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Progress in Research on Influencing Factors and Assessment of Urban Resilience

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Abstract: In recent years, with the accelerated process of urbanization, the continuous growth of urban areas and population sizes has posed higher demands on urban earthquake safety. The theory of resilient cities offers a new approach to effectively address urban earthquake safety risks. However, there is still a lack of reasonable methods for assessing and constructing urban seismic resilience both domestically and internationally. Therefore, this paper elucidates the connotation, essential characteristics, components, and evaluation indicators of a seismic-resilient city, summarizing the components of urban seismic resilience as "one fundamental, two guarantees," which include the engineering system, institutional system, and social and economic system. This paper establishes a dual-parameter urban seismic resilience assessment method based on post-earthquake losses and recovery time, proposing a "set goals, assess, improve, reassess" approach for building resilient cities. The proposed method can provide theoretical guidance and practical basis for assessing and enhancing the seismic resilience of individual infrastructures, engineering systems, urban systems, and resilience to other disasters.

Keywords: Urban seismic resilience; components; evaluation indicators; resilience assessment methods and construction

I. INTRODUCTION

China is situated between two major seismic belts, experiencing intense neotectonic movements. Approximately 70% of China's land area is located in seismic fortification zones of VII degree or above, and 40% of cities with populations over one million are threatened by strong earthquakes.

Earthquake disasters are highly sudden, with significant potential hazards and wide-ranging impacts. As areas with the highest concentration of resources and elements, cities are characterized by large-scale infrastructure, a mix of old and new buildings, and a complex, diverse, and dense development trend. The infrastructure systems are densely distributed, and people and social wealth are highly concentrated. With the continuous expansion of urban scale and the rapid increase in urban population, the disaster risks faced by cities are also growing.

Currently, the disaster resilience of Chinese cities has not yet adapted to the needs of economic and social development. If a major city experiences a severe disaster, the complexity of disaster types, the evolution of disaster situations, and the social impact will increase, making emergency rescue more challenging and potentially leading to a rapid loss of urban functions. For example, the catastrophic earthquakes on January 17, 1994, in Northridge, Los Angeles, California, and on January 17, 1995, in the Hanshin area, the second-largest metropolitan area in Japan, exposed the seismic vulnerability of modern urban areas. These events prompted deep reflection on earthquake disaster response, defense, and resilient city construction.

The disaster risk prevention and control of major cities, urban agglomerations, and significant infrastructure have become crucial for global sustainable development.

With China's economic development and the implementation of the new urbanization strategy, enhancing urban safety under natural disaster scenarios has become a significant national demand. Urban seismic resilience refers to the ability of urban systems to maintain or quickly restore their functions when affected by earthquake disasters, providing a fundamental solution to urban disaster vulnerability. A seismic-resilient city should have the capability to resist earthquake disasters, recover quickly, and adapt rapidly, reflecting the combined effects of engineering and non-engineering factors.

II. DISTINGUISHING BETWEEN RECOVERY, RESILIENCE, AND ROBUSTNESS

In recent years, with the introduction of the concept of resilience by the international academic community, the understanding and translation of this term in China have become diversified. This has led to confusion among the concepts of recovery, resilience, and robustness. To avoid this conceptual confusion, it is necessary to clearly distinguish between these three terms.

Some scholars do not make essential distinctions between recovery, resilience, and robustness. For example, Yan Haiming believes that recovery emphasizes the ability of a system to resist external disturbances, self-organize, learn, and adapt when facing complex adaptive challenges. Guan Haoming supports the view that resilience is the system's ability to respond to disturbances by triggering changes, adaptation, and transformation, with the system always being in a state of continuous dynamic change. However, these explanations do not fully distinguish the fundamental characteristics of recovery, resilience, and robustness.

Recovery refers to the ability of a system to return to its initial normal state in a short period after experiencing minor disturbances. It mainly focuses on the system's ability to quickly recover and restore its original condition after being disturbed.

Resilience emphasizes the system's ability to restore balance in a short period after experiencing minor or moderate disturbances. Resilience focuses more on the system's short-term response capability and recovery speed, i.e., the ability of the system to return to its pre-disturbance state in a short time.

Robustness, on the other hand, is oriented towards coping with disturbances of varying scales. It emphasizes the system's dynamic balance ability to continuously achieve self-adaptation and self-recovery during the process of change. Robustness not only focuses on the system's short-term response ability but also its ability to adapt and sustain changes over the long term in the face of various types of disturbances. Robustness reflects the comprehensive ability of the system to self-adapt, self-recover, and maintain long-term stability when facing disturbances of different scales and types.

Clearly, recovery, resilience, and robustness each have distinct focuses regarding the scale, time, and capacity of responding to disturbances. Recovery emphasizes the ability to recover from minor disturbances in the short term; resilience emphasizes the ability to restore balance from minor or moderate disturbances in the short term; robustness integrates the concepts of recovery and resilience, highlighting the system's advantage in coping with various scales of disturbances and adapting to risks over the long term.

Although recovery, resilience, and robustness have different emphases conceptually, they are also interrelated. Robustness incorporates the rapid response of recovery and the balanced recovery ability of resilience, becoming the optimal defense line for the system against disturbances. Robustness highlights the system's ability to cope with different types of disturbances at any time and adapt to risks over the long term, making it a key capability in dealing with complex environmental changes.

Through the above analysis, it can be seen that recovery, resilience, and robustness, although different in their conceptual connotations and emphases, are interconnected in their responses to disturbances. Together, they form a comprehensive capability for systems to cope with risks and changes. Clearly distinguishing between these three concepts helps better understand and apply resilience theory, enhancing the system's ability to respond to complex environments and various disturbances.

III. COMPONENTS AND SAFEGUARD SYSTEM OF URBAN SEISMIC RESILIENCE

Resilience refers to the ability of a system or community to maintain functionality, resist shocks, adapt, and recover its functions when faced with external environmental disturbances. The concept of resilience was first applied in ecological studies in the early 1970s and gradually expanded to other fields. By the early 21st century, the concept was introduced into the study of urban complex systems, giving rise to the concept of a "Resilient City." In the event of a disaster, a resilient city can withstand shocks, respond quickly, recover, and maintain the normal operation of urban functions, thus better adapting to future disaster risks. Urban seismic resilience refers to the ability of an urban system to maintain or restore its functions when affected by an earthquake. Its core objective is to ensure that, after an earthquake disaster, the engineering structures, the city, and even the entire society can maintain or quickly restore functionality and withstand rare seismic events. In terms of resilience, urban seismic resilience encompasses systemic, functional, and recovery characteristics, offering a broader scope compared to traditional structural seismic studies.

Traditional seismic research primarily emphasizes the seismic performance of individual engineering structures, whereas resilience research focuses more on the overall performance of urban integrated systems. In terms of time, traditional seismic research often concentrates on the performance at the moment of the earthquake, while seismic resilience research emphasizes the entire process of response and recovery. From a scientific perspective, traditional seismic studies focus on the seismic performance of structural components, whereas seismic resilience emphasizes whether the system composed of both structural and non-structural components can maintain its functionality.

The normal functioning of urban engineering systems under seismic effects is the cornerstone of urban seismic resilience. However, it also requires the support of "institutional resilience" and "socio-economic resilience" to ensure its effectiveness. Based on the above discussion, the components of urban seismic resilience can be summarized as "one fundamental and two safeguards."

Engineering Resilience refers to the ability of buildings and infrastructure in the city to maintain their structural integrity and functionality during an earthquake. Engineering resilience is the foundation of urban seismic resilience and a crucial prerequisite for achieving overall urban resilience.

Institutional Resilience refers to the city's ability to quickly restore normal order and functionality after an earthquake through sound institutions, effective management, and efficient emergency response mechanisms. Institutional resilience includes the formulation and practice of emergency plans, the implementation of post-disaster recovery plans, and the coordination and cooperation among various social departments.

Socio-Economic Resilience refers to the ability of the urban social and economic systems to recover quickly from earthquake disasters. Socio-economic resilience is reflected in a robust social support network, the reserve and allocation of economic resources, and the psychological resilience of the society. These factors collectively ensure that the city can rapidly resume normal production and living conditions after a disaster.

A. Engineering Resilience

Urban engineering systems include building complexes and infrastructure, which are crucial for maintaining the social and economic functions of a city. They are central to urban seismic resilience. Engineering resilience primarily involves the following elements:

1) Building Complexes

The damage and collapse of building complexes are major factors contributing to casualties and economic losses. Additionally, building complexes can support emergency rescue and post-disaster recovery efforts by providing shelter and workspace, facilitating the deployment of rescue personnel and equipment, and playing a vital role in the city's emergency response.

2) Power Supply System

The power supply system is one of the most critical infrastructure systems. Its disruption directly affects the operation of other systems. The resilience of the power supply system can reduce damage to electrical equipment, transmission lines, and substations during an earthquake, ensure reliable power supply, minimize disruptions to daily life and economic activities, and support emergency and communication needs.

3) Transportation System

The transportation system provides evacuation routes and access for the removal of people and goods after an earthquake. It helps reduce damage to roads, bridges, and transportation facilities, ensures clear transportation routes, and facilitates the swift delivery of rescue personnel, supplies, and equipment to affected areas. Additionally, the transportation system can offer temporary facilities and transport capacity, supporting post-disaster reconstruction and supply chain recovery.

4) Water Supply System

The resilience of the water supply system can minimize damage to water sources, treatment facilities, and distribution networks, ensuring a continuous water supply. This is essential for meeting the basic needs of disaster-affected populations and supporting emergency rescue and recovery efforts.

5) Drainage System

The resilience of the drainage system can reduce damage to sewers, drainage networks, and pump stations, ensuring effective drainage and helping to mitigate flood and waterlogging risks caused by earthquakes. This protects people and buildings from water damage.

6) Gas Supply System

The resilience of the gas supply system can minimize damage to gas pipelines and facilities, reducing the risk of gas leaks and fires.

7) Heating System

The resilience of the heating system can lessen damage to heating equipment, pipelines, and distribution systems, ensuring continued heating capacity and providing essential living conditions for affected areas during an earthquake.

8) Communication System

The resilience of the communication system can reduce damage to communication facilities, base stations, and network systems, providing crucial communication channels for emergency rescue and post-disaster recovery. It ensures the reliability of telephone and internet communications.

9) Healthcare System

The resilience of the healthcare system can reduce damage to medical facilities, ensuring the availability of medical resources. This supports emergency medical treatment and care for injured individuals, reduces casualties, and accelerates rescue efforts.

B. Institutional Resilience

Building urban seismic resilience requires not only engineering measures but also a comprehensive approach that considers the city's institutional aspects, including policies, laws, and planning. Institutional resilience can be summarized into the following key elements:

1) Establishment and Implementation of Disaster Prevention and Mitigation Laws.

The creation and enforcement of disaster prevention laws provide a legal basis and guidance for earthquake preparedness and response. These laws clarify responsibilities and obligations for various stakeholders, promote the development of earthquake early warning systems, risk assessment, and monitoring measures, and enhance the capacity for predicting and responding to seismic events. This is crucial for improving overall societal resilience.

2) Timely Updating and Implementation of Seismic Standards and Codes

Regular updates and implementation of seismic standards and codes ensure that the latest scientific and technological advancements, as well as earthquake damage experiences, are integrated into engineering practices. This improves the safety of buildings and infrastructure. These standards and codes also provide guidance for governments, developers, and construction professionals, raising the awareness of seismic responsibilities across society.

3) Development of Urban Emergency Management Plans and Platforms

The establishment of emergency management plans offers guidance for responding to earthquake disasters, specifying the roles and responsibilities of various levels of government and related departments, and outlining emergency response procedures. Emergency management platforms facilitate information sharing, command and coordination, and disaster monitoring, ensuring efficient operation of disaster relief and resource allocation.

4) Establishment of Earthquake Early Warning Systems

Earthquake early warning systems can quickly and accurately send warning information to city residents and relevant organizations, allowing them to take emergency actions and seek safety. These systems also enhance coordination in emergency responses, including evacuation plans, rescue preparations, and medical resource allocation, thereby minimizing casualties and property damage caused by earthquakes.

5) Institutionalization of Earthquake Emergency Drills

Regularly conducted earthquake emergency drills ensure that governments, departments, and organizations at all levels regularly practice and refine their emergency response skills. These drills test and validate the feasibility of emergency plans and provide practical opportunities to enhance personnel's emergency skills.

6) Implementation of Earthquake Insurance Systems

Earthquake insurance systems provide economic protection for individuals, families, and businesses, alleviating financial losses caused by earthquakes. This helps to strengthen societal disaster resistance and recovery capabilities, reducing the burden of post-disaster reconstruction.

IV. FACTORS INFLUENCING URBAN RESILIENCE

Identifying influencing factors is a key foundation for constructing an urban resilience assessment system. This identification simplifies the description of urban resilience levels and supports urban decision-making. Based on the concept of urban resilience proposed in this paper and existing research, we summarize the impact of multiple disturbances, the state of urban systems, and their coping capacities on urban resilience from a process-oriented perspective. The aim is to provide theoretical references for the construction of an urban resilience assessment indicator system.

A. The Impact of Diverse Disturbances on Urban Resilience

In the development of resilient cities, urban systems face challenges from various disturbances. Acute disturbances are characterized by their unpredictability, suddenness, and strong destructive impact, making them difficult to forecast. In contrast, chronic disturbances act slowly and may not pose immediate threats to cities, but once these disturbances reach a certain threshold, they can fundamentally alter the essential attributes of urban systems. Disturbances can be broadly categorized into natural and non-natural sources. Natural disturbances are external to the city and occur universally, while non-natural disturbances stem from human environments and their impacts on urban resilience are influenced by human activities.

As pressures on resilient cities, disturbances manifest in the following three ways. Firstly, the frequency, intensity, and duration of disturbances affect urban resilience. Generally, as disturbances become more frequent, intense, and prolonged, urban resilience tends to decline more significantly. Secondly, cities face multiple and complexly interconnected disturbances, with different combinations of disturbances exerting varied pressures on urban resilience. Thirdly, there are cascading effects among disturbances, where one disturbance can trigger multiple others through multi-level chain reactions. When multiple disturbances coexist, one disturbance can alter the state of others.

For instance, the 2011 Great East Japan Earthquake and the accompanying tsunami affected 474 cities in Japan, altering urban distribution patterns and resulting in economic losses of $157.5 billion. Clearly, excessive disturbances pose serious threats to human health and well-being, cause significant economic losses, and present risks to enhancing urban resilience and sustainability.

B. The Impact of Urban System State on Urban Resilience

The condition of urban systems significantly influences their resilience levels when facing various changes and disturbances. Currently, many scholars describe the state of urban systems from the perspective of their constituent elements, mainly analyzing the impact of material (infrastructure, ecology) and non-material elements (economy, society, organization) on urban resilience.

Infrastructure is the primary disaster-bearing body of a city and the first line of defense against disasters. It is a crucial carrier for ensuring the resilience of urban systems and the normal production and living activities of residents. Urban infrastructure includes buildings, transportation facilities, public utilities, and communication facilities.

These provide residential and workspaces for the urban population. According to Pal et al., reducing the vulnerability of buildings and enhancing their safety performance is the foremost barrier to ensuring the safety of people and property.

Transportation Network: This plays a vital role in disaster relief. Better road traffic performance facilitates rescue efforts.

Public Utilities and Communication Facilities: These maintain the flow of materials and information with the outside world. They provide essential services such as water, electricity, and gas to urban residents, meet the hardware needs for education, healthcare, and recreational activities, and support the development of urban resilience.

The ecological environment is a crucial carrier for coordinating the relationship between humans and urban environments. It integrates the ability to resist disturbances through various ecosystem services such as provisioning, regulating, cultural, and supporting functions, playing a significant role in maintaining urban ecological security and enhancing urban resilience. The main factors influencing urban resilience through the ecological environment include the type, quality, and spatial characteristics of the ecological environment. Urban ecological environments are primarily divided into natural environments and human-dominated urban ecological landscapes.

C. The Impact of Non-Material Elements on Urban Resilience

The urban economic system provides the material foundation and economic security for building urban resilience. It also serves as a dynamic force in regulating and maintaining urban resilience. Existing research shows a positive correlation between urban economic development and resilience. The level and pattern of economic development affect infrastructure construction, social development maturity, and the city's ability to respond to disturbances. Urban adaptability is also influenced by factors such as economic diversity, fiscal capacity, economic vitality, innovation capability, and economic potential. Furthermore, cities that maintain close economic ties with external entities while being less dependent on external economies are better positioned to secure resources and overcome disturbances. In urban economic operations, the moderate efficiency of the production-supply-consumption chain accelerates the formation of urban resilience. However, excessively high economic efficiency, achieved at the cost of expanded production scales, can increase environmental dependence and socio-economic costs, thereby inhibiting the development of urban resilience. Thus, urban resilience is influenced by the economic foundation (development level and pattern, diversity, potential, vitality, capital reserves), innovation capacity, external dependence, and operational efficiency.

The social environment is closely related to human life. A stable social environment ensures the well-being of residents and sustains the development of urban resilience. Many scholars have incorporated specific aspects of the social environment into urban resilience assessment systems. These aspects include housing conditions, healthcare availability, insurance coverage, social capital, community participation, demographic characteristics, social risks, human capital, and lifestyle factors. In recent years, social equity has emerged as a core issue in shaping resilient cities. This includes the vulnerability of disadvantaged groups, poverty issues, environmental justice, and public participation in decision-making.

Additionally, comprehensive social security coverage, high educational standards and public awareness, and reasonable urban population size and structure contribute to enhancing urban resilience. Overall, the social environment encompasses health, education, capital, equity, population, employment, and security, each of which contributes to strengthening urban resilience.

D. Response Capability

The objective of response capability is to reduce resilience losses caused by disturbances. The level of this capability primarily depends on the urban system's abilities to prevent, recover, and learn/adapt, corresponding to the phases of planning, recovery, and adaptation in the lifecycle of a resilient city.

This forms the first line of defense against disturbances and includes monitoring and early warning systems, emergency plan formulation, and pre-disaster reserves. Monitoring and early warning systems leverage 3S technologies (GIS, remote sensing, GPS) to create big data platforms for real-time disaster data. Emergency plans provide detailed action strategies at all levels, and pre-disaster reserves ensure that cities have adequate emergency relief supplies, high-mobility human resources, and redundant infrastructure when facing disturbances.

The government is the primary actor in implementing urban recovery, employing various governance measures to mitigate the negative impacts of disturbances. For example, increasing building seismic standards and enhancing post-earthquake emergency repair efforts are fundamental to earthquake disaster prevention and mitigation. Sponge city construction and improved stormwater management are key measures in flood control systems. Financial support from social funds, fiscal budgets, and green finance is crucial for environmental management under the ecological civilization strategy.

This refers to a city's ongoing process of learning from experiences and creating new knowledge, enabling the city to build resilience against future disturbances. It is a dynamic cycle where experiences, knowledge, and actions are transformed into policies, laws, regulations, and standards. This continuous integration of new experiences and knowledge provides a reference for decision-making in resilient cities.

Innovation capability is a crucial driving force for enhancing urban resilience. Current research focuses on knowledge innovation and technological innovation.

Building resilient cities relies on both internal and external knowledge innovation. Internal innovation emphasizes deriving knowledge from the city's resilience practices, while external innovation benefits from external knowledge and resource support. Additionally, fostering knowledge exchange among talents from different fields contributes to the innovation and improvement of resilient urban theories and practices.

Through continuous updates and technological iterations, cities can achieve greater resilience. Modern technologies such as information and communication technology (ICT), digital technology, artificial intelligence (AI), Internet of Things (IoT), and remote sensing have replaced traditional methods, enabling city managers to accurately and efficiently monitor the state of urban resilience anytime and anywhere. Furthermore, the innovative thinking and creativity of scientific researchers, combined with the investment in innovation by urban decision-makers, play significant roles in enhancing urban resilience.

V. URBAN RESILIENCE ASSESSMENT

A. Domains of Urban Resilience Assessment

Urban resilience assessment can be divided into single-domain and multi-domain assessments. Single-domain assessments focus on evaluating a single element within the city, such as infrastructure, disasters, energy, networks, psychology, community, and social-ecological systems. Multi-domain assessments combine various factors, including social, economic, ecological, institutional, and physical elements, to evaluate the overall resilience of the city, reflecting its comprehensive adaptability to changes. Due to the complexity and wide range of factors involved in multi-domain assessments, as well as the difficulty in obtaining complete data, current research often emphasizes single-domain assessments.

These assessments focus on how cities respond to specific disturbances. However, cities are complex systems encompassing multiple sub-environments, constantly facing challenges from various sources. Therefore, urban resilience assessments need to focus on the city's overall, comprehensive, and systematic nature, integrating all urban elements to maximize their effectiveness in mitigating multi-source disturbances and enhancing resilience.

B. Urban Resilience Assessment Indicator System

Assessment indicator systems based on urban resilience components are widely used. The Rockefeller Foundation’s 100 Resilient Cities (100RC) framework includes four dimensions—health and well-being, economy and society, infrastructure and environment, and leadership and strategy—encompassing a total of 50 indicators. Other frameworks divide urban resilience into natural, economic, social, physical, and institutional dimensions. Commonly used dimensions in urban resilience assessment systems include natural, social, economic, infrastructure, and organizational environments. Due to data availability, indicators for natural, social, economic, and infrastructure environments are more widely applied than those for organizational environments.

Assessment indicator systems based on urban resilience characteristics are directive frameworks that help cities develop specific resilience traits. Functional characteristics of resilient cities include sensitivity, resistance, adaptability, inclusiveness, efficiency, innovation, and connectivity, while structural characteristics include diversity, redundancy, robustness, and modularity. Early assessments incorporated robustness and speed, with additional traits added based on regional development needs. Some scholars combine city characteristics with urban components, aiming to configure elements to achieve corresponding resilience traits. For instance, resilience traits such as resistance, redundancy, intelligence, and rapidity are reflected in socio-political-technical, economic, and hydrological aspects, while the integration of physical, human, and socio-economic elements fosters sensitivity, responsiveness, interactivity, and growth.

Assessment indicator systems based on the process of achieving urban resilience use time as an axis to quantify the city’s ability to respond to disturbances at different stages. For example, Ouyang assesses urban infrastructure resilience through resistance, absorption, and recovery stages, while Zhang evaluates disaster resilience by examining the physical system's resistance followed by human societal feedback during rainfall-induced landslides. In the Yangtze River Delta region, resilience levels of industrial cities are assessed through resistance, renewal, repositioning, and recovery capabilities. Drawing from the "Pressure-State-Response" model in safety domains, some studies dynamically assess the resilience capacity of cities like Huangshi in response to disturbances. Given the complex chain of influencing factors and the varied perceptions of resilience processes, fewer assessment systems have been constructed based on resilience processes.

The prevailing approach to constructing urban resilience assessment indicator systems primarily involves dividing elements, with characteristics and processes serving as supplementary divisions. Due to differences in scholars' expertise and conceptual approaches, the selection of indicators varies significantly, although there are common indicators widely used (see Table 3). Overall, indicators established based on the frameworks of urban elements, characteristics, and resilience processes exhibit certain correspondences.

Indicators based on elements correspond to various resilience characteristics of urban areas. For example, resistance is the most commonly used characteristic, linked to many indicators, signifying that enhancing the ability of urban system elements to withstand disturbances is a key strategy for maintaining urban resilience. Inclusiveness corresponds to the attention given to vulnerable groups within society, while efficiency reflects an organization’s ability to quickly respond to issues through monitoring systems and information feedback.

In indicator systems constructed based on process thinking, state indicators dominate. These indicators integrate various elements of the city, with stress corresponding to sensitivity indicators and response primarily aligning with organizational element indicators. However, most existing research constructs indicator frameworks from a single perspective, lacking connections between urban resilience elements, characteristics, and processes.

In reality, identifying the resilience characteristics exhibited by urban elements and their roles in achieving resilience is crucial for developing a comprehensive assessment indicator system. Therefore, when constructing indicator systems, it is essential to link ecological, economic, social, infrastructure, and organizational aspects with urban resilience characteristics and processes.

From an indicator perspective, social element indicators combine objective and subjective metrics, with human attitudes and perceptions of risk becoming vital components in building resilient cities. For instance, Saja et al. incorporated community values and perceptions of local risks into social resilience assessments, while Zhong et al. highlighted the importance of children's risk awareness in enhancing disaster resilience and climate change adaptation. Li et al. assessed public risk perceptions in China from aspects such as risk concern, benefits, risk, acceptance, and trust.

Due to the limitations in data accessibility, indicators related to organizational elements, non-natural disturbances, and vulnerable groups are less frequently applied, leading to the marginalization of diverse stakeholder participation. Future efforts should aim to include more indicators related to organizational management and implementation effects, multiple disturbances, disaster-vulnerable groups, and multi-stakeholder participation. Continual tracking and innovation of indicators are necessary to meet evolving societal needs, ultimately establishing a comprehensive and scientifically sound evaluation indicator system that combines objective and subjective measures. Currently, urban resilience assessment methods are transitioning from qualitative analysis to mature quantitative analysis. Qualitative methods primarily use conceptual frameworks or case studies as their endpoints. These methods provide theoretical foundations for quantitative approaches but often overlook the quantifiability and practical application of conceptual frameworks. In quantitative methods, single-domain assessment techniques are relatively well-developed. For example, threshold and surrogate methods are commonly used in ecosystem assessments, lag effect models are frequently applied in urban economic studies, and network models are often employed in the evaluation of urban infrastructure and social networks. In contrast, comprehensive urban assessment methods are relatively scarce, with composite indicators being the most widely used method for evaluating overall urban resilience. The academic community has made significant progress in refining quantitative methods. Current efforts mainly focus on measuring the static levels of urban resilience under a single disturbance and identifying key influencing factors. However, as a long-term development goal for urban systems, achieving resilience requires the accumulation of resilience across various subsystems, the coupling and feedback of multiple mechanisms, and dynamic early warning systems. These challenges and key points are the main constraints on the quantitative assessment methods of urban resilience.

VI. CONCLUSION

Facing diverse and frequent disasters, urban resilience provides new guidance for urban development, helping cities flexibly respond to disturbances and enhance their ability to withstand disruptions. It breaks away from the traditional rigid engineering approach focused on short-term benefits, contributing to a more comprehensive understanding of the essential characteristics, internal coupling mechanisms, and dynamic changes of urban systems. Recent advancements in the field of urban resilience are significant, mainly reflected in conceptual paradigm exploration, influencing factor analysis, and resilience assessment.

A review of urban resilience research shows that the concept of "resilience" emphasizes the ability to handle diverse disturbances and adapt flexibly, making it highly applicable to urban systems. There is broad consensus in academia that urban resilience should encompass elements such as "prevention, resistance, recovery, and adaptive learning capabilities." However, due to the complexity of urban systems, there are varying definitions of urban resilience. Current research often begins with urban system components to summarize various factors affecting urban resilience and provides references for constructing a process-based factor system from aspects such as multiple disturbances, urban system states, and response capabilities.

At present, urban resilience assessment primarily focuses on single-domain research, leading to an indicator framework dominated by urban system elements. The assessment methods have gradually transitioned from qualitative to quantitative analysis, with quantitative methods mainly used for short-term spatial scale analysis and brief identification of influencing factors. However, there are still gaps that need further exploration. Specifically, the current issues are as follows:

Urban resilience is often viewed as a developmental outcome, with insufficient exploration of how resilience can become an intrinsic characteristic of cities. Due to data availability limitations, existing assessment indicators give less attention to organizational elements, diverse disturbances, and multiple stakeholders, with a relatively singular approach to indicator system construction. Assessment methods are in a transitional phase from qualitative guidance to quantitative exploration, lacking in-depth coupling and dynamic simulation prediction methods for urban resilience influencing factors. Overall research remains in the transition from theoretical to empirical study, facing challenges in practical application.

Therefore, future research should focus on the following four areas:

Emphasize the analysis of urban resilience processes: Strengthen the exploration of how urban systems change in state, response capabilities, and stakeholder participation during different disturbance stages, clarifying how resilience is formed. Design a more comprehensive and targeted indicator system: Enhance data support for organizational management, institutional implementation, non-natural disturbances, and stakeholder participation, and incorporate these elements into the indicator system. Focus on the psychological perception and equitable benefits of different stakeholders. When constructing the indicator framework, assess the contribution of indicators to the characteristics of urban resilience and its formation process, and explore weak links in urban resilience, such as using matrix methods. Promote the scientific and dynamic improvement of research methods: Develop nonlinear causal analysis, interaction coupling mechanisms of influencing factors, and early warning prediction models for urban resilience, further integrating quantitative and qualitative methods to improve the scientific and practical aspects of the research. Strengthen the operability of the "mechanism-assessment-management" closed loop: Study how to seamlessly integrate urban resilience mechanisms and assessment results into urban management, and explore the feedback effects of managerial decisions on theoretical research to achieve effective enhancement of urban resilience.

A. Data Availability Statement

All data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

[1] Shimpo N. Community garden management for resilient cities: A case study in suburban Tokyo during the COVID-19 pandemic [J]. Landscape and Urban Planning, 2024, 251 105148-105148.

[2] T. M S ,J. A P . “They just forget about the students”: Growing resilient urban farmers with a research practice partnership [J]. Discover Education, 2024, 3 (1):

[3] Suárez M ,Benayas J ,Justel A , et al. A holistic index-based framework to assess urban resilience: Application to the Madrid Region, Spain [J]. Ecological Indicators, 2024, 166 112293-112293.

[4] Zhang C ,Zhou Y ,Yin S . Interaction mechanisms of urban ecosystem resilience based on pressure-state-response framework: A case study of the Yangtze River Delta [J]. Ecological Indicators, 2024, 166 112263-112263.

[5] Zhiqiang X ,Xingfeng F ,Fengshan J , et al. Resilience Levels of Natural–Social Security in Urbanization: A Case Study of Kunming, China [J]. Journal of Urban Planning and Development, 2024, 150 (3):

[6] Nikitas A ,Bakogiannis E . Editorial: Urban transport, resilient cities and Covid-19: Testing mobility interventions for a disrupted world [J]. Cities, 2024, 152 105183-.

[7] Liu J ,Wang C ,Zhang R . Experiment in resilient city: An evaluation of China's demonstration city of safe development policies. [J]. Heliyon, 2024, 10 (11): e32000-e32000.

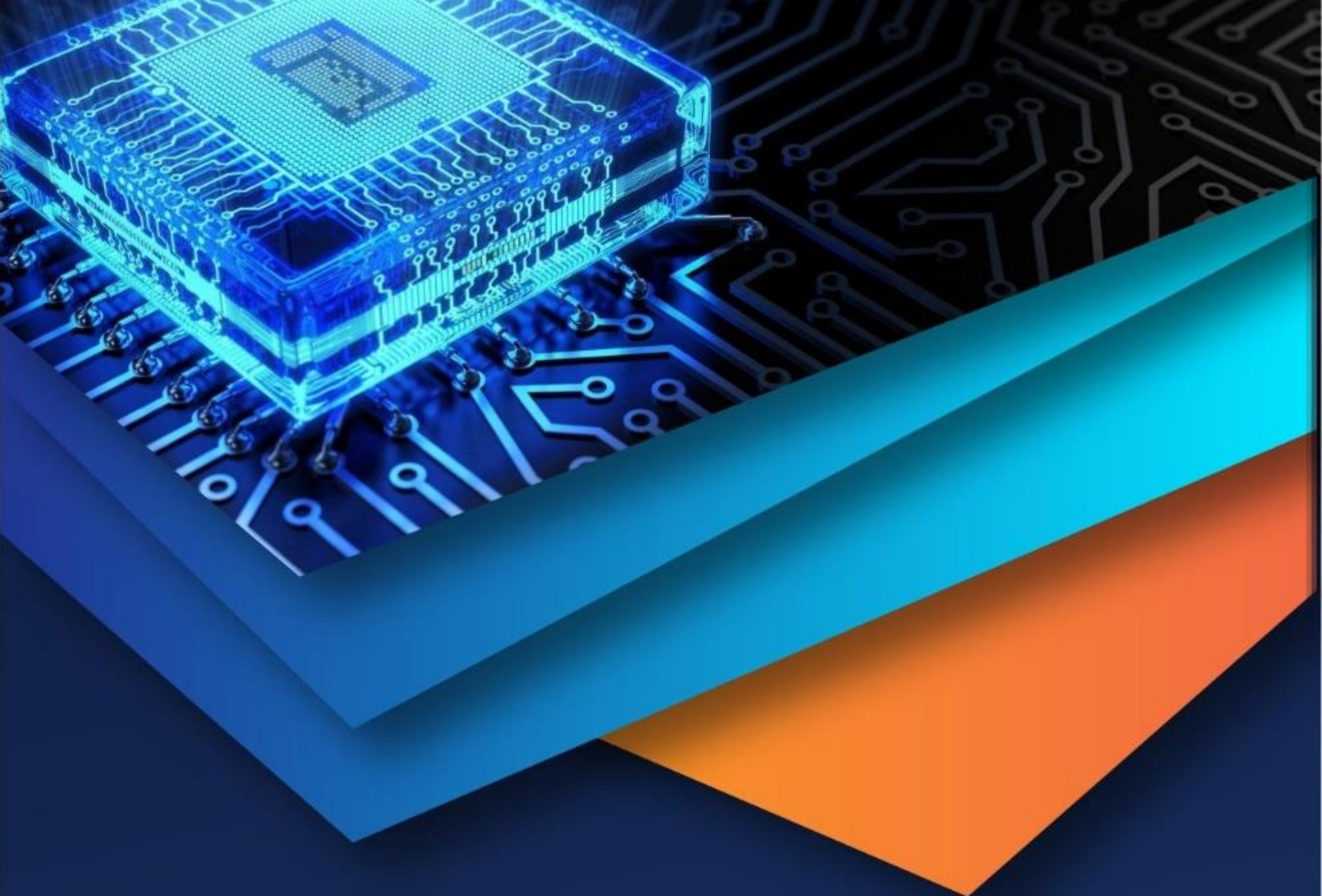
[8] McDonnell R D ,Aragón F L D V M ,McDonnell R L , et al. Toward Resilient Urban Design: Pedestrians as an Important Element of City Design [J]. Urban Science, 2024, 8 (2): 65-65.

[9] Costa D X Z ,Boogaard C F ,Ferreira V , et al. Wastewater Management Strategy for Resilient Cities—Case Study: Challenges and Opportunities for Planning a Sustainable Timor-Leste [J]. Land, 2024, 13 (6): 799-799.

[10] McCarton L ,O'Hogain S . Editorial special issue: Integrating nature-based solutions (NBS) for resilient cities and communities [J]. Nature-Based Solutions, 2024, 5 100105-100105.

[11] Badea D ,Halmaghi E E ,Gorski T A , et al. Building the Urban Organizational Capability for Resilience as a Matter of Updating Security Education of Community [J]. International conference KNOWLEDGE-BASED ORGANIZATION, 2024, 30 (1): 1-7.

[12] Xiang H ,Heng X ,Zhai B , et al. Digital and Culture: Towards More Resilient Urban Community Governance [J]. Land, 2024, 13 (6): 758-758.



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