Research progress in urban resilience assessments

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Abstract. Against the backdrop of global environmental change and rapid urbanization, how cities can enhance their capacity to withstand and adapt to uncertain risks has become an urgent and emerging topic across related academic disciplines. Urban resilience assessment has consistently been a core focus within urban resilience studies. Current research mainly concentrates on two aspects: assessment methodologies and the construction of indicator systems. Assessment approaches include indicator-based evaluation methods, simulation modeling, and social network analysis. The development of indicator systems generally draws on models such as Primary Side Regulator (PSR), Driving-Pressure-State-Impact-Response (DPSIR), and Baseline Resilience Indicators for Communities (BRIC), selecting indicators that reflect various dimensions of urban resilience, including social resilience, economic/financial resilience, physical/infrastructure resilience, institutional resilience, and environmental resilience.

Keywords: resilience, assessment methods, indicator system, research progress

1. Introduction

Urban areas concentrate populations, infrastructure, and various resources. When sudden events occur, cities often suffer more severe losses. Therefore, greater emphasis should be placed on urban risk management and emergency response. Moreover, rapid population growth has accelerated the depletion of natural resources and worsened environmental pollution, rendering cities increasingly vulnerable and more prone to secondary disasters. These challenges have also raised the difficulty of post-disaster recovery and prevention. Traditionally, cities have prioritized economic growth, yet in the face of unexpected public crises, they often exhibit characteristics of “high input, high energy consumption, and low output,” leading to excessive social costs and making swift recovery unmanageable. In this context, integrating the concept and theory of resilience into urban governance has become an effective response strategy. Consequently, building resilient cities has emerged as a key focus in urban risk governance and emergency management [1]. As an open and complex system, a city’s level of resilience directly determines its capacity to navigate public crises and achieve sustainable development.

2. Conceptual framework

2.1. Resilience

The concept of resilience originated in mechanics, referring to the capacity of materials (such as metals or wood) to recover their original shape after deformation under external force—termed “engineering resilience.” Between the 1950s and 1980s, Western psychology adopted the term to describe psychological recovery after trauma. In 1973, ecologist C.S. Holling was the first to introduce the concept into the field of systems ecology. He defined resilience as a system’s capacity to absorb disturbance, adapt to external shocks, and maintain essential functions, distinguishing it from stability [2]. He further classified resilience into two types: engineering resilience and ecological resilience. Unlike engineering resilience, ecological resilience does not emphasize returning to the original state. Instead, it focuses on the system’s ability to develop a new equilibrium through processes of resistance, absorption, recovery, and transformation—highlighting sustainability [3].

By the 1980s, resilience theory expanded into disaster management, shifting focus from vulnerability to resilience. In the late 1990s, resilience research extended from natural ecology to human ecology, increasingly penetrating the study of social systems—leading to the concept of evolutionary resilience. This form integrates elements from social science, management, and economics, emphasizing adaptability, learning capacity, and innovation. It is widely applied in social resilience research, such as in community resilience studies [4]. Since the 21st century, scholars in urban and regional planning, ecology, and environmental science—particularly in the U.S.—have begun to focus on urban systems' resilience to disasters. As a central element of human ecology, the urban system naturally became a focal point for resilience theory, laying the groundwork for the development of urban resilience as a distinct research domain [5].

2.2. Urban resilience

The integration of resilience theory into disaster management catalyzed the emergence of the urban resilience concept. Urban resilience, a new governance paradigm following the "smart city" concept, refers to a city's ability to survive and thrive despite chronic stresses or acute shocks. It emphasizes adaptive learning and seeks to enhance a city's capacity to endure and recover from disasters. International attention to urban resilience began relatively early. In 2010, the United Nations Office for Disaster Risk Reduction (UNDRR) launched the "Making Cities Resilient" campaign. That same year, ARUP initiated a global resilient cities competition from an urban planning perspective, selecting ten cities worldwide. In 2013, the Rockefeller Foundation launched its "100 Resilient Cities" initiative, providing technical and financial support to help cities build resilience strategies. Several global organizations have since emerged with urban resilience at their core, such as the Resilience Alliance, Resilient City Organization, and Resilient Organization. In March 2013, the UNDRR recommended the global construction of resilient cities to address natural disasters and published supporting reports. The Rockefeller Foundation highlighted five characteristics of urban resilience: inclusiveness, integrity, robustness, redundancy, and flexibility [6]. Domestically, China's 14th Five-Year Plan emphasized building livable, innovative, smart, green, humanistic, and resilient cities. Recent master plans for cities such as Beijing and Shanghai have also incorporated resilient city planning components. Chinese scholar Shao Yiwen, from an urban planning perspective, defined urban resilience as the capacity of systems and regions to maintain public safety, social order, and economic function through adequate preparation, buffering, and response to uncertain disturbances [7]. In summary, urban resilience is characterized by the diversity of urban structures and functions, the ability of alternative systems or components to assume critical roles, and the coordination and collaboration among diverse stakeholders within the urban system to enhance overall functionality.

3. Research methods

3.1. Search strategy

This study uses the China Academic Journals Full-text Database (CAJD) on China National Knowledge Infrastructure (CNKI) as its data source. Using advanced search functions and topic-based search items, keywords such as "urban resilience," "resilient city," "assessment survey," and "evaluation" were employed.

3.2. Information extraction

Articles were included if their research theme aligned with the topic of urban resilience and the research subject was a city. Publications with low relevance or non-research documents such as news reports, conference notices, and work reports were excluded. A total of 54 papers were selected for analysis.

4. Results

Urban resilience assessment primarily focuses on evaluating a city's capacity for organization, adaptation, and recovery in the face of disturbances. Urban systems are inherently limited in their ability to cope with uncertain shocks, and evaluations must consider both spatial integrity and the continuity of functional operations. The theoretical foundations for resilience assessment are largely based on Social-Ecological Systems (SESs) [8] and Complex Adaptive Systems (CAS) [9]. Social-Ecological Systems (SESs) are complex adaptive systems linking human (social systems) and nature (ecological systems), shaped by internal and external drivers. CAS theory posits that each component of the system adapts to disturbances autonomously, and that interactions among heterogeneous agents collectively influence the system's structure and evolutionary path. Urban resilience assessment research focuses primarily on two areas: (1) Assessment Methods; (2) Evaluation Indicator Systems [10]

4.1. Urban resilience assessment methods

Urban resilience assessment includes both domain-specific and comprehensive evaluations of urban systems (as shown in Table 1). These methods are generally divided into qualitative and quantitative approaches. When selecting a method, it is important to consider the real-world context and the nature of the method, balancing strengths and limitations while emphasizing the intrinsic characteristics of resilience. Currently, the field is shifting from qualitative to more mature quantitative methods. Qualitative methods, such as conceptual frameworks or case studies, offer theoretical foundations but often lack quantifiability and practical applicability [11].

Table 1. Urban resilience assessment methods

Method Type	Specific Method	Description	Advantages	Limitations
Qualitative	Survey Method	Uses questionnaires or interviews to gauge attention and perception of urban resilience among social groups, organizations, and individuals.	Highly subjective but operationally feasible.	High cost; results influenced by respondent bias.
	Document Analysis	Collects and analyzes city resilience data, typically forming a conceptual framework to classify and assess resilience levels.	Reliable data sources can illustrate resilience status clearly.	Lacks flexibility and limits in-depth analysis.
Quantitative	Indicator-Based Assessment	Builds an indicator system with weighted metrics to evaluate urban resilience.	Simple calculation and easy operation.	Susceptible to subjective bias in weighting; low comparability across cases.
	Model Simulation	Uses mathematical functions to evaluate resilience and interactions among resilience factors.	Clarifies interactions among components; explains causes of resilience.	Lack of consensus on definitions and relationships.
	Social Network Analysis	Analyzes network node structures and relationships using big data or GIS tools to identify structural features.	Effectively reflects inter-system linkages.	Does not simulate spatial scenarios; suffers from data limitations and inaccuracies.
	Scenario Analysis	Simulates future development and management scenarios based on resilience mechanisms and narratives.	Models multiple-factor interactions under various scenarios; supports spatial simulation.	Focuses more on reducing specific risks than broader adaptability.
	Resilience Maturity Model (RMM)	Analyzes cities through five stages (Initial, Intermediate, Advanced, Robust, Enhanced) with corresponding strategies.	Suitable for explaining systemic complexity and iterative development.	Limited in spatial simulation; typically applied to specific systems.
	Layer Overlay Method	Maps components of resilience and overlays them spatially.	Provides intuitive, visual representation of resilience.	Cannot reflect the weight or impact of individual factors.
	Threshold Method	Identifies system thresholds or tipping points.	Suitable for evaluating SESs or ecological resilience capacity.	Ignores individual variability, limiting application.

Various scholars have applied both qualitative and quantitative methods: Saja [12] proposed the “5S” model for social resilience, establishing an indicator system through qualitative features. Qiu Baoxing and colleagues employed CAS theory to build mathematical models for simulating resilience functions. Bruneau et al. [13] developed resilience function curves for infrastructure using probability, vulnerability, and resilience functions—bringing operational feasibility to resilience simulation. Davidson et al. [14] created a resilience process model for power infrastructure, measuring resilience through recovery time from economic loss. Chen et al. [15] described urban resilience as an outcome, using the time to control an epidemic as a measurement index. Social Network Analysis methods, based on graph theory and probability, are used to map interrelations in disaster management [16]. For instance: Peng [8] applied Gephi to assess the structural resilience of city clusters and spatial features, highlighting data access and accuracy challenges. Zhang et al. [17] used scenario simulation, combining multi-agent modeling and Ordered Weighted Averaging (OWA) to simulate Social-Ecological Landscape Resilience (SELR). Sun [8] used the layer overlay method with GIS spatial analysis, applying SES theory to assess city-level resilience in the Yangtze River Delta. Mixed-method approaches are increasingly common: Bixler et al. [18] combined interviews with network analysis to connect urban networks with resilience planning. Li et al. [19] proposed a multi-stage evaluation framework based on resilience values and threshold analysis, using early warning indicators for social-environmental system resilience.

4.2. Urban resilience evaluation indicator systems

In 2011, the Regional Institute at the State University of New York at Buffalo developed the Resilience Capacity Index (RCI). This framework categorizes the United States’ risk response capacity into three dimensions comprising a total of twelve indicators: Regional Economic Capacity: Income equality, economic diversity, regional affordability, and business environment. Community Demographics: Educational attainment, disability ratio, poverty reduction rate, and health insurance coverage. Community Connectivity: Urban form, urban stability, home ownership rate, and voter participation [20]. In 2014, the Rockefeller Foundation in the United States proposed a comprehensive urban resilience framework based on its extensive global research. The framework evaluates resilient cities across four domains: Leadership and Strategy, Health and Wellbeing, Economy and Society, and Infrastructure and Environment [21]. Su et al. [22], applying the DPSIR model (Driving forces – Pressures – State – Impact – Response), constructed a city resilience evaluation indicator system comprising 25 indicators across 11 element layers. This system was empirically applied to assess the resilience of 11 cities within the Guanzhong urban agglomeration. From a public health perspective, in April 2020, the United Nations Office for Disaster Risk Reduction (UNDRR), in collaboration with the World Health Organization (WHO) and other institutions, developed a Public Health System Resilience Scorecard. This tool complements the existing Urban Disaster Resilience Scorecard with a focus on public health. It uses scenario-based scoring to cumulatively evaluate indicators. Unlike standardized indicator sets, this tool aims to identify risks within urban public health systems, promote inter-agency collaboration and information sharing, and allows users to determine indicator weights themselves. Yang et al. [23] and Lin et al. [24] constructed indicator systems based on the BRIC model [25]. Zhu et al. [26], using the Fuzzy Delphi Method, established a comprehensive evaluation indicator system for sponge city resilience. It includes five dimensions and 25 indicators and was empirically applied to the sponge city pilot in Pingxiang. Chang et al. [27], taking the COVID-19 outbreak in Shanxi Province as a case, constructed a resilience measurement system for 11 cities, using four dimensions: stability, sensitivity, adaptability, and government efficiency. Wu et al. [28] selected 20 indicators from five dimensions—economy, society, ecology, infrastructure, and technological innovation—to construct a comprehensive resilience evaluation system. They applied the entropy weight method, variance decomposition, and obstacle factor diagnosis to evaluate the overall, component, and limiting factors affecting urban resilience in nine national central cities from 2008 to 2020. Zhang et al. [29] established an urban resilience evaluation system from four perspectives: social, ecological, infrastructure, and economic resilience, determining indicator weights using the entropy weight method. Urban resilience research can adopt either single-dimensional or multi-dimensional approaches. Due to the complexity of urban systems, multi-dimensional frameworks have gained broader recognition among scholars. In general, resilience indicator systems select from five core dimensions: Social Resilience; Economic/Financial Resilience; Physical/Infrastructure Resilience; Institutional Resilience; Environmental Resilience. These systems typically include a mix of common and context-specific indicators.

5. Discussion

Overall, qualitative methods offer the advantage of fully leveraging expert knowledge to provide a comprehensive and systematic understanding of urban resilience. However, they are often influenced by subjective judgment. Most qualitative assessments focus on single domains—such as climate change or flooding—because domain-specific urban resilience is easier to analyze in terms of causal mechanisms and measurable indicators. By contrast, comprehensive resilience spans multiple fields, involves complex causal chains, and poses challenges for quantitative evaluation. Given that cities are complex coupled systems, the coordinated development of subsystems is vital for healthy and sustainable urban growth. Thus, it is necessary to enhance integrated assessments of urban resilience. Nevertheless, due to the inherent complexity and dynamism of urban systems, the wide range of indicators, and intricate causal relationships, developing a comprehensive resilience evaluation system remains difficult. Future research should integrate knowledge from diverse fields to establish a clear and operational definition and assessment standard for urban resilience.

From a practical perspective, key questions in resilience research include how cities maintain functionality in the face of external risks and how they can recover quickly from disturbances. Governments, researchers, and the public have shown increasing concern in this area. Therefore, future work should advance in three directions: 1. Emphasize Process-Based Resilience Analysis: Investigate how urban systems respond to disturbances over time, analyze changes in system states, response capacities, and stakeholder engagement during various stages, and identify key issues. 2. Advance Methodological Rigor and Dynamism: Strengthen studies on human–environment coupled systems, the interactive mechanisms of influencing factors, and the development of early warning and predictive models. Integrate quantitative and qualitative methods to enhance analytical precision. 3. Enhance Systematic and Scientific Understanding of Resilience: Promote interdisciplinary collaboration and apply empirical findings to develop innovative applications for urban resilience. Explore how resilience mechanisms and evaluation outcomes can be seamlessly integrated with urban governance, enabling evidence-based decision-making by city managers.

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