Planning perspectives on urban resilience to stormwater hazards in the context of climate change: key concepts, basic ideas and generic frameworks*

ZHAI Guofang

Summary In recent years, urban rain and flood disasters have occurred frequently in China, causing huge casualties and economic losses. On the one hand, the Party and government of China have attached great importance to the response to urban rain and flood disasters, and introduced a series of policies and measures, including the construction of resilient cities; on the other hand, climate change and its impact on urban rain and flood disasters, and even economic and social development have been increasingly emphasized by the international community. However, there is no clear administrative guideline or guideline on how to implement the concept of resilient city construction in China's territorial spatial planning system, and there is no clear administrative guideline or guideline on the specific operational practice of planning. From the perspective of planning, we elaborate the connotation of key concepts such as urban rain and flood disaster resilience and urban rain and flood disaster risk, and based on the international experience of urban rain and flood disaster resilience response, combined with the author's experience of planning practice, we try to put forward the basic idea and generalized framework of urban rain and flood disaster resilience response in the context of climate change from the perspective of planning, based on the five-dimensional system of the process, element, subject, level and disaster type of risk governance. The framework.
Keywords urban stormwater hazard; resilient response; climate change; basic ideas; generic frameworks

Resilient Planning Responses to Urban Flood Disasters in the Context of Climate Change: Key Concepts, Fundamental Ideas, and a Comprehensive Framework ZHAI Guofang

Abstract: In recent years, China has experienced a surge in urban flood disasters, resulting in heavy casualties and economic losses. Party and the government have implemented a series of policy measures to mitigate flood haz- ards, including developing resilient cities, on the other hand, climate change, with its escalating economic and social impacts. on the other hand, climate change, with its escalating economic and social impacts, has garnered increasing attention internation- ally. However, within the national territorial spatial planning system, clear administra- tive guidance for the implementation of resilient city strategies is inadequate. However, within the national territorial spatial planning system, clear administra- tive guidance for the implementation of resilient city strategies is inadequate. From a planning perspective, this paper succinctly explains key concepts such as urban flood resilience and urban flood hazard. Drawing on international experiences in resilient urban flood hazard management and the author's planning practice, this paper intro- duces a comprehensive planning framework for resilient urban flood hazard management. - Drawing on international experiences in resilient urban flood hazard management and the author's planning practice, this paper introduces a comprehensive planning framework for resiliently responding to urban flood disasters in the era of climate change. The framework encompasses five dimensions of risk management, including the process of response, risk elements, disaster man- agement authorities, risk levels, and risk types. The framework encompasses five dimensions of risk management, including the process of response, risk elements, disaster man- agement authorities, risk levels, and risk types.
Keywords: urban flood disasters; resilience response; climate change; basic ideas; general framework

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With the continuous construction and improvement of China's flood control facilities, urban flooding has been controlled to a certain extent, with the average annual affected population dropping from 180 million in 1990-2000 to 100 million in 2010-2018, and the corresponding population
Mortality rate decreased from 21.1 to 6.6 per million affected population, and the number of deaths decreased from 3,909 per year.
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[1]In recent years, however, heavy rain and flood disasters have continued to occur, causing serious losses. 2021, a very heavy rainstorm occurred in Zhengzhou City, Henan Province, on July 20, 2021, causing 292 people killed and 47 missing. However, heavy rainfall and flooding disasters have continued to occur in recent years, resulting in serious losses. 292 people were killed, 47 were missing, and direct economic losses amounted to 40.9 billion yuan in Zhengzhou City, Henan Province, on July 20, 2021. 33 people were killed and 18 were missing in Beijing, and 29 people were killed and 16 were missing in Hebei Province, as a result of the extreme rainfall that occurred in Beijing-Tianjin-Hebei from July 29 to August 1, 2023.3 The impacts of the extreme rainfall were notable. In Hebei Province, 29 people were killed and 16 were missing. In addition, the ratio of economic loss caused by rain and flood to GDP in Japan from 2010 to 2020 is 0.186%[2] , which is only less than half of that in China, meaning that there is still much room for improvement in rain and flood disaster defense in China.
Party committees and governments at all levels in China attach great importance to urban
Response to Rain and Flood Disasters The "Recommendations of the Central Committee of the Communist Party of China on the Formulation of the Fourteenth Five-Year Plan for National Economic and Social Development and the Vision and Goals for the 2035 Years," released on November 3, 2020, proposed to strengthen the renovation of old urban districts and community construction, enhance the ability of cities to prevent flooding and drainage, and build sponge cities and resilient cities. In November 2021, Beijing issued the Guiding Opinions on Accelerating the Construction of Resilient Cities, becoming the first city in the country to formally issue guiding opinions on the construction of resilient cities.
United Nations Intergovernmental Panel on Climate Change
(Intergovernmental Panel on Climate Change (IPCC), which has successively released various parts of the Sixth Assessment Report since August 2021, clearly states that human emissions of greenhouse gases through the combustion of fossil fuels have created an unprecedented and irreversible global warming problem, which will cause extreme rainfall events to become more frequent, more powerful typhoons and hurricanes to occur, and fatal heatwaves to become unusual, and that compounded of extreme weather events will also become more frequent. Nine of the 15 extreme tipping points of global climate change are said to have been activated, and human civilization is in danger of being devastated by rain and floods, high temperatures, and other climate disasters[3-4] . The China Climate Change Center of the China Meteorological Administration (CMA) released the "China Blue Book on Climate Change (2021)" on August 4, 2021, which also pointed out that China's average annual precipitation is on an increasing trend, with an average increase of 5.1 mm per decade, and that the average number of days of precipitation per year is on a significant decreasing trend, whereas the cumulative number of days of heavy rainfall is on an increasing trend, which indicates that the risk of rain and flooding disasters is increasing.
In the context of growing concerns about global climate change and resilient cities
In the context of city planning and construction, how to implement the concept of resilient city

construction in China's territorial spatial planning, in terms of theory and technology, although there has been a relatively rich research results, but the planning community's understanding is not complete.

Full Harmonization[5-8] . In the process of planning practice at present, although there is already a "Comprehensive Disaster Prevention Planning Regulations for Territorial Space", it is still only a requirement for the content of different levels and types of planning[9] , and there is no clear administrative guide or guideline on how to enhance urban stormwater resilience and mitigation of stormwater disasters in the context of climate change. In this paper, by elaborating the core connotation of key concepts such as urban stormwater disaster and urban stormwater disaster resilience, and drawing on the international urban stormwater disaster resilience response framework, combined with the five-dimensional system of resilience governance put forward by the author[10] , we conduct preliminary thinking and discussion on the basic idea and general framework of urban stormwater disaster resilience response in the context of climate change, and we look forward to providing several insights for the planning and construction of urban stormwater disaster resilient cities in China. It is expected to provide a number of insights for the planning and construction of urban rain and flood disaster resilient cities in China.

1 Key concepts related to urban stormwater hazard resilience

China's attention to urban rain and flood disaster resilience is relatively late, starting with the article by Wang Hui et al.[11] in 2016. Most of our definitions of urban rain and flood disaster resilience are borrowed from the general definition of urban resilience and do not reflect the specificity of urban rain and flood disasters. In the following, based on the evolution of the definition of urban rain and flood resilience at home and abroad, we discuss the conceptual connotation of urban rain and flood resilience and its essential characteristics from the perspective of the planning discipline, and analyze the conceptual similarities and differences with urban rain and flood disaster risk.

1.1 Urban stormwater resilience

Resilience of urban rainstorm disaster is a specific reflection of the application of urban resilience concept to deal with urban rainstorm disaster, and resilience and resilient city only began to become a hotspot of urban research discussion 10 years ago[12-13] . Resilience (resil- ience) is originally a mechanical concept, meaning rebound to the original state. Resilience was introduced into ecology by the Canadian ecologist Holling[14] in 1973, and then introduced into urban research by Wong et al.[15] in 2009, forming the concept of resilient city, which believes that as a city integrating various systems, it should be designed to be able to better face the threat of disasters and reduce the loss of disasters. There are many researches applying the concept of resilient city to urban rain and flood disaster, such as Zhou Yinan et al.[16] defined urban rain and flood disaster resilience from three aspects of resilience, such as subject, object and connotation of resilience based on the concept of resilience from IPCC, but basically confined to the balance of the sewer system.[17] For this reason, Bruijn et al.[18] called for integration of social vulnerability in response to rain and flood to defend against rain and flood becoming disasters. The United Nations Disaster Risk Reduction Agency (UNISDR)[19] defines resilience in terms of human, ecological and economic aspects.

and that there is a need to enhance the resilience of each aspect. Most of the current discussions on urban stormwater hazard resilience come from the fields of ecology or hydrology, which are more outward extensions of their specific fields, and less often consider urban stormwater from the perspective of the dynamic development of the city as a whole, i.e., from the whole to the parts.

In the author's opinion, the rain and flood disaster resilient city refers to the city that has the ability to resist absorption, learn to adapt and quickly recover when it is impacted by rain and flood. The size of urban rain and flood disaster losses, not only with the pre-disaster defense measures, but also with the disaster after the emergency response, post-disaster recovery and reconstruction, etc., therefore, the urban rain and flood disaster response needs to be considered in the whole process, the total economic and social impacts caused by urban rain and flood disaster is reduced to a minimum. In other words, a city with rain and flood disaster resilience is neither a city without rain and flood phenomenon nor a city without rain and flood disaster losses, but a city where casualties, economic losses and impacts on the operation of urban functions are not only small but can be quickly recovered after being hit by rain and flood. The stronger the rain and flood disaster resilience, the smaller the total impact on the city's economy and society, and vice versa. Therefore, the resilience of urban rain and flood disaster resilience city has the resilience, not only refers to the ability to have a post-disaster rapid response to reconstruction, but also includes the ability to resist external shocks and disaster mitigation and relief when the disaster occurs, with foresight, robustness, innovation, stability, redundancy, flexibility, adaptability, diversity, independence, dependence on laziness, agility, network connectivity, high efficiency, and collaborative nature, fairness, self-learning ability, self-organizing ability and many other characteristics.

The assessment of urban rain and flood resilience is the core and foundation of urban rain and flood resilience urban planning, which will be conducive to establishing a resilience construction baseline, clarifying resilience construction needs and setting goals, monitoring resilience construction progress, grasping the costs and benefits of resilience construction and evaluating policy performance, and is therefore of great significance. Due to the rich connotation of the concept of "resilience" itself, from the development process of resilience research engineering resilience, ecological resilience and evolutionary resilience, from the resilience of the factors affecting the infrastructure resilience, economic resilience, social resilience and institutional resilience of the difference between[20] , so the understanding of the resilience of the resilience of the different perspectives, therefore, the city resilience Therefore, the assessment methods of urban resilience are also very colorful[21-22] . Existing resilience assessment is mainly based on three aspects: (1) resilience as a process[23] ; (2) resilience as a result of the state[24] ; (3) resilience as a comprehensive concept, including multi-dimensional connotations and characterization[25] .

1.2 Urban storm water disaster risk

Closely related to the concept of urban stormwater disaster resilience is also urban stormwater disaster risk. This paper argues that urban stormwater disaster risk is the possibility of urban stormwater disaster and its consequences. From the perspective of probability theory, there is only an infinitely small possibility, there is no absolute zero probability, therefore, there is only an absolutely small risk, there is no "zero" risk. In other words, there is no absolute safety, only relative safety. The so-called urban stormwater safety is the acceptable level of individual or social risk of urban stormwater disasters. This acceptable level is not only subject to the level of risk of other disasters such as earthquakes, landslides, mudslides, etc., but also affected by the local economy, society, culture and political system, with a more complex formation mechanism[26] .

The classification of factors affecting urban stormwater hazard risk is generally based on haz- ard, exposure, and vulnerability.

（There is a trichotomy of vulnerability[27] but there is also a tetrachotomy of causal factors, exposure, vulnerability and re- sponse[28] (IPCC 2023). However, due to the interactions between natural, economic, social and political systems, the 6th IPCC report concludes that the linear traditional risk assessment and governance model is no longer suitable for rain and flood disaster response in the context of climate change, and that a climate resilient development model based on the coupling of climatic, ecological, and human-social systems is needed[29] .

The relationship between urban rain and flood disaster resilience and rain and flood disaster risk influencing factors, both in the narrow sense of the view of vulnerability, but also the carrier's exposure and vulnerability of the understanding of the broader understanding of the factors including danger, exposure, vulnerability and so on. In the author's view, compared with risk governance, which focuses on the study of risk reduction countermeasures from the disaster-causing factors, resilience governance focuses on thinking about how to cope with disaster risk from the human society as a disaster carrier, which is very similar to the difference in the ideas of treatment between Western medicine and traditional Chinese medicine.

2 International developments in resilience response to urban stormwater disasters

The response to urban rain and flood disasters involves natural, political, economic, social, cultural and technological aspects, and is a systematic project, in which the natural sciences, the social sciences, the humanities and other fields have accumulated relatively rich research results. Australia, Japan, the United Kingdom, the United States and other developed countries, as well as the United Nations, the World Bank and other international organizations, have attached great importance to the management of urban rain and flood disasters.

As well as the impact of climate change on urban rain and flood disasters, a series of relatively systematic and comprehensive policy documents have been introduced, which are worthy of reference for our country.

2.1 Australia

Australia's response to urban stormwater flooding in the context of climate change, the Australian Disaster Resilience Handbook Collection: Handbook 7: Floodplain Management: A Guide to Best Practice in Flood Risk Management in Australia[30] , introduced in 2017, sets out the need for a collaborative, proactive, consultative and informed approach to accepting risks that cannot be eliminated, and calls for a corresponding responsibility of individuals for community disaster preparedness. The 2020 Australian Disaster Resilience Handbook Collection: Disaster Resilience Oriented Stormwater Emergency Planning[31] sets out the content and key processes for the preparation of urban stormwater emergency planning from a disaster resilience perspective.

2.2 Japanese

Considering that climate change may have a large impact on rainfall, coastal tide levels, etc., Japan revised the "Guidelines for Preparation of Comprehensive Stormwater Management Plans"[32] in 2021, and issued the "Guidelines for Flood Countermeasures for Government and Citizens: Explanation of Flood Countermeasure Zoning System"[33] . In 2022, the basic guidelines for river management were adjusted, and the river management concepts, technological paths, and response processes were changed considerably, with emphasis on basin management and zonal response [34]. The basic approach to river management was adjusted in 2022, with major changes in river management concepts and response processes, emphasizing watershed management and zonal response, and a 1.2-fold increase in river flow planning targets in the context of climate change [34].

2.3 United Kingdom of Great Britain and Northern Ireland

UK Environment Agency 2020's review of the 2011 publication

The UK National Flood and Coastal Erosion Risk Management Strategy[35] has been revised to set out a long-term vision for the country's response to rain and flooding, which is to be prepared and resilient to flooding and coastal change today, tomorrow and in 2100. This is expressed in three goals: first, climate resilient places; second, today's growth and infrastructure resilient in tomorrow's climate; and third, a climate that is prepared to respond to and mitigate the impacts of flooding and coastal change. today's growth and infrastructure resilient in tomor- row's climate; and third, a nation ready to respond and adapt to flooding and coastal change. Watershed planning generally follows an iterative process of goal setting - possible measures - technical feasibility and cost-benefit analysis - and integration of goals and responses.

2.4 United States of America

Urban stormwater disaster management in the United States, before the 1950s, mainly focused on the construction of reservoirs, flood lifts, and other engineered flood control facilities, and after 2011, its focus shifted to resilience enhancement, technological advances, risk communication, and concerns about climate change exacerbating stormwater disasters, resulting in risk assessment and risk information, risk communication, early warning, risk mitigation and risk preparedness, risk transfer, and risk finance, urban rain and flood disaster risk management system consisting of post-disaster response and reconstruction, monitoring and evaluation feedback, multi-stakeholder participation, increased financial investment, training and education, and climate change impacts [36].

2.5 World Bank

The World Bank 2021 proposes an innovative governance model for urban stormwater disasters, the EPIC Response Framework[37] , which is based on a combination of enabling, planning, and management.

(planning), investment (investing) and control (con- trolling) and other four aspects to realize the rapid response to urban flood and drought disaster (responding). The response mainly includes monitoring and early warning, emergency rescue, recovery and reconstruction, and risk finance. The innovation of this model is to change the previous passive response to the current active response, through the integration of various government programs, to play the downward cascade of influence, so it is also called the joint-up gov- ernment leading a whole-of-society ap- proach.

2.6 United Nations

The United Nations has long emphasized urban stormwater hazard and climate resilience enhancement, and as early as 2007 issued the

The Flood Loss Reduction Guide[38] presents a framework for flood risk assessment and management, including natural monitoring systems, flood hazard construction, vulnerability assessment, risk assessment, protection objectives/risk acceptability, planning/mitigation measures, implementation, and cyclical assessment. The Sendai Framework for Disaster Risk Reduction was finalized in 2023.

It also conducted a midterm review of the progress in the implementation of the 2015-2030 Agenda and looked forward to future work, calling on all member States to shift their approach and enhance disaster resilience based on a systemic approach, with a holistic, whole-of-hazard, whole-of-society, whole-of-process, whole-of-region, and whole-of-factors approach, so as to effectively reduce disaster risk and fully realize the goals of the 2030 Agenda.[39] .

2.7 wrap-up

Whether it is the urban storm water disaster management system implemented by developed countries or the urban flood disaster management system advocated by international organizations, it is not the case.

The Framework for Resilient Response to Stormwater Disasters emphasizes the following nine aspects, despite the differences in perspective, focus and expression of concern about urban stormwater disasters. First, urban stormwater disasters need systematic management; second, urban stormwater disaster risk cannot be completely eliminated, i.e., there is no "zero" risk; third, effective response to urban stormwater disasters beyond the standard of defense is the focus of future stormwater management; fourth, urban stormwater disasters require both engineering and non-engineering measures, but the focus will be different in different economic and social development stages; fifth, floodplain maps, stormwater flooding maps, and stormwater flooding maps will be used for the management of urban flooding disasters. Fifth, floodplain maps, flood hazard maps, land use planning, territorial spatial planning, etc., play an important role in urban rain and flood disaster management; Sixth, there are countermeasures with different focuses at different stages of the disaster (before, during, and after); and Seventh, the different participating bodies, such as the government, the society, enterprises, and individuals, all have an important role to play in the management of urban rain and flood disasters; The process of formulating urban stormwater disaster response strategies includes risk identification, hazard assessment, resilience assessment, multi-scenario risk assessment, safety targeting, and development of response strategies; and climate change can exacerbate urban stormwater disasters. Drawing on the existing urban rain and flood disaster resilience response framework, it is one of the main tasks of this paper to construct a generalized framework that can cover all of the above and guide the preparation of urban rain and flood disaster resilience response planning in the context of the territorial spatial planning system.

3 Basic ideas for resilient response to urban rain and flood disasters

In addition to the practice cases of developed countries and international organizations introduced above, many scholars have paid attention to and discussed the resilience response to urban rain and flood disasters. For example, Ma Kun et al.[40] studied the rainwater flood management model of hilly granite from the perspective of natural system based on the resilience theory; Yang Fan et al.[41] explored the transformation and realization path of urban flood resilience governance system from the perspective of intelligence; Ye et al.[42] constructed a planning and design framework of multi-scale rainwater flood disaster resilience from the AI-driven perspective based on the resilient city form conceptual model of Sharifi et al.[43] ; Wang Peak et al.[44] discussed the theoretical framework of rainwater flood disaster resilience response from the perspective of built environment focusing on the city. Wang et al. explored the theoretical framework of rain and flood resilience from the perspective of built environment. Generally speaking, the research on rain and flood resilience mainly focuses on one aspect that affects the resilience of urban rain and flood, either the built environment, the rain and flood mechanism, or the application of new technologies, but the research on urban rain and flood resilience from the perspective of the system as a whole is still relatively small. Therefore, this paper, based on the practical cases of developed countries and the policy recommendations of major international organizations on urban rain and flood disaster response.

Attempts to explore the construction of a new framework for resilience response to urban rain and flood disasters in the context of climate change from the perspective of planning, specifically, firstly, on the basis of establishing systems thinking and resilience thinking, from the whole process of governance, the whole factor inputs, the participation of the whole society, according to the local conditions, according to the appropriate disaster, and other five dimensions (i.e., the process, the elements, the main body, the scale/level, the type of disaster), to coordinate the urban rain and flood resilience response to the planning and implementation. The following is a summary of the five dimensions

3.1 Two basic ways of thinking

3.1.1 systems thinking

Whether it is a watershed or a city, it is a self-organizing system that evolves and develops through the coupling of various subsystems, such as natural, economic, social, political, cultural, and infrastructure systems, each of which is formed at different times and at different speeds, and at the same time exchanges material and energy with the outside of the system continuously to maintain the system's operation. Disasters such as rain and floods can be seen as adjustments in the relationship within, or between, subsystems, or between the outside of the system and the system, which are embedded in the evolutionary process of the territorial system. Only through the mutual coordination between the subsystems of a territory such as a watershed or a city, the whole system can realize sustainable development. On the other hand, a watershed or city, from a spatial point of view, exists not only its internal spatial system, but also its external spatial system, which together form a complete territorial system.

3.1.2 Resilient thinking

Since there is no absolute safety, it is necessary to determine the acceptable level of rainfall disaster risk, that is, the bottom line. How safe is safe enough? This is one of the most basic questions in risk-benefit analysis, not only by the perceived risk, perceived benefits, risk attributes and acceptable risk level and other factors, such as[45] , but also by the relative magnitude of rainfall risk among all risks, as well as economic, technological, institutional and other influences. The relative magnitude of stormwater risk among all risks, as well as economic, social, technological, and institutional influences. This acceptable level is often the basis for the development of urban fortification standards. For extreme rainfall that exceeds the fortification standards, although the probability is small, if it occurs, the damage is huge, so it is important to be prepared to deal with it accordingly. Therefore, the resilience thinking is not only to have a certain standard of fortification response, that is, "+ fortification standard", but also have a rain and flood events beyond the fortification standard reasonable response, that is, "fortification standard +", unified and in short " + fortification standard+".

3.2 Five key underlying dimensions

3.2.1 comprehensive policymaking

Disasters occur, and sometimes it seems as if they are sudden issued, but in fact often undergoes a longer development process. The whole process of urban rain and flood disaster risk management includes three phases, including pre-disaster risk management of rain and flood, emergency evacuation and rescue in disaster, and post-disaster recovery and reconstruction, which are interlocked. In the pre-disaster, disaster, post-disaster different stages, through the whole disaster, the whole region, the whole element, the whole subject of the comprehensive management, can overall enhance the urban rain and flood disaster prevention and resilience, to minimize the urban rain and flood disaster losses, specifically reflected in the country's concept of disaster prevention, mitigation and relief in the new era of disaster prevention and mitigation is the concept of "two adhere to, three transformations" put forward: insist on Prevention-oriented, prevention, resistance and rescue combination; adhere to the unity of normal disaster reduction and non-normal disaster relief; from focusing on post-disaster relief to focusing on pre-disaster prevention change; from responding to a single type of disaster to the comprehensive disaster reduction change; from disaster loss reduction to disaster risk reduction change. From a planning perspective, each stage can prepare corresponding response planning, such as emergency evacuation and rescue planning in times of disaster[46] .

3.2.2 Total social participation

The main bodies of urban storm disaster risk management include all levels of government, society and individuals. Society is the sum of human beings and their relationships, and families, neighborhoods, schools, associations, enterprises, communities and so on are the basic units of society, but they play different roles in the process of urban rain and flood disaster management. Japan's disaster cases show that the rescue of people after the disaster really by the army and other government rescue teams is not a large proportion of only 1.7%, mainly still rely on individual self-help and local community organizations to help each other[47] , therefore, Japan in disaster prevention, mitigation and relief work attaches great importance to give full play to the government departments of the "public assistance", enterprise - Therefore, Japan attaches great importance to giving full play to the "public assistance" of government departments, the "common assistance" of enterprises, social groups and other organizations, as well as the "self-help" role of individual residents. In light of our national conditions, we can follow the principle of "government organization, expert leadership, sectoral cooperation, public participation, and scientific decision-making" to give full play to the enthusiasm of all governance bodies and stakeholders.

3.2.3 total factor input

The enhancement of the resilience of urban rain and flood disaster is not only inseparable from the input of human, financial, material, technology and other resource elements, but also inseparable from the foundation of the existing urban rain and flood disaster response measures. Urban rain and flood disaster response measures, including flood control, reservoirs, sewerage network and other engineering measures, but also includes disaster awareness, disaster prevention skills, disaster insurance and other non-engineering measures, as well as laws and regulations, technical standards, organizations, governance mechanisms, and information support for the implementation of engineering measures and non-engineering measures to provide protection. Due to the large one-time investment in the construction of urban storm water disaster prevention facilities, coupled with the unique tenure mechanism of our officials, in the limited financial resources a It is generally difficult to get prioritized. In reality, however, the benefits of investing in disaster prevention are high. According to the Multi-Hazard Mitigation Committee of the National Institute of Building Sciences (NIBS), the benefit-to-cost ratio of building to a fortification standard is 11:1, with federal agencies funding a benefit-to-cost ratio of 6:1. A further benefit-to-cost ratio of 4:1 can be achieved by building beyond the fortification standard.[48] .

3.2.4 (idiom) use methods in line with local circumstances

The earth's surface has both plains and mountains and seas; it has both cities and villages; it has first-tier cities like Shanghai, Shenzhen, Beijing and Guangzhou, as well as third- and fourth-tier remote cities like Mohe, Karamay and Manzhouli; and it has both the city with the "heaviest rainfall" - Ya'an - which receives rain more than 200 days a year, and a city with very little rainfall like Turpan City, which receives only 16.5 mm per year. -Ya'an, which receives more than 200 days of rainfall a year, and cities like Turpan, which receives very little rainfall, with an average annual rainfall of only 16.5 mm. Different scales or tiers, such as watersheds or cities or streets, will have different goals, focuses, and paths of rainfall and flood disaster management due to the differences in the natural, economic, social, technological, and other conditions. Therefore, different administrative units should have different strategies to deal with stormwater flooding, even within a watershed or the same administrative unit (e.g., a city), based on scientific urban stormwater flood risk mapping work, to adapt to the local conditions, and develop corresponding response measures.

3.2.5 (idiom) use methods appropriate to the disaster

Urban stormwater disasters can also be categorized into many types based on their formation and development mechanisms. For example, according to the source of water, there are main water and guest water. Urban stormwater disasters mainly refer to flooding and waterlogging, the former mainly refers to heavy rainfall and torrential rainfall causing waterway rapids, flash floods, and river flooding, while the latter mainly refers to the accumulation of water into a disaster. Both flooding and waterlogging have the potential to inundate agricultural land and destroy the environment and various facilities. The occurrence of urban rainfall and flooding disasters often causes secondary disasters such as landslides, landslides and subsidence, resulting in a cascading effect.

(cascading effect); in extreme cases, this can sometimes occur in conjunction with other disasters (earthquakes, typhoons, storm surges, etc.), resulting in a compound disaster.

（The occurrence of urban rain and flood disasters will not only affect the disaster-bearing body, but may even sometimes have systemic risk on the whole territorial system[49] . Therefore, it is especially important to clarify the types of urban stormwater disasters and to formulate measures to deal with them.address

China's territorial spatial planning system consists of "five levels and three types", which are the five administrative levels of the state, provinces, cities, counties and townships, as well as the three planning types of master planning, detailed planning and special planning. The resilient response to urban rain and flood disasters not only involves territorial spatial planning, but also relates to meteorology, water conservancy, emergency response, housing and construction and many other departments, which is a very comprehensive systematic project. Therefore, the author believes that the disaster prevention planning focusing on the prevention of disasters before the disaster is a special type of security resilience planning that emphasizes the whole process, and these two types of planning projected in the system of territorial spatial planning, that is, disaster prevention special planning and security resilience special planning, specific to urban rain and flooding disaster is all kinds of urban flood prevention and drainage special planning and urban rain and flooding resilience special planning is the relationship between the local and the whole. Obviously, the urban rain and flood resilience planning is also a complete system consisting of "five levels and three categories", and if climate change is taken into account, it is also necessary to take into account the national and local action programs to address climate change, forming the rain and flood resilience (special) planning in the context of climate change (Figure 1). In recent years, work on resilient city planning has been advancing rapidly, with comprehensive resilient city planning focusing on all types of disasters, the whole process, and the whole city (e.g., Beijing, Zhengzhou, Xining, etc.), and specialized resilient city planning focusing on post-disaster emergency response (Fig. 1).

(e.g. Shenzhen Emergency Evacuation and Rescue Space Planning, etc.), and there are also special plans for urban rain and flood resilient cities that are ready to be initiated by some cities on the basis of sponge city planning and construction.

4.2 A Framework for Resilient Urban Stormwater Hazard Response from a Planning Perspective

Based on the international experience and basic ideas of urban rain and flood resilience response, the author has attempted to construct a general framework for urban rain and flood resilience response from the planning perspective (Figure 2). Based on the underlying logic of systems thinking and resilience thinking, the framework carries out planning-implementation-assessment-action (PDCA) for urban rain and flood resilience enhancement in different dimensions, such as scales/levels, processes, elements, and participating subjects, and at the same time implements monitoring and evaluation and multi-subject communication. Since the stages of implementation, evaluation and action are not the focus of this paper, this paper focuses on the content of planning. In the planning stage, it includes the steps of urban stormwater hazard risk inventory determination, urban stormwater hazard and resilience assessment, urban stormwater hazard risk assessment under different scenarios such as climate change and economic and social development, urban stormwater hazard resilience enhancement target determination, urban stormwater hazard resilience enhancement strategy and its prioritization and classification determination, and so on. At each step, the government, society and individuals related to urban rain and flood disaster resilience enhancement need to participate in the communication, and then determine whether to move to the next step.

Urban stormwater hazard resilience assessment and urban stormwater hazard risk assessment under different scenarios are fundamental to the overall response framework. Methods for urban flood resilience assessment vary according to the purpose of the assessment. If the purpose is to understand the spatial and temporal variability, methods such as the Evaluation Indicator System (EIS) method[50] and the Comprehensive Resilience Index (CRI) method[51] are preferable. If the purpose is to find out the urban rainfall disaster resilience, then the evaluation index system method and the comprehensive resilience index method are better.

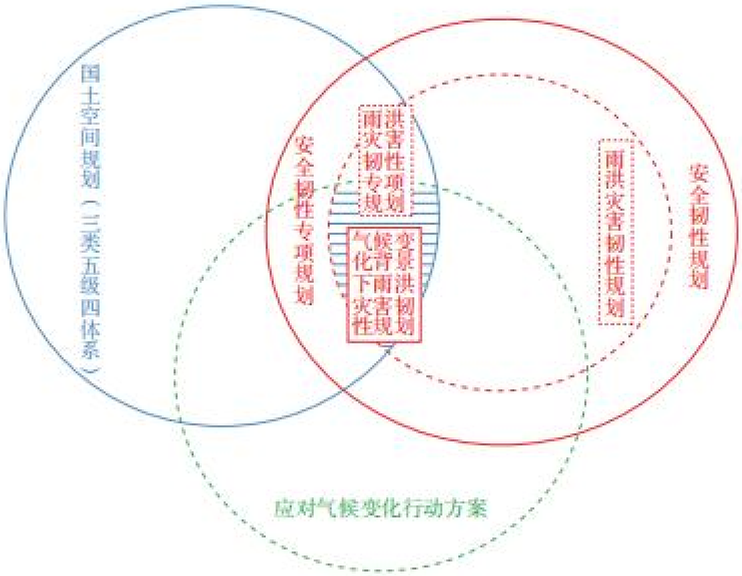

Fig.1 Relationship between territorial spatial planning and resilience planning in the context of climate change

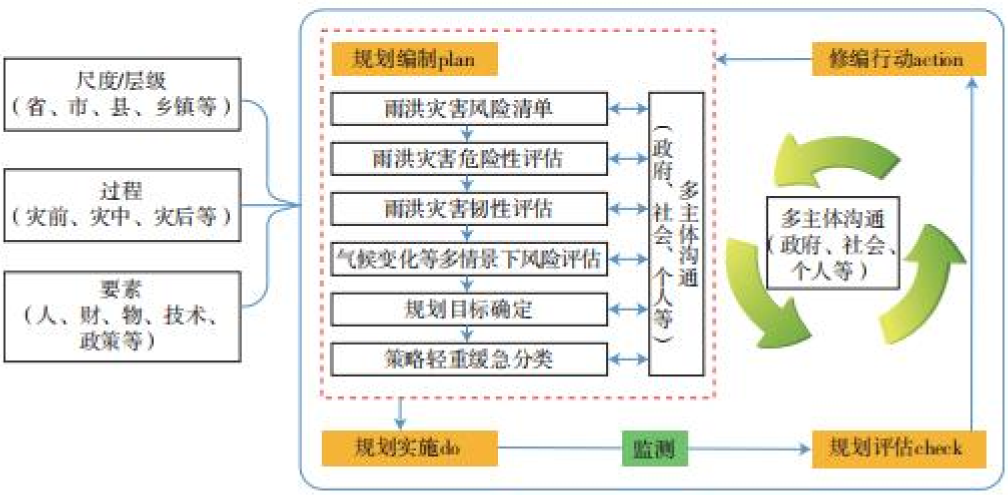

Fig.2 PDCA general planning framework for resilient flood hazard management in the context of climate change

4 A Generic Framework for Resilient Urban Stormwater Hazard Response from a Planning Perspective

4.1 Territorial spatial planning and urban stormwater resilience

For the shortcomings or deficiencies of resilience, the risk assessment method under extreme scenarios used in Japan's land resilience planning[52] and New York's resilience planning[53] is better, and this method is actually more and more applied in resilient city planning in China. For example, the Beijing Resilient City Space Special Plan (2022-2035) takes the 2021 "7-20" Zhengzhou flood as the limit scenario of disaster-causing factors in the setting of rain and flood disaster scenarios; the Shenzhen Emergency Evacuation and Rescue The Spatial Planning for Emergency Evacuation and Rescue in Shenzhen (2021-2035) takes the maximum number of evacuees after the strongest typhoon in history as the limit scenario for the emergency evacuation and rescue needs in rain and flood disasters.

In addition to the limiting scenarios of urban stormwater hazard, stormwater disaster risk can also be assessed under different scenarios of the correspondence strategy. For example, different scenarios of individual influencing factors such as levee defense standard, drainage system capacity, motorized drainage pump configuration, timely evacuation rate of residents before disaster, surface sponging rate, temperature rise, sea level rise, and rainfall insurance purchase rate, or different scenarios of different combinations of two or more factors, can be used to assess the size of rainfall disaster risk qualitatively or quantitatively, and to determine the main factors affecting the resilience of the city's rainfall disaster. This will determine the main factors affecting the resilience of urban rain and flood disasters, and provide a scientific basis for the formulation of goals and strategies for improving the resilience of urban rain and flood disasters.

The scientific and reasonable determination of urban stormwater hazard resilience planning objectives is the soul of successful planning. Planning objectives can be multi-objective, multi-level and spatially differentiated. Multi-objective, refers to the urban rain and flood resilience city construction goal is not a single, for example, Japan's territorial toughness planning in the general goal has four aspects of the composition: to maximize the people's lives to ensure safety; the important functions of the state and society will not be fatal due to external impacts and can maintain the relative stability of the system; to ensure that the people's property and public facilities to minimize the degree of victimization;

The ability to recover quickly after a disaster. Multi-caliber refers to the multiple safeguard capabilities of prevention, resistance and rescue in response to urban rain and flood disasters. Spatial differentiation refers to the fact that, because the spatial distribution of rain and flood hazard risk and exposure and vulnerability is heterogeneous, the planning objectives and planning standards should be spatially differentiated in terms of maximizing the effectiveness of disaster prevention. For example, Japan plans to change the current practice of uniform standards for flood prevention within cities

(e.g. 1 in 5 years of rainfall), and depending on the potential damage, the standard of flood protection can be raised appropriately for certain sections (e.g. 1 in 7 years, or even 1 in 10 years)[54] .

5 A System of Resilient Response Strategies for Urban Rain and Flood Hazards

Urban rain and flood disasters have been developing along with human progress. With the continuous advancement of urbanization, research on coping strategies for urban stormwater disasters has also been emerging, and a wealth of research results has been accumulated. For example, the U.S. Environmental Protection Agency (EPA), together with the Federal Emergency Management Agency (FEMA)

（At the invitation of the State of Vermont, which was devastated by Tropical Storm Irene, FEMA prepared the Vermont Stormwater Hazard Recovery and Long-Term Resiliency Plan (VHSRP) to develop urban stormwater resiliency strategies at the local land use planning and state government policy levels. In particular, the local land use planning part, from the river corridor (river corridor), vulnerable settlement (vulnerable settlement), safer area (safer area), the whole watershed (the whole watershed) and other four aspects of the response to the measures carried out a very detailed institutional arrangements[55] . In Japan, under the increasingly serious situation of urban rain and flood disasters, on the one hand, the water management planning guidelines of more than 10 years ago have been revised and improved, and the hardware and software have been developed to be compatible with global climate change.

and software-balanced transformation of water management planning[56] , on the other hand, local governments are required to do emergency drills, early warning, evacuation, rescue, and recovery and reconstruction before, during, and after disasters, and a detailed work list is provided[57] . Cigler[58] summarizes the system of urban stormwater disaster response from the perspective of engineering and non-engineering countermeasures.

In recent years, scholars in China have carried out innovative research on the resilience coping strategy system for urban rain and flood disasters. For example, Cheng Xiaotao et al.[59] explored the flood disaster prevention and control strategies in the climate change environment that are appropriate to the basic national conditions of China in the new era, based on field research and reflection on the "7-20" flood in Zhengzhou. Chen Bilin et al.[60] translated urban rain and flood resilience into four dimensions of physical space such as ecological landscape, transportation network, neighborhood function and flood infrastructure, and conducted empirical assessment and response research in Shenzhen as an example. Xie Lei et al.[61] established a resilience model and index system of "spatial reservation" "temporal guarantee" and "functional composite" for coastal areas, and carried out planning practice with Ningbo as an example. However, most of the studies on urban rain and flood disaster resilience enhancement strategies start from individual areas such as physical space, water management, emergency evacuation and rescue, which are heavily fragmented and need to be systematized.

Urban storm flood disaster response strategies, based on a spatial perspective, can be broadly categorized into spatial and non-spatial strategies. Climate change, which affects both the frequency, scale, and intensity of stormwater flooding and the spatial and temporal distribution of stormwater flooding, thus directly or indirectly affects the development of spatial and non-spatial strategies (Figure 3). Spatial strategies, based on their relationship to rainfall flood hazard, can be further classified as avoidance, intensification, preparedness, spatial structure optimization, and hazard mitigation. Avoidance refers to moving away from high rainfall flood hazard areas such as river floodplains, floodplains, and floodplains. Reinforcement refers to the construction of structures that are more likely to be threatened by rainwater flooding.

Fig.3 Strategies for resilient flood hazard management in the context of climate change

There is a need to strengthen the capacity of rain and flood disaster defense. For example, strengthening the construction of levees and drainage systems, enhancing the flood-resistant structures of buildings and structures (flood boards, footbridges, etc.), and installing additional drainage pumping stations, cisterns, and other facilities. Disaster preparedness refers to the fact that after the occurrence of rain or flood disaster beyond the defense standard, local residents can be evacuated and rescued in time, and there are enough emergency shelters, emergency evacuation channels, emergency rescue materials, emergency medical care, emergency communication and other basic life protection facilities. Optimization of spatial structure refers to the reduction of urban rain and flood disaster risk through the reasonable allocation of land for population, industry, transportation and other purposes. For example, group distributed layout structure, Japan's district-based policy based on rain and flood disaster risk zoning, Japan's terrace city creation and Shenzhen Sea-Shenzhen-Hong Kong Modern Service Industry Cooperation Zone's three-dimensional city construction. Reducing the risk can be achieved on the one hand by reducing the global temperature rise through reducing carbon emissions, thus mitigating the negative impacts of climate change on human beings, and on the other hand, it can also be achieved through nature-based solutions such as sponge cities, which can reduce the amount of surface runoff and the scale of rainwater flooding, and slow down the danger of rainwater flooding impacts, thus reducing the risk of rainwater flooding disasters.

Non-spatial strategies, including integrated urban stormwater
Disaster prevention system, emergency management system, regional linkage, emergency plan, application of new technology such as AI, improvement of rain and flood disaster insurance system, etc. The comprehensive urban rain and flood disaster prevention system includes rain monitoring, analysis, forecasting, and warning system before disaster occurs, flood monitoring, analysis, forecasting, and warning system, compilation and disclosure of rain and flood hazard maps, and flood prevention education and drills. The urban rain and flood emergency management system refers to the administrative function of dealing with rain and flood disaster and its carrier system, the main work
The work is the emergency response and disposal of urban rain and flood disasters, including the issuance of orders and the timely organization and deployment of emergency evacuation and rescue resources, such as people, property and materials. The occurrence of urban rain and flood disaster and its impact is often cross-administrative region, even if the urban rain and flood disaster occurred in an administrative region, if it is a catastrophe, the emergency evacuation and rescue resources in the region often can not meet the demand, and need to be out of the region to assist, so it is very important to collaborate and linkage in the region. For example, the signing of the Memorandum of Understanding on Synergistic Development of Integrated Emergency Management in the Yangtze River Delta (YRD) marks the beginning of regional linkage in disaster response in the YRD region. Emergency planning refers to the prior deployment of emergency management, command, and rescue plans in the face of urban rain and flood disasters, and generally includes subsystems such as the emergency organization and management command system, the emergency engineering and rescue protection system, the comprehensive coordination and support system, the protection and supply system, and the emergency team for comprehensive rescue. Robots, drones, AI and other new technologies in rain and flood disaster defense, based on big data analysis, have the advantages of early forecasting and warning, rapid response and decision support. Disaster insurance is the insurance of the property itself and the economic interests related to it as the insurance subject, the United States, Japan and other developed countries have a relatively perfect rain and flood disaster insurance system, the market plays the main role, and the government is the final bearer of risk.
The history of mankind has been a struggle with rain and floods, earthquakes and other disasters.
The history of the continuous struggle against natural disasters. Each natural disaster, to varying degrees, has reshaped the spatial pattern of regional economic and social geography, and at the same time is an important driving force in adjusting human-land relations. Urban storm water disaster and urban storm water resources, itself is the urban storm water on human society to produce two completely different nature of the impact, but as long as the scientific follow the formation of storm water, the development of the objective regulations
In order to minimize urban stormwater disasters and maximize the use of stormwater resources, and to achieve a harmonious symbiosis between stormwater and human beings, the Dujiangyan built by Li Bing more than 2,200 years ago not only effectively controlled stormwater disasters, but also irrigated more than 10 million acres of land, making it possible for the Sichuan Basin to become a heavenly capital, which has provided a good case study on how we can live in symbiosis with stormwater.
The generalized framework for resilience response to urban rain and flood disasters proposed in this paper, although a framework for the specific disaster category of urban rain and flood disasters, is also useful for resilience response to other natural disasters such as earthquakes, landslides, mudslides, and so on. In fact, some of the ideas in this paper mainly come from the author's experience and theoretical reflections on the Hefei Municipal Facilities Resilience Enhancement Planning Study, Shenzhen Emergency Evacuation and Rescue Spatial Planning, and other related work. Although these works are not aimed at individual urban rain and flood disasters, they have all given focused attention to urban rain and flood disasters, and the relevant results have been highly recognized by the relevant departments. In addition, it is expected that the framework can be continuously refined, upgraded and improved in the future planning practice, and even transformed into relevant standards or norms, so as to better serve the smooth implementation of urban rain and flood disaster resilience in China's territorial spatial planning system.
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References

[1] DU S, CHENG X, HUANGE Q, et al.Brief communication: rethinking the 1998 China floods to prepare for a nonstationary future[J]. Nat. Hazards Earth Syst. Sci., 2019, 19: 715 - 719.

[2] Cabinet Office of Japan. Disaster Prevention White Paper | Subsidiary Information 15 Ratio of Damage to Gross Domestic Product by Facilities and Other Damage [EB/OL]. 2022. 2022. https://www. bousai. go. jp/kaigirep/hakusho/r04/honbun/3b_6s_ 15_00.html

[3] lenton t m, rockström j.GAFFNEY O, et al. Climate tipping points: too risky to bet against[J]. Nature, 2019, 575: 592-595.

[4] STEFFEN W, ROCKSTROM J, RICH- ARDSON K, et al. Trajectories of the earth system in the anthropocene[J]. Pro- ceedings of the National Academy of Sci- ences, 2018, 115: 8252-8259.

[5] Yan Wentao, Ren Jie, Zhang Shangwu, et al. Shanghai Resilient City Planning: Key issues, general framework and planning strategies [J].Journal of Urban Planning, 2022(3): 19-28.

[6] PAN Haixiao, DAI Shenzhi, ZHAO Yanjing, et al. Academic Talk on "Urban Resilience and Spatial Planning for Climate Change"[J]. Journal of Urban Planning, 2021(5): 1-10.

[7] Yang Xuanmei. Territorial Spatial Resilience: Conceptual Framework and Implementation Path [J]. Journal of Urban Planning, 2021(3): 112-118.

[8] Yang Minxing, Huang Bo, Cui Chong, et al. Review and prospect of disaster prevention and control research based on resilient city theory[J]. Journal of Urban Planning, 2016(1): 48-55.

[9] Dai Shenzhi, Liu Tingting, Gao Xiaoyu, et al. Planning System and Implementation Mechanism of Territorial Spatial Disaster Prevention and Mitigation[J]. Journal of Urban Planning, 2023(1): 48-53.

[10] Zhai Guofang. Making cities safer and epidemics more efficient[J]. Human Habitat, 2020(1): 10-13.

[11] WANG Hui, REN Yilu, LU Siqi, et al. Responding to the threat and occurrence of floods with urban resilience guided by ecological wisdom[J]. Journal of Ecology, 2016, 36(16): 4958- 4960.

[12] International Bank for Reconstruction and Development, World Bank. Building ur- ban resilience : principles, tools, and prac- tice, directions in development: environ- ment and sustainable development [R]. 2013.

[13] UNISDR (UN International Strategy for Disaster Reduction). Making cities resi- lent: my city is getting ready [R]. 2012.

[14] HOLLING C S. Resilience and stability of ecological systems[J]. Ann. Rev. Ecol. Syst. 1973, 4:1 - 23.

[15] WONG T H F, BROWN R R. The wa- Ter sensitive city: principles for practice [M]. Water Sci. Technol. 2009.

[16] Zhou Yinan, Li Baowei. Shaping with Water: Stormwater Resilient Cities Design research[J]. Planner, 2017, 33(2): 90-97.

[17] BERTILSSON L, WIKLUND K, TE- BALDI I D M, et al. Urban flood resil- ience: a multi-criteria index to integrate flood resilience into urban planning[J]. Journal of Hydrology, 2019, 573: 970-982.

[18] de bruijn k m, jafino b a, merz B. et al. Flood risk management through a resilience lens[J]. Commun Earth Environ, 2022(3): 285.

[19] The United Nations Office for Disaster Risk Reduction. GAR special report: mea- suring resilience for the sustainable devel- opment goals[R]. Geneva, 2023.

[20] JHA A K, MINER T W, STANTON- GEDDES Z. Building urban resilience: principles, tools, and practice[M]. Wash- ington DC, USA: World Bank Publica- tions, 2013.

[21] Zhai Guofang, He Zhongyu, Gu Fumei. Resilient City Planning: Theory and Practice [M]. China Building Materials Industry Press, 2021.

[22] DUAN Yiyan, ZHAI Guofang, LI Wenjing. Progress of International Research on Urban Resilience Measurement[J]. International Urban Planning, 2021(6). 79-85.

[23] sherrieb k, norris f, galea s. Measuring capacities for community resil- ience[J]. Social Indicators Research: An In- ternational and

Interdisciplinary Journal for Quality-of-Life Measurement, 2010, 99 (2): 227-247.

[24] JEROME H, KAHAN A C, et al. An operational framework for resilience[J]. Journal of Homeland Security and Emergency Management, 2009, 6(1): 83.

[25] COLTEN C E, KATES R W, LASKA S B. Three years after Katrina: lessons for community resilience[J]. Environment Science & Policy for Sustainable Development, 2008, 50(5): 36-47.

[26] ZHAI G, IKEDA S. Empirical analysis of Japanese flood risk acceptability within multi-risk context[J]. Natural Hazards and Earth System Sciences, 2008, 8: 1049-1066.

[27] UNDRR (The United Nations Office for Disaster Risk Reduction). Words into action: engaging for resilience in support of the Sendai framework for disaster risk reduction 2015-2030 [R]. 2020.

[28] IPCC (Intergovernmental Panel on Climat e Change), Sections[R]//Core Writing Team, LEE H, ROMERO J. Climate change 2023: synthesis report. IPCC, Geneva, Switzerland, 2023. IPCC, Geneva, Switzerland, 2023.

[29] pÖRTNER H O, ROBERTS D C.TIGNOR M M B. et al. Climate change 2022: impacts, adaptation and vulnerability [M]. Cambridge University Press, Cambridge, UK and New York, 2022.

[30] Commonwealth of Australia. Australian disaster resilience handbook collection: managing the floodplain: a guide to best practice in flood risk management in Australia [R]. 3rd ed. Australian Institute for Disaster Resilience, 2017.

[31] Commonwealth of Australia. Australian disaster resilience handbook collection: flood emergency planning for disaster resilience [R]. Australian Institute for Disaster Resilience, 2020.

[32] Ministry of Land, Infrastructure, Transportation and Tourism Stormwater Management Strategy Plan Guideline (Case) [R]. Ministry of Land, Infrastructure, Transport and Tourism, Water Management and Land Conservation Bureau, Sewerage Department, 2021-11.

[33] Ministry of Land, Infrastructure, Transportation and Tourism. A guide to flooding countermeasures by the government and the private sector: Explanation of the regional system for flooding countermeasures [R]. Ministry of Land, Infrastructure, Transport and Tourism, Water Management and Land Conservation Bureau, Sewerage Division, Japan, 2021-11 .

[34] Ministry of Land, Infrastructure, Transportation and Tourism, Japan. Consideration of changes in the basic policy for river restoration[R]. Ministry of Land, Infrastructure, Transport and Tourism, Water Management and Land Conservation Bureau, Japan, 2022-5-27.

[35] DEFRA (Department for Environment, Food and Rural Affairs). River basin planning guidance [R]. 2021-9.

[36] The Geneva Association. Flood risk management in the United States [R]. The Geneva Association: International Association for the Study of Insurance Economics, Zurich, 2020.

[37] BROWDER G, NUNEZ S A, JONGMAN B, et al. An epic response: innovative governance for flood and drought risk management [R]. World Bank, Washington, DC, 2021.

[38] United Nations. Guidelines for reducing flood losses [R]. Guidelines for reducing flood losses [R]. 2007.

[39] UNDRR (The United Nations Office for Disaster Risk Reduction). The report of The midterm review of the implementation of the Sendai framework for disaster risk reduction 2015-2030[R]. UNDRR: Geneva, Switzerland, 2023.

[40] MA Kun, TANG Xiaolan, REN Yujie, et al. Research on constructing rainfall and flood management model in hilly granite based on resilience theory[J]. Journal of Nanjing Forestry University (Natural Science Edition), 2018, 42(3): 139-145.

[41] Yang Fan, Xu Ying, Duan Ning. Intelligent transformation of urban flood resilience governance system and innovation of realization path[J]. Urban Development Research,2021, 28(5):119-126.

[42] YE X, WAN G, LU Z, et al. Towards an AI-driven framework for multiscale urban flood resilience planning and design[J]. Computational Urban Science, 2021(1):11.

[43] SHARIFI A, YAMAGATA Y. Resilient urban form: a conceptual framework[R]// Resilience-oriented

Urban Planning, 2018: 167-179.
[44] Wang, Hanyan Li, Xinyu Zang. Coping with storm waterlogging in a city A theoretical framework for the resilience of built environments[J]. Journal of Architecture, 2022(S1): 18-23.
[45] FISCHHOFF B, SLOVIC P, LICHTEN- STEIN S, et al. How safe is safe enough? a psychometric study of attitudes towards technological risks and benefits[J]. Policy Sciences, 1978(9): 127-152.
[46] Zhai GF, Lu YW. Spatial planning for emergency evacuation and rescue:Theory-methodology-practice [M]. China Building Material Industry Press, 2023.
[47] （Fire Disaster Society of Japan. A survey report on fires associated with the 1995 Hyogo earthquake in southern Japan [R].1996.
[48] NIB (National Institute of Building Scienc- es). Natural hazard mitigation saves, 2019 report[R]. 2019.
[49] UNDRR (The United Nations Office for Disaster Risk Reduction). Scoping study on compound, cascading and systemic risks in the asia pacific [R]. 2022.
[50] Li Y, Zhai GF. China's urban disaster resilience assessment and Research on Its Enhancement Strategy[J]. Planner, 2017(8): 5- 11.
[51] GUO Jia, ZHAI Guofang, GE YiFu. Construction and Empirical Research on the Comprehensive Resilience Index of Rural Habitat: The Case of Jiangsu Province [J]. Shanghai Urban Planning, 2023(2): 15-22.
[52] Japan Ministry of Land Reinforcement. Results of Vulnerability Evaluation[R]. 2023.
[53] The City of New York: A stronger, more resilient New York[R]. 2013.
[54] Ministry of Land, Infrastructure, Transportation and Tourism. Countermeasures against flooding by the government and the public.Explanation of the Regional System for Countermeasures against Flood Damage [R]. Ministry of Land, Infrastructure, Transport and Tourism, Water Management and Land Conservation Bureau, Sewerage Department, Japan, 2021.
[55] EPA (U.S. Environmental Protection Agency). Planning for flood recovery and long-term resilience in Vermont: smart growth approaches for disaster-resilient communities[R]. 2014.
[56] Technology for Water Management Plan for Climate Transformation Search. Climate Change in Water Management Plans [R]. 2021.
[57] Cabinet Office (Disaster Prevention). Water Damage in Municipalities Countermeasures [R]. 2016.
[58] CIGLER B A. U.S. floods: the necessity of mitigation[J]. State and Local Government Review, 2017(2): 1-13.
[59] CHENG Xiaotao, LIU Changjun, LI Changzhi, et al. Characteristics of Flood Risk Evolution and Urban Resilience Enhancement Strategies in a Changing Environment [J]. Journal of Water Resources, 2022, 53(7): 757-768.
[60] CHEN Bilin, LI Yinglong. Flood resilience-oriented adaptive transition planning assessment for high-density coastal cities: A case study of Shenzhen Mangrove Bay Area[J]. Journal of Urban Planning, 2023(4).
77-86.
[61] Xie Lei, Zhou Pengfei, Yang Hongyi, et al. Exploring the resilience paradigm of lifeline projects in coastal areas under the impact of climate change: The case of Ningbo[J]. Journal of Urban Planning, 2022 (S2): 81-88.

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