mainly include the population affected by disasters, facility monitoring data, rainfall and duration, and economic losses caused by disasters. These indicators touch upon six of the seven dimensions except for cultural/worldviews. For instance, within the technology/infrastructure dimension, the Hydrological and Water Resources Survey Bureau strengthens hydrological monitoring,

increases the frequency of monitoring data collection, and closely monitors the trend and changes of floods[47]. This includes scrutinizing river water levels and embankment conditions to forecast disaster trends and impacts, thereby enabling government departments to set appropriate emergency or early warning response level for floods. For the social/community dimension, Wenchuan mainly considers the number of people affected by the disaster and necessity for their resettlement.

The resilience pathways in Wenchuan's policies focus more on post-disaster recovery and response, and with less emphasis on developing enduring resilience. This suggests that the concept of resilience is still nascent within the policy framework. The approaches to disaster relief lean towards engineering measures and emergency management, such as strengthening monitoring systems, ecological restoration, environmental management, and bolstering disaster relief command infrastructure. These pathways span the technology/infrastructure, political/governance, and environment-climate dimensions. Wenchuan also pays attention to social/community, economic/livelihood, and cultural/worldviews dimensions. This includes mobilizing community participation in disaster relief, securing necessary funding for flood and drought prevention, offering post-disaster psychological support, and fostering a positive spirit, rounding out the resilient measures of Wenchuan. For the dimension of urban-rural-spatial, efforts to optimize urban spatial layout and planning zones are considered to improve environmental carrying capacity and disaster prevention capabilities.

4.5 Policy Review of San Juan City

San Juan City adopts the perspective that "thinking about building resilience requires looking at an Island or community holistically, understanding their strengths and where they lie, the systems that make up the place and the interdependencies and risks they may face"[48]. The disaster risk assessment of the city covers all the seven dimensions. In the dimensions of social/community and technology/infrastructure, "the high poverty rate in Puerto Rico and the lack of affordable housing have contributed to the inappropriate use of land, the increase of vulnerable populations that settled in high-risk areas"[48]. The settling of population in the high-risk areas is attributed to historical injustices (within Puerto Rico and in its relations to the USA) and the inept responses from a collapsed state, product of decades of colonialism③[49], recent neoliberal austerity, and debt policies[50]. Not only poverty and social inequality will exacerbate San Juan City's vulnerability, but insufficient disaster preparedness and coordination mechanisms, limited investment, and rising sea levels caused by climate change are also factors that pose significant challenges to the city.

Against the backdrop of various disaster threats such as hurricanes and heavy rainfall, San Juan City's comprehensive resilience strategies and mitigation plans provide diverse and specific resilience pathway construction suggestions for its rapid recovery and adaptation to changes, covering all the dimensions. In terms of the technology/infrastructure dimension, San Juan City focuses on the research and development of infrastructure such as energy, telecommunications, and water supply systems. In the political/governance dimension, the city prioritizes the creation of water use plans, resource management plans, and housing improvement policies to enhance urban resilience. In addition, measures such as developing resilient community centers, protecting existing drinking water sources, and investing in improving physical infrastructure also help San Juan City advance towards resilience.

4.6 Policy Review Summary

A comprehensive review of policy documents about the five case study cities offers a detailed perspective of risk-resilience awareness. Generally, the dimensions of social/community, technology/infrastructure, environment-climate, economic/livelihood, and political/governance receive relatively higher attention in resilience construction (Fig. 2). For the less emphasized dimensions—cultural/worldviews and urban-rural-spatial—it is imperative to acknowledge the existence of cultural gaps and barriers in public awareness and education, which may lead to mindset changes to the ignorance, skepticism, and denial of increasing hazard risks. Such divergent perceptions of risk may influence people's willingness to pay for disaster risk reduction and preparedness efforts. Additionally, the urban-rural-spatial dimension is not sufficiently considered in risk assessments, indicating two crucial deficiencies that demand attention to address systemic problems in disaster risk reduction. Firstly, the perception of risk is often treated as a static process, rather than a dynamic and evolving system. While the probability and intensity of hazards can be projected over the next 50 or 100 years, it is challenging to forecast the dynamic changes in urban-rural land use and spatial distribution, resulting in their being underemphasized. Secondly,

③ San Juan was once home to the Taíno who were the indigenous people of the Caribbean. Founded in the 15th century, San Juan became an important strategic port, first as a colony of Spain and later the USA (source: Ref. [49]).

the prevalent disconnection between the sectors of spatial planning and disaster management in many countries perpetuates biased understandings of risk, undermining efforts to build resilience.

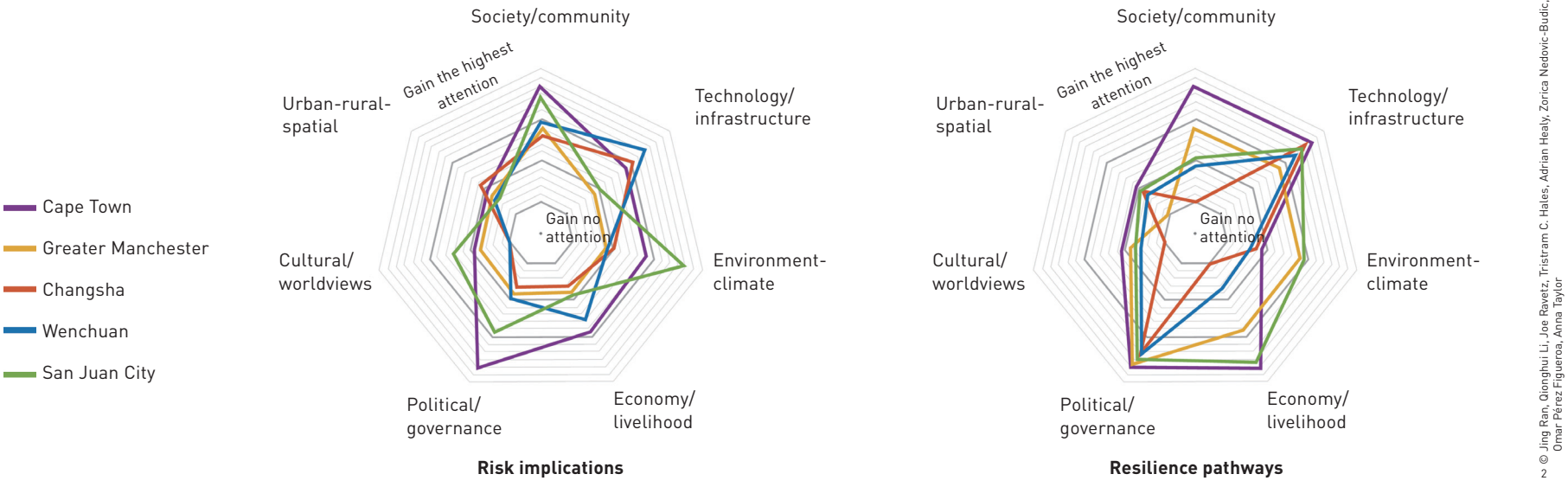
Analysis of resilience pathways of the five cities reveals divergent priorities in their policies (Fig. 2). Taking Changsha as an example, its focus leans towards technology/infrastructure and political/governance dimensions, with relatively less emphasis on social/community, economic/livelihood, and cultural/worldviews dimensions. Notably, the response measures outlined in its policies predominantly involve practical, short- and long-term engineering solutions, such as enhancing flood disaster warning systems, strengthening engineering construction, promoting ecological restoration, and developing emergency service systems. In contrast, Cape Town places emphasis on the impact of financial investment on water resource management, highlighting the significance of cooperation between the government, enterprises, communities, and residents. The city values not only the political/governance and technology/infrastructure dimensions in its resilience-related strategies, but also the dimensions of social/community and economic/livelihood. Understanding the interplay among various dimensions, identifying key factors within the social-environmental system, and redirecting attention to underrepresented dimensions are pivotal in effectively bridging resilience gaps.

The comparative analysis suggests that the formulation of comprehensive resilience strategies can incentivize cities to prioritize the overall planning and development of hazard-resilient urban areas. Strategies adopted by Cape Town, Greater Manchester, and San Juan City provide an extensive overview of recovery objectives and actions in response to disasters. These strategies underscore clear concepts and comprehensive planning, which can be strategically and effectively applied in practical projects. While Changsha and Wenchuan's strategies primarily focus on post-disaster response and recovery actions, such as detailed engineering plans and coordinated response strategies. Due to the lack of specialized disaster resilience planning or recovery strategies, it is difficult to combine long-term livelihood restoration and economic aspects with engineering disaster prevention measures. For cities aspiring to build resilience, strategic planning actions can align more closely with the overarching goal, thereby providing broader guidance for the city.

5 Resilience Pathways in Local Practices of the Case Study Cities

Recognizing policies outlined in the documents may not always equate to translating into actions. Therefore, the significance of local practices in disaster response and resilience-building efforts should not be overlooked. These practices encompass the implementation, experimentation, and enhancement of policies, and frequently mirror the collective understanding of resilience through the lens of specific cultural and social contexts. Moreover, local practices also emphasize the value of indigenous knowledge in

2. Comparison of risk implications and resilience pathways in resilience-related policy documents across the five cities.



mitigating disaster impacts, thereby complementing professional expertise.

5.1 Local Practices in Cape Town

In response to the 2018 drought and the consequent water scarcity crisis, Cape Town's residents were encouraged to substantially reduce their water consumption to 50 liters of supply per person per day at the height of the drought[51]. Restrictions were imposed on using municipal water for car washing, filling swimming pools, and irrigating gardens. The amalgamation of penalties and ethical persuasion prompted residents to adopt significant behavioral changes, such as shortening shower time and reusing greywater collected from showers and sinks[52]. To supplement limited municipal water supplies, many residents accessed groundwater by commissioning their own boreholes or wellpoints for non-potable uses, and some collected water from natural springs in the city. Collectively, these individual measures played a crucial role in alleviating pressure on municipal water supplies, contributing to Cape Town's resilience against the "Day Zero" drought scenario.

However, the equity of these individual efforts has been debated[53]. Questions arise regarding whether those who can afford private water access should be allowed to do so, and whether it is fair or equitable that the cost of the drought is not evenly distributed across the city. Moreover, the actions taken by individuals also form the foundations for new resilience pathways. For the city, using boreholes for domestic irrigation can decrease the demand on municipal water supplies during summer peaks, thus allowing the focus to shift towards meeting the broader domestic needs across the city, albeit at the expense of municipal revenue. Set against this, the use of groundwater resources by Cape Town's elite may represent the capture of a previously common pool resource④.

The case of Cape Town demonstrates the collective power of individual actions in enabling hazard-resilient cities, particularly when working towards a shared goal. Yet, it also reveals the potential of individual actions to establish new adaptive pathways with unintended consequences. Achieving a balance between household resilience and urban resilience requires unified goals and collaborative efforts from all stakeholders. This is crucial in navigating the complexities of water management and ensuring sustainable water provision amid future challenges. Recognizing the agentic role of households in actively shaping resilience outcomes highlights the significance of robust governance structures and regulatory frameworks in choreographing the iterative, power-laden dance between the state, residents, and other actors as each tries to secure a resilient future of their own imagination.

5.2 Local Practices in Greater Manchester

The Greater Manchester government explores appropriate frameworks for flood risk management by promoting cooperation among a wide range of departments and stakeholders interested in the future of related fields. The governance of water systems involves a complex network of private water firms (e.g., United Utilities), national agencies (e.g., Environment Agency of the UK), municipalities, together with a mix of other private and civic partnerships[54]. Although the current governance structures are fragmented both spatially and administratively, promising practices are emerging, including 1) informal partnerships with a mandate and role within larger institutional arrangements (e.g., River Catchment Partnerships), 2) independent third sector formal organizations actively participating in informal partnerships (e.g., Wildlife Trusts), 3) formal governance partnerships uniting different levels and units of government (e.g., local authority-based Technical Flood Risk Officers Group), and 4) innovative public-private-civic partnerships aimed at cross-jurisdictional, integrated planning (e.g., Pennine Prospects).

However, there are also gaps or conflicts between these local measures and top-down policies. For example, the Moors partnership⑤ recognized that extreme flooding in small towns in steep sided valleys, such as Hebden Bridge, was partly due to upland land management by distant landowners only interested in profit from shooting activities. According to a long-running investigation by the government's conservation agency, Natural England, there was little legal basis for taking action against such

④ In Cape Town, the elite class is often more likely to have private drilling, allowing them to extract groundwater to cope with severe drought problems. However, for those who cannot afford drilling costs, they can only rely on limited municipal water supply. Although private drilling can to some extent alleviate the pressure on municipal water supply, the exploitation of groundwater by the elite has an undeniable impact on the fairness of urban drought response. Similarly, from the allocation of groundwater resources, we can also glimpse similar controversies and challenges faced by other water resources such as reservoirs and surface water in terms of fairness in allocation.

⑤ Moors for the Future, established in 2003, is one of the local partnership projects aimed at bringing together stakeholders from a wide range of landscape fields to protect damaged blanket bog habitats across the Peak District and South Pennines. It is led by the Peak District National Park Authority and has received support and advice from multiple agencies.

landowners, but some analysts report that the agency itself was instructed by the national government to conceal the evidence[55]. At a more local scale, there are frequent conflicts between developers, infrastructure providers, and visitors/tourists regarding local community space, nature conservation, and flood defence or resilience works[54]. Such conflicts are compounded by structural disparities, such as the correlation between the lowest-income households in substandard housing conditions and high flood risk areas, coupled with prohibitive insurance costs[56], and the systematic de-funding of local government since 2010, where the poorest areas have lost around 50% of their previous funding[57].

5.3 Local Practices in Changsha

Communities and organizations in Changsha are actively engaging in efforts to bolster urban resilience. For instance, in 2021, the Yuhua District of the city issued guidelines to enhance urban flood control and drainage capabilities in anticipation of heavy rains[58]. These guidelines included assigning flood control community personnel for underground inspections and flood management. Additionally, subdistrict offices and property management companies proactively participated in flood prevention activities, identifying vulnerabilities promptly, and providing support to affected residents.

Furthermore, residents of Changsha, particularly those directly impacted by disasters, have played a crucial role in disaster response. Acting as primary actors at the micro-level of the urban system, they collaborated to transport sandbags, reinforce embankments, and conduct emergency drills in preparation for rainstorms and floods, as well as participate in post-disaster activities such as clean-up, disinfection, sterilization, and epidemic prevention[59][60].

Although these practices commendably focus on disaster preparedness, response, and community engagement, they must also address a significant underlying issue contributing to urban flooding: the conflict between development and safety. Changsha, like many other rapidly urbanized cities in China, faces multifaceted challenges stemming from economic imperatives and urban expansion. In the past decades, the pursuit of development, driven by economic interests, housing scarcity in city and the desire for prime locations, has resulted in the encroachment upon waterfront areas[61], exacerbating flood vulnerabilities. The current economic slowdown and surplus housing supply prompt critical reassessment of the sustainability of prevailing urban development paradigms and their implications for urban resilience, particularly in the context of escalating flood risks.

5.4 Local Practices in Wenchuan

The aftermath of the 2008 earthquake in Wenchuan has been meticulously examined through long-term research, revealing rich experience in post-disaster response and emergency governance. The Earthquake Relief Headquarter of China effectively coordinated information and command across military personnel, local government, and communities, demonstrating a robust and well-organized response to disasters[62]. The extensive involvement of officers, soldiers, NGOs, foundations, and volunteers in relief efforts reflected the scale and complexity of these efforts.

However, local practices in Wenchuan also uncovered certain gaps, particularly in the technology/infrastructure and economic/livelihood dimensions. Despite substantial investments in critical infrastructure such as water supply, electricity, educational institutions, and transport networks, the regional susceptibility to frequent geological disasters necessitates a cautious approach to engineering disaster mitigation measures. The utilization of check dams to control debris flows has exhibited limitations[63], such as the inability to manage peak flow discharges and the inadvertent exacerbation of debris flow, highlighting the complexities and challenges in post-disaster infrastructure rehabilitation.

Furthermore, examining the economic resilience of Wenchuan 15 years after the earthquake offers insights into the concept of economic resilience. While resilience is often associated with maintaining the status quo and bouncing back, different impacts on individual households within a state-led resilience-building context require further attention and research[64][65]. The observed disparity in economic recovery and development among households in different areas, influenced by economic capacity, accessibility of transportation, and geographic features, underscores the need for a sophisticated understanding of economic resilience at both city and household scales. Wenchuan's experience once again emphasizes a focus on post-disaster response and reconstruction, while indicating less attention to long-term resilience.

5.5 Local Practices in San Juan City

The approach taken by San Juan City to bolster local resilience against disasters underscores the importance of financial assistance and community participation. However, for an island with a large population of minority ethnic groups and relatively lower levels of education, success hinges on adapting strategies to the local cultural and social context.

For instance, the state government of the USA has allocated funds to local communities to improve infrastructure and mitigate disaster risks through programs like the Building

Resilient Infrastructure and Communities, Hazard Mitigation Grant Program, and Flood Mitigation Assistance administered by the Federal Emergency Management Agency (FEMA). Moreover, communities are constantly advocating for inclusion in the recovery process by actively pressing the government's involvement. Public consultations, local labour engagement, collaboration with community leaders, and educational campaigns have been promoted to foster community participation and enhance hazard-resilience[66]. In the aftermath of the hurricanes, communities in San Juan City sought recovery funds from FEMA, facing obstacles such as limited publicity of FEMA funds and cumbersome procedures, which hindered local communities' access to financial assistance[67]. Notably, the damages from these events were exacerbated by the fact that 60% of aid applicants were denied by FEMA due to residents' lack of land ownership documentation[68]. This reveals federal agencies' lack of cultural competence and failure to understand that the absence of land ownership in Puerto Rico is rooted in historical, political, and economic contexts[68].

While the USA government struggles to make funds available to local communities on the island, there is a robust social capital and aid network by the residents who develop their own methods of resilience[69]. These pathways are built through informal planning practices and sometimes illegible for scholars[70]. For instance, the singing and dancing of *bomba*, a local Afro-descendent music genre, have played a significant role in supporting community recovery processes, both in San Juan City and across the island. The vocal aspect of *bomba* introduces a dynamic platform for grassroots participation, as activists and stage organizers, to convey planning and recovery messages. Meanwhile, residents gather in the *batey* (the dancing area), dancing to express their aspirations and response to the planning messages. The interplay of these elements creates a mutually influential grassroots engagement, which serves to promote bottom-up community recovery efforts⑥[70].

5.6 Summary of Local Practices of the Case Study Cities

In the analysis of the five case study cities, on the one hand, local practices to some extent supplemented areas that may have been overlooked in the formal policy framework. In Changsha, extensive participation and innovative practices among residents and communities have yielded valuable insights into building resilience across social/community and economic/livelihood dimensions. On the other hand, local experience has strengthened the key dimensions of policy review. Notably, Cape Town's groundwater exploration, residential drilling, and greywater reuse have enhanced resilience in the dimensions of social/community and technology/infrastructure. The post-disaster response and emergency management in Wenchuan have enriched the political/governance dimension of measures. In San Juan City, the utilization of FEMA-managed funding projects has bolstered its ability to tackle disaster threats like hurricanes and storms, strengthening the resilience in economic/livelihood dimension.

These examples also reveal significant differences between centralized and decentralized governance models. Collaborative efforts between government and relevant stakeholder groups, coupled with local cultural measures, form the bedrock of hazard-resilience. Nonetheless, potential conflicts between top-down policies and bottom-up local initiatives may impact the implementation and effectiveness of resilience policies. Moreover, effective post-disaster response and thoughtful, context-specific technological interventions, along with long-term economic/livelihood resilience-building strategies, are crucial. Addressing these challenges will enhance a city's ability to withstand hazards and minimize the impact on local communities and residents.

6 Conclusions and Discussion

This study has employed a comprehensive methodology, integrating policy analysis and local practice examination, to offer nuanced insights into resilience pathways across diverse urban contexts. An in-depth analysis of five case cities—Cape Town, Greater Manchester, Changsha, Wenchuan, and San Juan City—within a hazard-resilience policy framework, reveals distinct approaches to addressing disaster risk and building resilience. Cape Town's resilience in water infrastructure adaptation, Greater Manchester's focus on climate adaptation and multi-sector cooperation, Changsha's emphasis on government-led planning and community engagement, Wenchuan's multifaceted post-disaster recovery methods, and San Juan City's response to various urban disaster risks collectively underscore the significance of government, financial support, and community participation in enhancing resilience.

However, a common trend across most case cities is the relatively little consideration on the cultural/worldviews and urban-rural-spatial dimensions, especially within governmental planning.

⑥ Singing and dancing to convey disaster response information is a simple and efficient communication method for local residents in San Juan City, which helps compensate for their lack of resilience expertise in conveying disaster response actions.

Bridging this gap is paramount for effectively managing direct technological risks and mitigating the impact of interconnected social risks. Moreover, respect for traditional concepts can foster community participation and enhance cooperation among stakeholders to bolster urban resilience.

Expanding considerations to the urban-rural-spatial dimension is essential for resilient city construction, as rural areas often have less access to resources and services, despite facing similar risks as urban centers. Identifying urban-rural locations of social risks/vulnerabilities can aid in effective disaster recovery planning.

Furthermore, aligning policy formulation with local practices across diverse city sizes and types is essential. Effective coordination between top-down policy-making and bottom-up local practices will facilitate comprehensive regulation of social-environmental systems. Cities should formulate recovery plans tailored to their specific risks and leverage urban resilience networks for shared benefits.

In conclusion, the insights derived from this research offer valuable lessons for cities worldwide grappling with climate changes and natural disasters, contributing to the ongoing pursuit of resilient and sustainable urban futures. Further research could explore the theory and practice of multi-level adaptive governance and the concept of "transformative resilience" in the face of uncertainty.

Competing interests | The authors declare that they have no competing interests.

REFERENCES

[1] Masnavi, M. R., Gharai, F., & Hajibandeh, M. (2019). Exploring urban resilience thinking for its application in urban planning: A review of literature. *International Journal of Environmental Science and Technology*, (16), 567–582.

[2] Carter, J. G., Cavan, G., Connelly, A., Guy, S., Handley, J., & Kazmierczak, A. (2015). Climate change and the city: Building capacity for urban adaptation. *Progress in Planning*, (95), 1–66.

[3] United Nations Office for Disaster Risk Reduction. (2015). *Sendai framework for disaster risk reduction 2015–2030*.

[4] United Nations Office for Disaster Risk Reduction. (2012). *How to make cities more resilient: A handbook for local government leaders (2012)*.

[5] United Nations Office for Disaster Risk Reduction. (2017). *How to make cities more resilient: A handbook for local government leaders (2017)*.

[6] Hofmann, S. Z. (2021). 100 Resilient Cities program and the role of the Sendai framework and disaster risk reduction for resilient cities. *Progress in Disaster Science*, (11), 100189.

[7] Zebrowski, C. (2020). Acting local, thinking global: Globalizing resilience through 100 Resilient Cities. *New Perspectives*, 28(1), 71–88.

[8] Kelman, I., Gaillard, J. C., Lewis, J., & Mercer, J. (2016). Learning from the history of disaster vulnerability and resilience research and practice for climate change. *Natural Hazards*, (82), S129–S143.

[9] Pescaroli, G., Nones, M., Galbusera, L., & Alexander, D. (2018). Understanding and mitigating cascading crises in the global interconnected system. *International Journal of Disaster Risk Reduction*, (30), 159–163.

[10] United Nations Office for Disaster Risk Reduction. (2023). *The report of the midterm review of the implementation of the Sendai framework for disaster risk reduction 2015–2030*.

[11] Manyena, S. B. (2006). The concept of resilience revisited. *Disasters*, 30(4), 434–450.

[12] Fekete, A., Hufschmidt, G., & Kruse, S. (2014). Benefits and challenges of resilience and vulnerability for disaster risk management. *International Journal of Disaster Risk Science*, (5), 3–20.

[13] Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, 18(4), 598–606.

[14] Burton, C. G. (2015). A validation of metrics for community resilience to natural hazards and disasters using the recovery from Hurricane Katrina as a case study. *Annals of the Association of American Geographers*, 105(1), 67–86.

[15] Ravetz, J. (2020). How to Thrive: Resilience-III. *Deeper City: Collective Intelligence and the Pathways From Smart to Wise*. Routledge.

[16] He, J., Meng, Y., & Zheng, P. (2022). Research progress and trends of urban resilience governance in China (2000–2021)—Visual analysis based on CitespaceV. *Journal of Catastrophology*, 37(3), 148–154.

[17] Balch, J. K., Iglesias, V., Braswell, A. E., Rossi, M. W., Joseph, M. B., Mahood, A. L., Shrum, T. R., White, C. T., Scholl, V. M., McGuire, B., Karban, C., Buckland, M., & Travis, W. R. (2020). Social-environmental extremes: Rethinking extraordinary events as outcomes of interacting

biophysical and social systems. *Earth's Future*, 8(7), e2019EF001319.

[18] Endfield, G. H. (2012). The resilience and adaptive capacity of social-environmental systems in colonial Mexico. *PNAS*, 109(10), 3676–3681.

[19] People's Government of Wenchuan County. (2022, June 28). *The draft of the 14th Five Year Plan for ecological environment protection in Wenchuan County (draft for comment) is open for comments*.

[20] Wu, C. T., Gunko, M., Stryjakiewicz, T., & Zhou, K (Eds.). (2022). Introduction to the China Section. *Postsocialist Shrinking Cities*. Routledge.

[21] City of Cape Town. (2020). *City of Cape Town metropolitan municipality: Profile and analysis district development model*.

[22] Research Analytics, Policy and Strategy Department, City of Cape Town. (2023). *Census 2022: Cape Town trends and changes*.

[23] Enqvist, J. P., & Ziervogel, G. (2019). Water governance and justice in Cape Town: An overview. *WIREs: Water*, 6(4), e1354.

[24] Wolski, P. (2018). How severe is Cape Town's "Day Zero" drought?. *Significance*, 15(2), 24–27.

[25] Greater Manchester Combined Authority. (2021). *Greater Manchester resilience strategy 2020–2030*.

[26] BBC News. (2015, December 28). G*reater Manchester flooding: More than 1,100 homes without power*.

[27] Hartley-Parkinson, R. (2019, July 29). *Manchester battered by floods as homes and businesses are left under water*. Metro.

[28] Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2023). *2022 Urban-rural construction statistical yearbook*.

[29] Changsha Municipal Bureau of Natural Resources and Planning. (2021, December 29). *Public announcement of the Overall Territorial Spatial Planning of Changsha (2021–2035)*.

[30] Changsha Hydrological Bureau. (2018, January 31). *Flood analysis of "2017, July 3" extremely heavy rainstorm in Changsha*.

[31] Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2017, February 22). *List of 60 cities with severe waterlogging disasters in recent years*.

[32] The Central People's Government of the People's Republic of China. (2008, May 18). *The China Earthquake Administration revised the magnitude of the Wenchuan earthquake from 7.8 to 8.0*.

[33] The State Council Information Office of the People's Republic of China. (2008, September 4). *Assessment of 5.12 Wenchuan earthquake and its damage*.

[34] The Central People's Government of the People's Republic of China. (2008, July 22). *Wenchuan County and 10 other counties (cities) in Sichuan Province have been assessed as severely affected areas*.

[35] The Central People's Government of the People's Republic of China. (2008, September 22). *As of 12:00 on September 22, the Wenchuan earthquake in Sichuan has confirmed 69,227 deaths*.

[36] Yan Y., Ge, Y., Zhang, J., & Zeng, C. (2014). Research on the debris flow hazards in Cutou Gully, Wenchuan County on July 10. *Journal of Catastrophology*, 29(3), 229–234.

[37] The Central People's Government of the People's Republic of China. (2013, July 10). *Wenchuan, Sichuan: More than 80,000 people were affected by the "7.10" flash and debris flow disaster*.

[38] Chen, S. E., Pando, M. A., Irizarry, A. A., Baez-Rivera, Y., Tang, W., & Ng, Y. (2021). Resiliency of power grid infrastructure under extreme hazards-observations and lessons learned from Hurricane Maria in Puerto Rico. In: J. Neves, B. Zhu, P. Rahardjo (Eds.), *Advanced Geotechnical and Structural Engineering in the Design and Performance of Sustainable Civil Infrastructures: Proceedings of the 6th GeoChina International Conference on Civil & Transportation Infrastructures: From Engineering to Smart & Green Life Cycle Solutions—Nanchang, China, 2021* (pp. 1–17). Springer.

[39] Owens, D. M. (2017, October 13). *Congressional Black Caucus pleads for more help for Virgin Islands*. NBC News.

[40] Brown, P., Vega, C. M. V., Murphy, C. B., Welton, M., Torres, H., Rosario, Z., Alshawabkeh, A., Cordero, J. F., Padilla, I. Y., & Meeker, J. D. (2018). Hurricanes and the environmental justice island: Irma and Maria in Puerto Rico. *Environmental Justice*, 11(4), 148–153.

[41] Kishore, N., Marqués, D., Mahmud, A., Kiang, M. V., Rodriguez, I., Fuller, A., Ebner, P., Sorensen, C., Racy, F., Lemery, J., Maas, L., Leaning, J., Irizarry, R. A., Balsari, S., & Buckee, C. O. (2018). Mortality in Puerto Rico after Hurricane Maria. *New England Journal of Medicine*, 379(2), 162–170.

[42] Mahamed, M. R. (2014). Developing a monitoring and evaluation system for the ceasefire gang violence programme in Hanover Park, Cape Town [Master's thesis]. University of Cape Town.

[43] City of Cape Town. (2019, August 22). *Cape Town resilience strategy*.

[44] Beane, G., Bruebach, K., Ellis, L., Fisher, S., Morgan, G., Munroe, J., Shouler, M., Sobey, M., & Svidran, R. (2020, January 4). *City water resilience assessment: Cape Town water resilience profile*. The Resilience Shift.

[45] Greater Manchester Combined Authority. (2023). *Integrated water management plan (draft plan)*.

[46] Department of Emergency Management of Changsha City. (2023). *Special plan of territorial space for disaster prevention, reduction, and emergency response system of Changsha City (2021–2035)*.

[47] People's Government of Wenchuan County. (2015, May 25). *Emergency Plan for Flood Control and Drought Relief of Wenchuan County (Revised in 2015)*.

[48] Resilient Puerto Rico Advisory Commission. (2018). *Relmagina Puerto Rico report. San Juan, PR*.

[49] O'Connor, S. (2022). *Exploring urban resilience pathways: San Juan, Puerto Rico*. URNet-UIC Barcelona.

[50] García-López, G. A. (2018). The multiple layers of environmental injustice in contexts of (un)natural disasters: The case of Puerto Rico post-Hurricane Maria. *Environmental Justice*, 11(3), 101–108.

[51] Brühl, J., & Visser, M. (2021). The Cape Town drought: A study of the combined effectiveness of measures implemented to prevent "Day Zero". *Water Resources and Economics*, (34), 100177.

[52] Robins, S. (2019). 'Day Zero', hydraulic citizenship and the defence of the commons in Cape Town: A case study of the politics of water and its infrastructures (2017–2018). *Journal of Southern African Studies*, 45(1), 5–29.

[53] Enqvist, J., & van Oyen, W. (2023). Sustainable water tariffs and inequality in post-drought Cape Town: Exploring perceptions of fairness.

Sustainability Science, (18), 891–905.

[54] Ravetz, J., & Connelly, A. (2018). *Review of water governance in Greater Manchester-Full report*. Natural Course Publications.

[55] Monbiot, G. (2013). *Feral: Searching for Enchantment on the Frontiers of Rewilding*. Penguin Books.

[56] White, I., & O'Hare, P. (2014). From rhetoric to reality: Which resilience, why resilience, and whose resilience in spatial planning?. *Environment and Planning C: Government and Policy*, 32(5), 934–950.

[57] Stuckler, D., & Basu, S. (2013). *The Body Economic:Why Austerity Kills*. Basic Books.

[58] Sanxiang City News. (2021, August 24). *How to deal with urban flooding? What are the flood-prone spots in Changsha due to continuous heavy rainfall*. Hunan Today.

[59] Xinhua News Agency. (2017). *Changsha responds to flood danger with full efforts*.

[60] Liu, C. (2017, July, 6). *Changsha Bianshan community actively carries out post-flood cleaning, disinfection, and sterilization*. Hunan Rednet.

[61] Yang, L., Li, H., Feng, C., Peng, L., & Sun, R. (2023). Study on the evolution and adaptability of the river network system under rapid urbanization in the Xiangjiang River Basin, China. *Water*, 15(21), 3768.

[62] The Central People's Government of the People's Republic of China. (2008, May 18). *Notice on the working group composition of the earthquake relief headquarters of the State Council*.

[63] Chen, X., Cui, P., You, Y., Chen, J., & Li, D. (2015). Engineering measures for debris flow hazard mitigation in the Wenchuan earthquake area. *Engineering Geology*, (194), 73–85.

[64] Xiang, T., Welch, E. W., & Liu, B. (2021). Power of social relations: The dynamics of social capital and household economic recovery post Wenchuan earthquake. *International Journal of Disaster Risk Reduction*, (66), 102607.

[65] Yang, B., Feldman, M. W., & Li, S. (2021). The status of family resilience: Effects of sustainable livelihoods in rural China. *Social Indicators Research*, 153(3), 1041–1064.

[66] Andrade, E. L., Barrett, N. D., Edberg, M. C., Seeger, M. W., & Santos-Burgoa, C. (2023). Resilience of communities in Puerto Rico following Hurricane Maria: Community-based preparedness and communication strategies. *Disaster Medicine and Public Health Preparedness*, 17(e53), 1–6.

[67] Molinari, S. (2022). Disaster fraud prevention by exclusion: Property, homeownership, and individual housing repair aid in Puerto Rico. *Centro Journal*, 34(2), 327–351.

[68] García, I. (2022). Deemed ineligible: Reasons homeowners in Puerto Rico were denied aid after Hurricane María. *Housing Policy Debate*, 32(1), 14–34.

[69] Figueroa, O. P. (2022). *Disaster recovery in Puerto Rico: Understanding resilience through the island's communities* [Doctoral dissertation]. University of California, Irvine.

[70] Torres-Cordero, A. L. (2024). Bomba planning and the pursuit of a just recovery. *Planning Theory*, 1–20.

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建设灾害韧性城市：全球五座城市韧性相关政策与地方实践比较研究

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摘要

本研究通过对全球五个典型城市——南非开普敦、英国大曼彻斯特地区、中国长沙和汶川，以及波多黎各圣胡安市——的韧性相关政策和地方实践进行比较分析，探讨了向灾害韧性城市转型的途径。通过构建社会－环境系统下覆盖七个相互关联的维度的概念性框架，本文系统梳理了这些城市在政策文件和地方实践中如何感知灾害风险和处理韧性问题。通过横向对比政策文件，城市间的不同韧性策略得以展现：开普敦采用多种节水措施，通过提高水韧性来应对干旱；大曼彻斯特地区在灾害风险减少方面较为重视人和组织机构的影响与作用；长沙和汶川优先考虑特定的灾害响应措施，而圣胡安市则通过多方面行动来应对环境和社会经济挑战。通过梳理各城市的地方实践，本文展示了当地居民自下而上提升韧性的有效性，相关案例包括开普敦的家庭钻井和长沙的社区参与。然而，整体而言，各城市对文化／世界观维度和城乡空间维度考虑不足。弥合这一差距对于有效的风险管理和灾后恢复至关重要。本文强调应当将政策制定与地方实践相结合，并呼吁优先考虑具有针对性的灾后恢复计划，加强对城乡空间维度的投入。总体上，本研究为构建灾害韧性城市提供了宝贵思路，为城市政策制定者和规划者提供了应对未来挑战和提升城市韧性的基础。

关键词

灾害韧性；政策框架；地方实践；比较分析；韧性路径

文章亮点

- 揭示了开普敦、大曼彻斯特地区、长沙、汶川和圣胡安市这全球五个城市在灾害韧性策略上的差异
- 展现了并未被官方文件所涵盖的地方实践，并强调了自下而上方法的有效性
- 证明了整合自上而下的政策和群众力量对于有效构建城市韧性的关键作用

基金项目

- 科学技术部高端外国专家引进计划“灾害韧性城市的国际比较研究——从风险评估到路径建构”（编号：G2022160005L）
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