Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 4907084, 13 pages
https://doi.org/10.1155/2022/4907084

Research Article

Urban Disaster Risk Prevention and Mitigation Strategies from the Perspective of Climate Resilience

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Received 4 July 2022; Revised 31 July 2022; Accepted 5 August 2022; Published 21 August 2022

Academic Editor: Kuruva Lakshmanna

Enhancing urban climate resilience and innovating urban risk governance model are of great significance to promote the security development of cities. This paper discusses urban disaster risk prevention and mitigation strategies from the perspective of climate resilience. The urban climate resilience index system is constructed through text mining. The entropy weight TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method and obstacle degree model are used to measure the climate resilience index and identify the main obstacle factors that affect the improvement of urban climate resilience. This provides a quantitative representation method for the analysis of urban climate resilience and clarifies the contribution of climate resilience to urban disaster risk prevention and mitigation, as well as the key and difficult points of urban disaster risk prevention and mitigation. Therefore, based on the quantitative analysis of climate resilience, this paper puts forward disaster risk prevention and mitigation strategies from five aspects: collaborative governance, urban planning, early warning system, scientific and technological empowerment, and disaster education. It is expected to provide a reference for the urban system to maintain green, low-carbon, and high-quality development under climate change.

1. Introduction

With the change in the global climate situation and the rapid urbanization process, cities are facing unprecedented climate risks. The impact and disturbance of disasters often lead to the failure of urban functions, the disorder of social functions, and even large and heavy casualties and property losses. As a complex giant system, the city contains many interdependent and interconnected subsystems and various dynamic change processes [1]. Population agglomeration, industrial clusters, and unbalanced spatial development also increase the city's vulnerability in the face of disasters. In China, seven of the ten natural disasters in 2021 were related to urban climate risk; the most typical were the severe urban waterlogging and river floods caused by the rare and catastrophic rainstorm in Zhengzhou, Henan Province. The disaster caused 380 deaths and 40.9 billion CNY of direct economic losses.

Improving climate resilience is considered an essential means of reducing future risks. The research on "resilience" has experienced from the field of mechanics to the field of ecology [2, 3], then transitioned to the field of social and environmental changes [4, 5], and then gradually received extensive attention in the field of disaster management [6, 7]. In the field of disaster science, resilience research has achieved a significant breakthrough, emphasizing the ability of the system to learn and adapt from disasters. Urban climate resilience not only describes the city's ability to resist disasters caused by climate change but also reflects the city's ability to continuously recover and adapt to disasters and changes as a complex giant system. Enhancing urban climate resilience and innovating urban risk governance models are not only the trend of the times but also the need for innovative development of urban risk governance research and practice.

Based on analyzing the practical logic of urban disaster risk prevention and mitigation from the perspective of climate resilience, this paper integrates the concept of climate resilience into the disaster risk management system, constructs the index system of urban climate resilience, measures the climate resilience index by using the entropy weight TOPSIS method, identifies the main obstacle factors affecting the improvement of resilience by using the obstacle degree model, and then discusses the strategies of urban disaster risk prevention and mitigation. It is expected to provide a reference for enhancing urban climate resilience and promoting urban security development.

2. Literature Review

Through the systematic study of the existing literature, it is found that

(a) mitigation and adaptation are considered to be the main ways to deal with climate change. In addition to paying attention to these two strategies, more and more scholars have begun to discuss and emphasize climate resilience [8, 9]. Compared with the "adaptation," "vulnerability reduction," or "countering climate-related threats," the notion of resilience may have more positive connotations [10, 11]. Urban climate resilience is a highly multidimensional concept. At present, the opinions on how to define and measure it are still broad and divergent, but there are two points that can be made clear: (1) cities must have the ability to resist interference and be prepared for climate change; (2) while striving to improve climate change resilience, efforts must be made to promote urban development [12]. The existing literature on climate resilience mainly focuses on urban design and planning. Since the 21st century, microclimate, low carbon, and risk response have become important research topics in the field of urban design and planning [13]. Japan, the United States, and the United Kingdom have accordingly issued the basic strategic framework and planning instructions for climate change mitigation to manage climate risks and enhance climate resilience. In recent years, Chinese scholars have also been actively exploring and integrating the concept of climate resilience into urban planning and design practices to cope with urban disaster risks [14]. Although there are more and more studies on urban climate resilience, a universal analysis framework has not been formed so far [15]

(b) the existing literature on urban risk management primarily focuses on traditional fields such as disaster prevention and mitigation [16, 17], ecological environment [18, 19], and emergency management of public security [20, 21], and the research objects focus on traditional risks such as rainstorm and flood [22, 23], earthquake disasters [24, 25], and environmental pollution [26, 27], while there is little research on compound risks and emerging risks. However, as a complex giant system, the city has the characteristics of nonlinearity, self-organization, and suddenness. The outbreak of traditional risks often affects all aspects of the urban system, thus forming a dynamic and complex system risk. Therefore, based on the uncertainty and complexity of urban risk, urban risk governance is a systematic project, which needs to gather multidisciplinary and multiprofessional knowledge to form a scientific and reasonable research layout, to improve the comprehensive management ability of urban risk. Secondly, the research on urban risk governance in China has gone through the stages from experience research such as viewpoint introduction [28], experience summary [29] to empirical research such as questionnaire survey [30], expert interview [31], and secondary data analysis [32], but most of them still focus on qualitative research, and quantitative research accounts for less than 10% [33]. However, the quantitative analysis can more effectively meet the refinement requirements of urban disaster risk management

(c) the existing literature on the coupling research between urban climate resilience and disaster risk prevention and mitigation strategies needs to be tentatively expanded. According to different research objects, disaster resilience can be divided into three categories: cities [34], communities [35], and individuals [36]. As the backbone of coping with climate change, cities will play a more critical role in the global climate governance system. Systematic research should be carried out from a policy perspective to continuously deepen the understanding of climate resilience; incorporate the concept of risk management and control into the governance system; and clarify the subject, content, and mechanism of risk prevention and mitigation [37]. To sum up, the organic combination of climate resilience and urban disaster risk governance provides a new idea for the innovation of urban disaster risk governance model and the construction of governance system. However, it is regrettable that the in-depth research, thinking, and practical innovation in this field still need to be improved. How to incorporate climate resilience into urban disaster risk prevention and control urgently needs theoretical support and successful practical experience

3. Materials and Methods

3.1. Study Area. Beijing is located in North China, with a total of 16 municipal districts covering a total area of 16,410 km^2. By the end of 2021, the city had a permanent population of 21.886 million. According to preliminary calculations, in 2021, Beijing's GDP was 4026.96 billion CNY, the industrial added value was 569.25 billion CNY, and per capita disposable income reached 75,002 CNY. Beijing has a typical temperate monsoon climate. According to statistics, from 2000 to 2020, the average maximum temperature in Beijing reached 38.6°C, while the average minimum temperature reached -13.3°C. Precipitation is mainly concentrated in summer, with high intensity, and the precipitation is

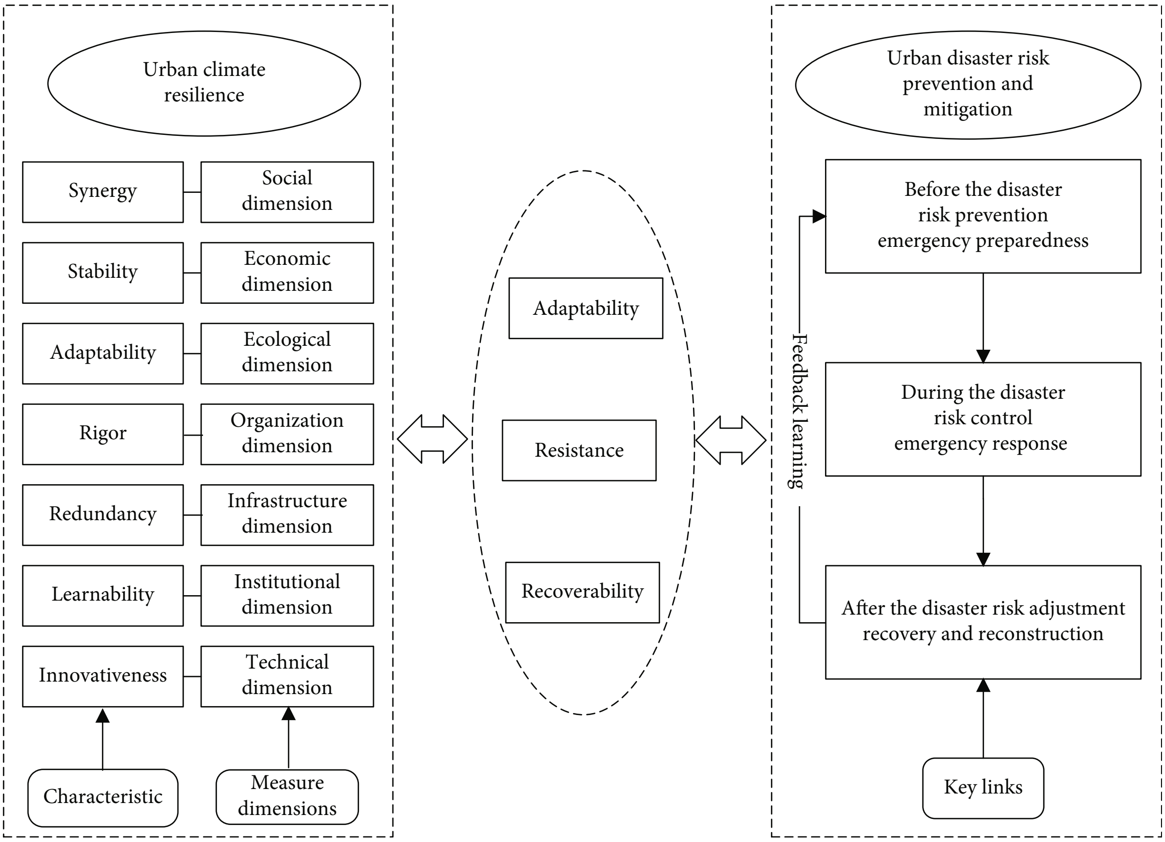

Figure 1: Practical logic of urban disaster risk prevention and mitigation from the perspective of climate resilience.

spatially uneven due to the influence of topography. The accumulation of population and industry and the complexity of the environment increase Beijing's vulnerability to climate risks. According to historical data statistics, in the past 10 years, there were 6 extreme rainfall events in Beijing and 165 extreme rainfall events at district level: one time of extreme high-temperature weather, twice extreme low-temperature weather, and three times of sandstorm weather; Mentougou District had one time of extreme snowfall; Huairou District, Yanqing District, and Miyun District had extreme snowfall for 1/1/3 times, respectively. It can be seen that Beijing is seriously threatened by climate risks and often suffers from extreme weather and climate events. Taking Beijing as an example, it is representative to explore how to integrate the concept of climate resilience into urban governance. In addition, due to the comprehensive influence of geographical location, resources and environment, economic level, and other factors, each district of Beijing presents different development, so it is realistic and reasonable to choose the district as the basic unit of the study.

3.2. Methods

3.2.1. Practical Logic. Climate change, characterized by warming and extreme weather, is having an increasingly significant impact on cities. Improving climate resilience is considered an important means of reducing future risks. As a critical region and backbone of climate change response, the urban system impacts climate resilience under the coupling effect of social, economic, ecological, infrastructure, organization, institution, and technology subsystems. The concept of urban climate resilience can be quantified from these dimensions.

Urban climate resilience means that the urban system has an excellent ability to resist, recover, and adapt to disasters caused by climate change, its tasks include (1) preventing possible threats, (2) resisting the interference, (3) responding, (4) quickly recovering urban functions, and (5) learning from events. Accordingly, these abilities can be reflected in the urban risk governance model, providing a basis for formulating urban disaster risk prevention and mitigation strategies. Adaptability plays a role in the risk prevention and emergency preparedness stage before the disaster, to do an excellent job in disaster prevention and strengthen the city's ability to absorb to interference; resistance plays a role in the risk control and emergency response stage during the disaster, realizing fast response and reducing disaster losses; recoverability plays a role in the risk adjustment and recovery and reconstruction stage after the disaster, realizing rapid recovery, generating feedback and learning behaviors, updating systems and policies in time, and improving predisaster preparation, to continuously improve the comprehensive prevention capacity of the urban system against disaster risk and promote the security development of the city (see Figure 1).

3.2.2. Index System. The study of urban climate resilience is still in its infancy, and there is a lack of relevant quantitative evaluation methods for reference. However, it is clear that urban climate resilience involves two significant elements: climate resilience and urban system. Therefore, this paper embarks from two angles: on the one hand, it is the adaptation and mitigation measures to deal with climate change, and on the other hand, it is the complexity and diversity of urban as a giant system. Through text mining, it sorts out and analyzes the relevant evaluation indexes and influencing factors. Seven subsystems, namely, society, economy, ecology, infrastructure, organization, institution, and technology, with 41 specific indexes, are selected to establish an evaluation index system for urban climate resilience (see Table 1). The index system is not only established for Beijing but also applicable to other cities. However, in the specific evaluation process, it can be adjusted appropriately with reference to the principle of index selection, so that the evaluation results are more in line with the actual situation.

Disaster-bearing bodies have two aspects: people and objects. Accordingly, the social subsystem mainly involves these two aspects, including relevant indexes of population density, population structure, residents' income, the proportion of social assistance recipients, number of doctors, and grain yield. Disaster prevention, mitigation, and relief work require adequate financial support, while the economic subsystem reflects the financial guarantee ability, including relevant indexes of GDP, industrial structure, foreign investment, number of enterprises, and unemployment rate. Low carbon is an important measure to cope with climate change. The carbon sequestration of plants can effectively reduce the concentration of carbon dioxide in the atmosphere. Therefore, the ecological subsystem includes relevant indexes of greening, forest coverage rate, per capita park green area, air quality, domestic garbage treatment rate, and total energy consumption. Orderly organization can improve the efficiency of disaster risk management. In the organizational subsystem, indexes related to subdistrict offices, number of community service organizations, number of disaster mitigation communities, and number of emergency drills are selected to measure the organizational ability of the system. A solid infrastructure system is conducive to enhancing the city's ability to absorb and respond to disaster disturbance. The system includes indexes related to the number of medical and health organizations and beds, construction area of indemnification housing, the number of adoptive units and beds, and area of emergency shelter. Nonstructural measures are essential for improving urban climate resilience, which is mainly reflected in the indexes related to insurance coverage and emergency plan in the institutional subsystem. With the development of wisdom city, sponge city, and artificial intelligence technology, the role of technology in the field of disaster prevention and mitigation has become increasingly prominent. Technology should also be an important dimension of climate resilience. Therefore, relevant indexes of early warning information, patent authorization, contract transaction in the technology market, and the proportion of R&D in GDP of the technology subsystem are also selected.

3.2.3. Calculation of Index Weight. In order to reduce the impact of subjective judgment on the evaluation results, this paper selects the entropy weight method to calculate the weight of each index, and the steps are as follows (see Table 1 for the results):

Constructing the original matrix X,

$$X = \left[x_{ij}\right]_{m\times n} \quad (i = 1, 2 \cdots m, j = 1, 2 \cdots n), \tag{1}$$

where m is the number of evaluation objects and n is the number of indexes.

Standardizing index, for positive index,

$$y_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}. \tag{2}$$

For negative index,

$$y_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}}. \tag{3}$$

Calculating the index entropy value,

$$E_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij}, \tag{4}$$

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}. \tag{5}$$

Calculating index weight,

$$\omega_j = \frac{1 - E_j}{\sum_{j=1}^{n}\left(1 - E_j\right)}. \tag{6}$$

3.2.4. TOPSIS Model. The basic principle of the TOPSIS method is to sort according to the distance between the evaluation object and the ideal solutions. However, the traditional TOPSIS model considers that the weights of different indexes are consistent, thus ignoring the relative importance of indexes. Therefore, this paper improves the original TOPSIS model, first calculates the weight of each index by using entropy weight method, and then calculates it into the TOPSIS model, to effectively overcome this defect [38, 39]. The specific calculation steps are as follows:

Weighting the standardized matrix Y to obtain the matrix Q,

$$Q = \left[q_{ij}\right]_{m\times n}, \tag{7}$$

$$q_{ij} = y_{ij} \times \omega_j. \tag{8}$$

Determining the positive and negative ideal solutions,

$$Q^{+} = \left\{\max q_{ij} \middle| j = 1, 2, \cdots, n\right\}, \tag{9}$$

$$Q^{-} = \left\{\min q_{ij} \middle| j = 1, 2, \cdots, n\right\}. \tag{10}$$

Table 1: Evaluation index system of urban climate resilience.

Target layer	Criterion layer	Index layer	Attribute	Weight
Urban climate resilience	Social (A)	Resident population density (A1)	Negative	0.0045
		The proportion of population aged 0-14 (A2)	Negative	0.0061
		The proportion of population aged over 65 (A3)	Negative	0.0109
		Per capita disposable income (A4)	Positive	0.0185
		The proportion of social assistance recipients (A5)	Negative	0.0051
		Number of licensed (assistant) physicians per 1000 permanent residents (A6)	Positive	0.0228
		Grain yield (A7)	Positive	0.0313
	Economic (B)	GDP (B1)	Positive	0.0283
		GDP per capita (B2)	Positive	0.0301
		Proportion of tertiary industry in GDP (B3)	Positive	0.0063
		Actual utilization of foreign direct investment (B4)	Positive	0.0485
		Number of enterprises above designated size (B5)	Positive	0.0207
		Unemployment rate (B6)	Negative	0.0036
	Ecological (C)	Greening coverage (C1)	Positive	0.0048
		Forest greening rate (C2)	Positive	0.0095
		Per capita park green area (C3)	Positive	0.0093
		The annual average concentration of sulfur dioxide (C4)	Positive	0.0205
		The annual average concentration of nitrogen dioxide (C5)	Negative	0.0142
		The annual average concentration of inhalable particles (C6)	Negative	0.0074
		The annual average concentration of PM2.5 (C7)	Negative	0.0119
		Harmless treatment rate of domestic garbage (C8)	Positive	0.1208
		Total energy consumption (C9)	Negative	0.0072
	Organizational (D)	Subdistrict offices (D1)	Positive	0.0199
		Number of community service organizations (D2)	Positive	0.0124
		National comprehensive disaster mitigation demonstration communities (D3)	Positive	0.0178
		Municipal comprehensive disaster mitigation demonstration communities (D4)	Positive	0.0185
		Number of emergency drills (D5)	Positive	0.0249
	Infrastructure (E)	Number of medical and health organizations (E1)	Positive	0.0153
		Hospital beds per 1000 permanent residents (E2)	Positive	0.0164
		Construction area of indemnification housing (E3)	Positive	0.0220
		Number of adoptive units (E4)	Positive	0.0137
		Number of beds in adoptive units (E5)	Positive	0.0160
		Area of emergency shelter (E6)	Positive	0.0405
	Institutional (F)	Medical insurance coverage (F1)	Positive	0.0210
		Unemployment insurance coverage (F2)	Positive	0.0200
		Endowment insurance coverage (F3)	Positive	0.0208
		Whether an emergency plan is prepared (F4)	Positive	0.1208
	Technical (G)	Early warning information (G1)	Positive	0.0091
		Patent authorization (G2)	Positive	0.0323
		Contract transaction in the technology market (G3)	Positive	0.0627
		The proportion of research and development (R&D) funds for information transmission, software, and information technology services in GDP (G4)	Positive	0.0534

Note: the value method of whether an emergency plan is a prepared index is as follows: yes: take 1 and no: take 0.

Calculating the distance between the evaluation object and the positive and negative ideal solutions,

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(q_{ij} - Q_j^+ \right)^2}, \tag{11}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(q_{ij} - Q_j^- \right)^2}. \tag{12}$$

Calculating the closeness degree between the evaluation object and the ideal solution,

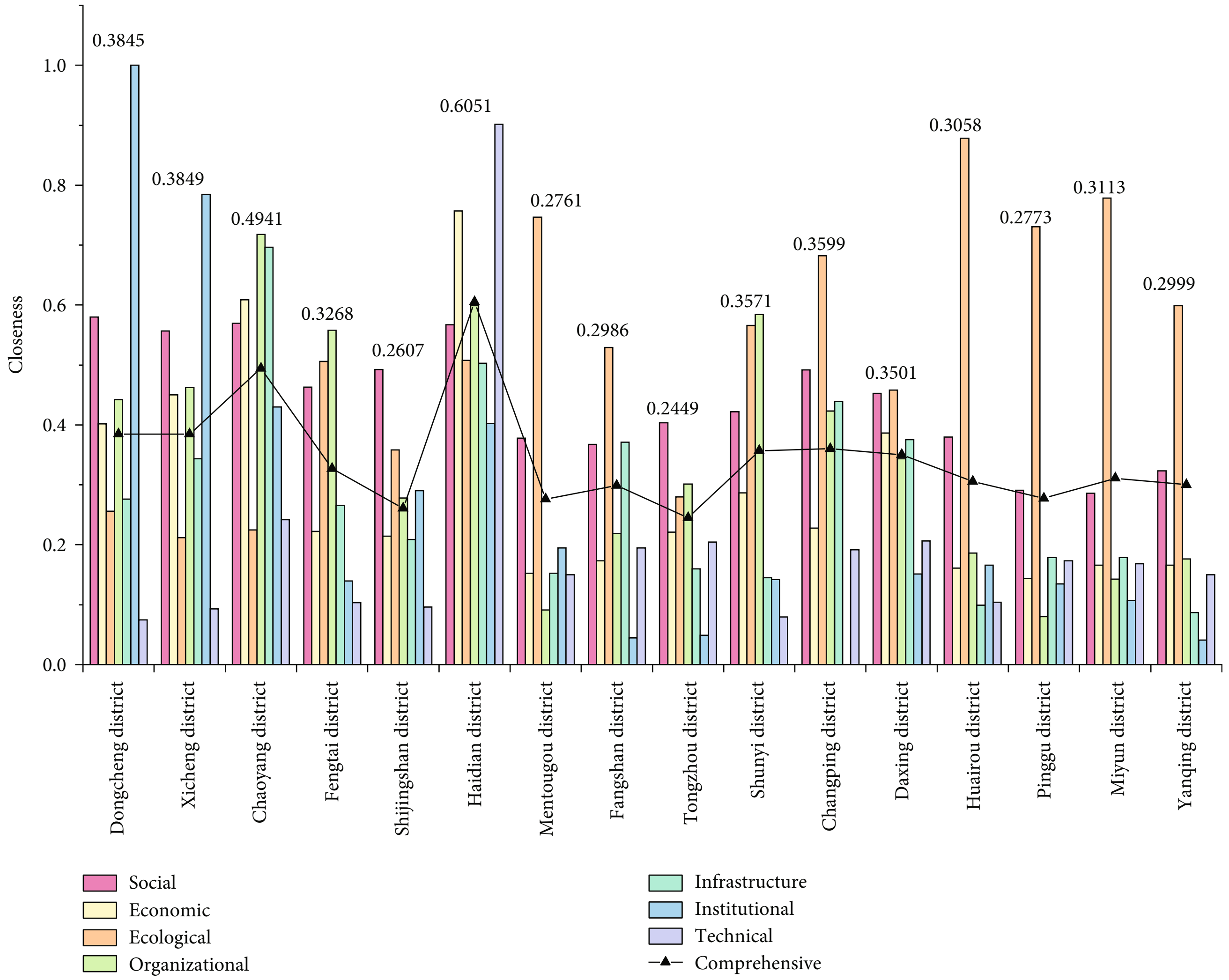

FIGURE 2: Climate resilience comprehensive and criterion layer closeness in 16 districts of Beijing.

$$\delta_i = \frac{D_i^-}{D_i^+ + D_i^-}. \quad (13)$$

3.2.5. Obstacle Degree Model. Based on the comprehensive evaluation of urban climate resilience, the obstacle degree model is selected to further explore the key factors hindering the construction of resilience. The specific formulas are as follows:

$$d_{ij} = 1 - y_{ij}, \quad (14)$$

$$A_{ij} = \frac{\omega_j \times d_{ij}}{\sum_{j=1}^{n} \omega_j \times d_{ij}} \times 100\%, \quad (15)$$

$$U = \sum A_{ij}, \quad (16)$$

where d_{ij} is the index deviation degree, indicating the distance between the evaluation value of index j and 100%; y_{ij} is the standard value, obtained by formula (1) or formula (2); A_{ij} is index obstacle degree, indicating the index j obstacle degree to urban climate resilience; ω_j represents the factor contribution degree, which is the weight value of the index j; and U is the obstacle degree of the index of the criterion layer, indicating the obstacle degree of the criterion layer index to the urban climate resilience.

4. Results

4.1. Evaluation Results of Urban Climate Resilience. Based on the entropy weight method and TOPSIS model, the climate resilience comprehensive and criterion layer closeness of 16 districts in Beijing are calculated. The results are shown in Figure 2. The comprehensive level of climate resilience in each district is uneven, and there is a large room for improvement on the whole. Among them, Haidian District (0.6051) has the highest resilience, while Tongzhou District (0.2449) has the lowest resilience, with a significant difference. According to the comprehensive score, the climate resilience of each district in Beijing is divided into three categories: high resilience with a score greater than 0.5, general resilience with a score between 0.3 and 0.5, and low resilience with a score lower than 0.5, as shown in Table 2.

Table 2: Classification of climate resilience level in 16 districts of Beijing.

Category	District
High resilience (>0.5)	Haidian District
General resilience (0.3-0.5)	Chaoyang District, Xicheng District, Dongcheng District, Changping District, Shunyi District, Daxing District, Fengtai District, Miyun District, and Huairou District
Low resilience (<0.3)	Yanqing District, Fangshan District, Pinggu District, Mentougou District, Shijingshan District, and Tongzhou District

Table 3: The obstacle degree of the criterion layer index (%).

District	Social	Economic	Ecological	Organizational	Infrastructure	Institutional	Technical
Dongcheng District	10.78	17.22	13.52	10.35	19.77	0.00	28.36
Xicheng District	11.39	15.63	14.52	9.91	17.76	2.59	28.20
Chaoyang District	15.46	13.01	18.21	5.24	6.63	9.14	32.31
Fengtai District	12.23	20.81	7.48	7.02	17.42	9.53	25.51
Shijingshan District	10.82	19.18	9.63	12.08	17.09	7.21	23.99
Haidian District	22.12	9.21	15.87	13.72	23.42	14.12	1.54
Mentougou District	12.16	20.91	2.95	13.89	17.86	8.03	24.20
Fangshan District	10.60	21.22	6.64	12.80	13.78	10.06	24.90
Tongzhou District	10.80	18.20	10.66	10.89	17.09	9.35	23.01
Shunyi District	9.51	19.07	6.50	6.45	20.53	9.90	28.04
Changping District	12.07	21.95	4.51	10.65	13.32	11.55	25.95
Daxing District	11.21	17.07	8.98	11.82	15.04	9.89	25.99
Huairou District	11.45	20.76	0.81	13.83	19.10	8.63	25.42
Pinggu District	11.72	20.65	3.04	14.42	17.35	8.65	24.17
Miyun District	10.46	21.25	1.85	14.41	17.84	9.31	24.88
Yanqing District	8.33	21.22	4.74	13.42	18.64	9.72	23.93

Haidian District is the only district with high resilience. In this district, except for the institution subsystem with low resilience, the other subsystems are at a high resilience, so the overall resilience is high. The districts with general resilience include Chaoyang District, Xicheng District, Dongcheng District, Changping District, Shunyi District, Daxing District, Fengtai District, Miyun District, and Huairou District. In these districts, the resilience of each subsystem is uneven, and the short board effect is pronounced, resulting in the low overall resilience. The districts with low resilience include Yanqing District, Fangshan District, Pinggu District, Mentougou District, Shijingshan District, and Tongzhou District. The resilience of each subsystem in these districts is basically at a low level, and only a few subsystems have high resilience, so the overall resilience is low.

4.2. Analysis Results of Obstacle Degree. Based on the obstacle degree model, the main obstacle factors and their influence degree in the process of climate resilience construction in 16 districts of Beijing are analyzed from two dimensions: criterion layer and index layer (the results are shown in Tables 3 and 4). The top four obstacle factors in index layer are listed for analysis.

As can be seen from Table 3, the influence degree of each criterion layer index on climate resilience varies in each district. Except for Haidian District, the rest of the 15 districts have the highest obstacle degree of the technology subsystem, reaching more than 23%. With the rapid development of science and technology and information technology, technology plays an essential role in all links of disaster prevention, mitigation, and relief. These 15 districts should pay more attention to the investment in technology and help disaster prevention and mitigation with scientific and technological progress. The economic and infrastructure subsystems have an obstacle degree of more than 15% in 87.50% and 81.25%of the districts, respectively. The steady development of the economy and the robustness and redundancy of infrastructure play a positive role in urban response to disaster disturbance, and the corresponding districts should pay attention to the construction of economic resilience and infrastructure resilience. In addition, except for a few districts, the obstacle degree of the three subsystems of society, ecology, and system is less than 15%, indicating that the three subsystems have a little obstacle to the construction of climate resilience in most districts; accordingly, for the few districts with high obstacle degree of the three subsystems, it is necessary to strengthen the resilience construction to avoid the impact of short board effect on the overall resilience.

Table 4: Main obstacle factors and degree (%).

District	Project	Index ranking 1	2	3	4
Dongcheng District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	11.30	10.02	8.33	7.45
Xicheng District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	11.06	10.09	9.06	7.67
Chaoyang District	Obstacle factor	G3	G4	A7	C4
	Obstacle degree	14.54	11.94	8.10	5.31
Fengtai District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	10.59	8.71	8.50	6.89
Shijingshan District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	9.92	8.06	7.42	6.34
Haidian District	Obstacle factor	E6	A7	A6	E2
	Obstacle degree	13.75	11.57	6.97	5.30
Mentougou District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	10.10	8.53	7.76	6.18
Fangshan District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	10.61	8.97	8.12	6.19
Tongzhou District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	9.83	8.49	6.94	6.16
Shunyi District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	11.51	9.89	7.92	7.36
Changping District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	11.32	9.09	8.81	5.97
Daxing District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	11.28	9.58	7.87	6.11
Huairou District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	10.42	8.92	8.00	6.71
Pinggu District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	10.13	8.62	7.78	6.55
Miyun District	Obstacle factor	G3	G4	B4	E6
	Obstacle degree	10.54	8.66	8.16	6.69
Yanqing District	Obstacle factor	G3	B4	G4	E6
	Obstacle degree	10.27	7.94	7.84	6.22

As can be seen from Table 4, the top four factors of obstacle degree in the index layer of each district are reflected in different subsystems. Among the selected samples of municipal districts, the obstacle factors that hinder the improvement of climate resilience in various districts are similar to some extent but not identical.

In the process of climate resilience construction in Dongcheng District, Xicheng District, Fengtai District, Shijingshan District, Mentougou District, Fangshan District, Tongzhou District, Shunyi District, Changping District, Daxing District, Huairou District, Pinggu District, and Miyun District, the obstacle degree of three subsystems of technology, infrastructure, and economy is relatively high. In comparison, the four subsystems of society, ecology, organization, and institution are relatively low. Reflected in the index layer, the obstacle degree of contract transaction in the technology market; the proportion of research and development (R&D) funds for information transmission, software, and information technology services in GDP; actual utilization of foreign direct investment; and area of emergency shelter ranks in the top four. These districts should strengthen the resilience construction of these three subsystems, establish a long-term and stable science and technology investment mechanism, strengthen the construction of infrastructure projects, promote high-quality economic development, and supplement the weak points, to improve the overall climate resilience.

In the process of climate resilience construction in Chaoyang District, the obstacle degree of the three subsystems of technology, ecology, and society is relatively high. In comparison, the four subsystems of economy, institution, infrastructure, and organization are relatively low. Reflected in the index layer, the obstacle degree of contract transaction in the technology market; the proportion of research and development (R&D) funds for information transmission, software, and information technology services in GDP; grain yield; and the annual average concentration of sulfur dioxide ranks in the top four. In 2020, there were 6,031 technology market contracts in Chaoyang District, 50,593 less than that in Haidian District (56,624), which ranked first; the proportion of research and development (R&D) funds for information transmission, software, and information technology services accounted for 0.66% of GDP, 4.10% lower than that of Haidian District (4.76%), which ranked first; the grain yield was 131.5 tons, ranking last among the 13 agriculture-related districts; the annual average concentration of sulfur dioxide was $4\,\mu g/m^3$, ranking joint first among the 16 districts.

In the process of climate resilience construction in Haidian District, the obstacle degree of two subsystems of infrastructure and society is relatively high. In comparison, the five subsystems of ecology, institution, organization, economy, and technology are relatively low. Reflected in the index layer, the obstacle degree of area of emergency shelter, grain yield, number of licensed (assistant) physicians per 1000 permanent residents, and hospital beds per 1000 permanent residents ranks in the top four. In 2020, Haidian District had 1,287,600 m^2 of emergency shelter area, 10,262,600 m^2 less than Chaoyang District (11,550,200 m^2), which had the largest emergency shelter area; the grain yield was 2201.9 tons, ranking 10th among the 13 agriculture-related districts; the number of licensed (assistant) physicians per 1000 permanent residents was 4.71, 10.03 less than Dongcheng District (14.74), which ranked first; the number of hospital beds per 1000 permanent residents was 4.32, 11.28 less than Xicheng District (15.60), which ranked first.

In the process of climate resilience construction in Yanqing District, the obstacle degree of the three subsystems of technology, economy, and infrastructure is relatively high. In comparison, the four subsystems of organization, institution, society, and ecology are relatively low. Reflected in the index layer, the obstacle degree of contract transaction in the technology market; actual utilization of foreign direct investment; the proportion of research and development (R&D) funds for information transmission, software, and information technology services in GDP; and area of emergency shelter ranks in the top four. The specific indexes are the same as those of Dongcheng District and the other 12 districts mentioned above, but the order of obstacle degree is slightly different. In 2020, 39 technology market contracts were concluded in Yanqing District, ranking last among 16 districts; the actual utilization of foreign direct investment was $3.04 million, ranking the last among the 16 districts; the proportion of research and development (R&D) funds for information transmission, software, and information technology services accounted for 0.50% of GDP, 4.26% lower than that of Haidian District (4.76%), which ranked first; the area of emergency shelter was 730,000 m^2, 10,820,200 m^2 less than Chaoyang District (11,550,200 m^2), which had the largest emergency shelter area.

5. Discussion and Strategy Suggestions

Under the coupling effect of climate change and urban system complexity, cities are more and more frequently and strongly attacked and disturbed by disasters caused by climate change. With the advancement of urban risk management modernization, enhancing urban and rural climate resilience and preventing and mitigating disaster risks have become urgent practical problems to be solved, which are highly consistent with the requirements of urban green, low-carbon, and sustainable development. By analyzing the practical logic of urban disaster risk prevention and mitigation from the perspective of climate resilience and quantitatively measuring the urban climate resilience, it is clear that the contribution of climate resilience to urban disaster prevention and mitigation is to enhance the resistance, recoverability, and adaptability of cities to disasters caused by climate change. Based on this, this paper proposes urban disaster risk prevention and mitigation strategies from the perspective of climate resilience:

5.1. Build a Collaborative Governance Model for Urban Climate Risk. The construction of urban climate resilience is a long-term and arduous systematic task. In addition to strengthening the research on the uncertainty of climate risks, attention should be paid to the complexity and diversity of urban systems. As the backbone of coping with climate change, various subsystems within the city should build a collaborative governance model covering multiple departments and fields. From the above research, it can be seen that the social, economic, ecological, organizational, infrastructure, institutional, and technical subsystems of cities impact urban climate resilience. Therefore, it is necessary to put forward suggestions on urban climate risk response from different dimensions to improve urban climate resilience comprehensively.

For the social subsystem, it is necessary to coordinate population development, reduce the population density in vulnerable areas, rationalize permanent population groups, and ensure emergency supplies and food reserves. For the economic subsystem, reasonably optimizing the industrial structure and improving the level of economic development is essential. For the ecological subsystem, it is necessary to expand the urban greening and vegetation coverage, build an open and interconnected urban park green space system, and improve ecological adaptability. For the organization subsystem, the establishment of comprehensive disaster reduction demonstration community should be promoted continuously, and emergency drills should be organized regularly. For the infrastructure subsystem, it is necessary to expand the construction of urban infrastructure projects, increase their physical strength, and improve redundancy. For the system subsystem, emergency plans should be made; the emergency system, mechanism, and the legal system should be perfected; and the catastrophe insurance system should be improved. For the technology subsystem, a long-term and stable mechanism for scientific and technical input should be established. Regular scientific and technical resource input should be carried out to facilitate disaster prevention and reduction with scientific and technical progress.

In addition, building a multiple subjects collaborative governance model is crucial. The complexity, diversity, and uncertainty of climate risks make it difficult to rely solely on governments at all levels and their functional departments to manage climate risks. It is necessary to expand the governance subjects; lead social organizations, enterprises, and the public to participate in it; and realize the transformation from "government-led" to "multigovernance." Firstly, it is necessary to ensure the sound interaction between the subjects. Governments at all levels should disclose relevant information in accordance with the law to ensure that more subjects can participate, to give full play to the strength and wisdom of each governance subject and form a governance pattern of cooperation and complementary advantages. Secondly, it is necessary to establish a stable cooperative relationship between the subjects, reduce the government's dominance in the governance process, encourage all governance subjects to participate actively, and become an essential partner of the government in the governance of climate risk. It is necessary to seek a balance point of cooperation through communication, negotiation, game, and other means and formulate effective cooperation rules to constraints. Finally, it is necessary to develop and expand the participation scale of social organizations, enterprises, and the public. Many of these subjects may have the awareness of preventing and mitigating climate risks, but they cannot effectively participate in the governance process due to limited cognition, insufficient ability, or insufficient information. Therefore, relevant subjects are required to strengthen personnel training, strengthen knowledge and skills, and improve professional ability. At the same time, the government and its relevant functional departments should also actively help and guide, to improve the governance capacity and expand the scale of participation.

It is also necessary to build a regional collaborative governance model. From the natural point of view, the impact of climate change in a region will spill over to the adjacent regions. Governance of a single city or region cannot systematically mitigate climate risk and improve climate resilience. From the perspective of society, as disasters caused by climate change disturb cities more and more frequently, the public's awareness of preventing and mitigating climate risks continues to improve, and the common goals and motivations among different regions constitute the premise of collaborative governance. Therefore, collaborative governance model should also be formed among different cities and different regions within cities. At the same time, we should continuously improve the regional collaborative governance model of climate risk and enhance governance synergy by strengthening legislative supply, enhancing cooperation motivation, and expanding governance subjects.

5.2. Carry Out Climate Risk Census and Integrate Climate Resilience Concept into Urban Planning. Firstly, climate risk census should be actively carried out to identify and assess climate risks in cities and use them as the scientific basis for climate resilience urban planning. Make full use of remote sensing, big data, GIS, and other technologies to conduct regional and key grid climate risk census and identification. Comprehensively investigate the disaster-causing factors, disaster-bearing bodies, disaster mitigation resources, and other elements related to climate risk. Based on investigation, evaluate the risk elements such as the hazard of the disaster, the distribution characteristics of the disaster-bearing bodies in various regions, the comprehensive disaster mitigation resources, and the disaster mitigation capacity. Based on evaluation, according to the features of the disaster risk, the exposure degree of disaster-bearing body, and the strength of disaster mitigation capacity, implement zoning and hierarchical management. Finally, integrate relevant data to form the urban climate risk zoning map and establish a complete and dynamic climate risk data database.

Second is to promote the translation of climate language into planning language, integrate climate resilience concept into urban planning, and formulate practical strategies to guide relevant actions. According to the census results, draw an urban climate risk analysis map, and on this basis, comprehensively consider the relevant requirements of overall urban planning and disaster prevention and mitigation, and further draw an urban climate planning proposal map. Zoning construction should be carried out according to the degree of the climate impact on cities, and climate resilience urban planning should be made according to local conditions. At the same time, comprehensively consider the relationship between urban design and land use, energy, buildings, transportation infrastructure, green infrastructure, water system, and other elements and climate change; integrate multidisciplinary and multifield knowledge; scientifically and reasonably integrate climate resilience concept into urban planning; and regularly update to ensure the practicality of the planning. During this period, technical means can be used to build a cooperation platform, realize data sharing, allow institutions and the public to participate together, optimize planning and decision-making with the concept of collaborative governance, and create a situation of coconstruction, cogovernance, and sharing.

Finally, probabilistic prediction and scenario analysis of extreme climate events are carried out, and corresponding emergency plans are formulated in combination with the requirements of urban security development. Actively carry out disaster education and training, promote the establishment of comprehensive disaster mitigation demonstration communities, and guide the public to awaken their awareness of preventing and mitigating climate risks to form a bottom-up response model, achieve coordination within the urban system, and systematically and long-term reduce the threat of climate risks to a safe and stable range.

5.3. Build Urban Climate Early Warning Information Platform and Early Warning System. Establish a coconstruction and shared disaster monitoring network to improve the accuracy of monitoring information and the sharing of monitoring data. Through satellites, radars, regional observation networks, and observation sites for key facilities in key areas, an all-weather air-space-earth observation and monitoring network will be formed. Make full use of emerging technologies such as the Internet and cloud computing to create a data sharing platform, strengthen cooperation between departments, and include disaster-bearing bodies and the environment into the monitoring scope to provide a basis for improving the timeliness and accuracy of early warning support.

Improve the early warning information release mechanism. In terms of ensuring its timeliness, it is necessary to focus on improving the high-speed and concise early warning release system to avoid redundant and complicated release procedures that delay disaster prevention and control. In terms of ensuring the breadth of its dissemination, it is necessary to consider the dissemination needs of different groups, improve the early warning information reception and dissemination facilities, and broaden the early warning information dissemination channels. In terms of ensuring its refinement, it is necessary to make full use of information technology to predict and evaluate the possible disaster types, the level of early warning, the range of fluctuations, and the start and end time to achieve more accurate early warning information dissemination.

Coordinate the resources of all parties and establish a cross-regional and cross-departmental emergency management system. Once the early warning information is received, all departments can respond quickly, start the emergency plan, and take linkage measures. Regularly organize the masses to carry out disaster prevention and mitigation knowledge publicity, rescue training, and emergency drills; expand the ranks of grass-roots volunteers; establish and improve the long-term mechanism for social forces to participate in emergency management; and form disaster prevention and emergency response system of departmental linkage and social response. Reasonably allocate the powers and responsibilities of each department to ensure equal rights and responsibilities. At the same time, improve the supervision and accountability system to ensure that emergency measures are implemented.

5.4. Strengthen Scientific and Technological Empowerment to Help Prevent and Mitigate Climate Risks.

With the development of technologies such as the Internet of Things, big data, and cloud computing, the role of technology in urban security risk management has become increasingly prominent. From the previous evaluation process, it can also be found that technology impacts climate resilience. Climate risk is one of the many risks faced by cities. Strengthening scientific and technological empowerment needs to adapt to the practical needs of urban climate risk prevention and mitigation and establish a long-term and stable science and technology investment mechanism based on the present and the future.

Efforts can be made in two directions to strengthen scientific and technological empowerment. The first direction is technological development: based on the whole-process management of disasters, research and develop quantitative risk evaluation technologies and systems to achieve more refined prevention and control requirements; establish a multisource information fusion monitoring network to promote the research and development of high-precision monitoring technology and equipment, and realize the intelligence and precision of monitoring and early warning; develop an emergency perception and rescue system with deep integration of "human-machine-object" to improve the timeliness, intelligence, and order of emergency response; make full use of the Internet of Things, big data, cloud computing, artificial intelligence, and other emerging information technologies to build a smart emergency response platform covering all aspects, and achieve deep integration across regions, levels, and departments.

The second direction is enhancing basic research: climate risks have the characteristics of complexity, diversity, and uncertainty, and the occurrence of major disasters often brings secondary and derivative disasters. The research can be focused on the mechanism of multidisaster coupling and the spatiotemporal evolution of disasters. The occurrence of disasters will lead to different degrees of loss. We can strengthen the research on disaster scenario deduction and situation evaluation and prevent disasters that may have significant consequences in advance. The location, vulnerability, and other data of disaster-bearing bodies reflect important information on whether they will suffer disaster losses and the extent of the losses. Therefore, it is necessary to strengthen the research on the disaster mechanism and vulnerability evaluation methods of the disaster-bearing bodies. The emergency rescue process needs to involve the allocation of materials and rescue equipment, and the rapid and efficient allocation can significantly improve the efficiency of emergency rescue. Therefore, it is necessary to strengthen the theoretical research on the emergency material guarantee system. In addition, the fusion analysis method of big data and big computing and the information integration and comprehensive analysis method of disasters are also the critical directions of basic research.

5.5. Carry Out Disaster Education and Enhance the Awareness of Disaster Risk Prevention and Mitigation.

It is necessary to carry out disaster education, improve the public's understanding and perception of climate disaster risks, and strengthen their awareness of climate crisis to prevent and mitigate urban climate risks. First, for the purpose of cultivating a strong disaster culture in the whole society, strengthen the construction of disaster culture learning places and education bases so that the public can be gradually influenced by the disaster culture and improve the awareness of disaster prevention, mitigation, and relief. Second, we should attach great importance to carrying out disaster education for the whole people, focusing on vulnerable areas and vulnerable groups, to improve the public's overall disaster literacy and awareness, actively carry out emergency drills, and strengthen combat skills training, so that the public can feel the threat of disasters and improve their ability to deal with disaster risks. Third, improve the public's ability to self-rescue and mutual rescue. Because self-rescue and mutual rescue are the most timely and effective ways of rescue. Regularly organize publicity and training activities to strengthen the public's awareness and skills of self-rescue and mutual rescue to improve the efficiency of disaster rescue and reduce casualties. Fourth, we should attach importance to the curriculum construction of disaster education, integrate disaster education into the curriculum system of the university, middle, and primary school students, and systematically and professionally train disaster education teachers. Fifth, strengthen the construction of laws and regulations on disaster education and make clear provisions on the requirements, contents, and methods of disaster education, so that disaster education has laws to follow.

6. Conclusions

(a) With the process of climate change and rapid urbanization, the climate risks faced by cities have increased unprecedentedly. Climate resilience means they have good resistance, recoverability, and adaptability to disasters caused by climate change. It provides a new perspective for cities to maintain security development under climate change. Resilience with urban disaster risk prevention and mitigation can be organically combined to innovate the urban security governance system and promote urban security development

(b) Using entropy weight TOPSIS method and obstacle degree model, the relative importance of various indexes of different urban subsystems to climate resilience can be considered, the comprehensive urban climate resilience index can be measured, and the main obstacle factors affecting the improvement of urban climate resilience can be identified. This method has strong operability. It provides a feasible quantitative representation method for analyzing urban climate resilience

(c) Combined with the results of climate resilience index measurement and identification of main obstacle factors, it is found that the social, economic, ecological, organizational, infrastructure, system, and technical subsystems of cities all impact climate resilience. The uncertainty of climate change and the complexity of urban systems are the key and difficult points of urban climate risk management. The prevention and mitigation strategies of cities against climate risks can be formulated from five dimensions: coordinated governance, climate resilience urban planning, climate early warning, scientific and technological empowerment, and disaster education

(d) In this paper, although we provide a method to measure urban climate resilience, the evaluation is static and lacks dynamic evaluation and prediction of the future urban climate resilience index, which should be improved. In addition, research and development of a universal framework for urban climate resilience analysis should be the direction of future efforts

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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