

# Research on Disaster Resilience Measurement and Its Differential Patterns in Southern Jiangsu Cities

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## ABSTRACT

As an important carrier of human social development, how to improve the response speed and adaptability of urban systems under uncertain factors such as disasters is currently a hot topic in international research. Based on panel data from the southern Jiangsu region from 2011 to 2020, this paper uses the entropy method to measure the resilience levels of various cities, analyzes the factors hindering urban resilience using the resilience barrier model, and explores regional resilience development differences through resilience spatial visualization analysis. The results show: (1) The overall level of urban resilience in the southern Jiangsu region presents a spatial distribution pattern of high in the east, low in the central region, and significant differences in urban resilience; (2) The ranking of urban resilience barriers in southern Jiangsu from 2011 to 2020 is: social resilience, infrastructure resilience, economic resilience, ecological resilience; (3) From the indicator level, factors such as the number of ordinary colleges and universities, total urban water supply, and general public budget revenue have a significant impact on the urban resilience barrier in southern Jiangsu. To enhance urban resilience, it is necessary to optimize the layout structure of higher education, improve urban infrastructure, and strengthen the synergy of urban construction.

## KEYWORDS

Urban Resilience; Resilience Measurement; Differential Patterns.

## 1. INTRODUCTION

Cities are the main battlefield and platform for modernizing national governance. Currently, China's urban development focuses more on quality improvement and gradually enters a new stage of transformation and development. However, due to the increasingly severe global situation, various urban disasters occur frequently, and the instability and uncertainty of urban development increase significantly. The construction of resilient cities reflects the level of high-quality urban development to a certain extent, and the "14th Five-Year" plan includes the construction of resilient cities into the urban development strategy for the first time, indicating that the construction of resilient cities will become a core element of development at this stage.

In the face of the turbulent pressure of internal and external environments, the southern Jiangsu region is strengthening the city's ability to resist crises, strengthening the "resilience index", enhancing the city's ability to resist risks, and maintaining the city's high-quality development, playing a leading and exemplary role for the central and northern Jiangsu regions and even the whole country. In this context, this paper takes the southern Jiangsu region of Jiangsu Province as an example to construct a resilience city evaluation system. Select appropriate resilience evaluation indicators, explore the factors of the city's "resilience barrier", and put forward effective suggestions for the development of urban resilience construction. This will help build Jiangsu into a model of "Safe China" and provide

a sample for reference for the construction of resilient cities across the country, and improve the level and degree of resilient development of Chinese cities.

“Resilience” originally evolved from the Latin word “resilio,” originating in applied science, meaning to return to the original state[1]. Canadian ecologist Holling[2] first introduced the concept of “resilience” in ecology in 1973 to describe the stability of ecosystems. After the 1990s, the academic understanding of resilience gradually shifted from natural ecology to human ecosystems. At the same time, theoretical research on engineering resilience, ecological resilience, and evolutionary resilience laid the foundation for scholars to further understand urban resilience theory. Entering the 21st century, urban studies gradually introduced the concept of “resilience” and formed a relatively complete theoretical system. The Resilience Alliance defines resilient cities as urban systems that can maintain their original structure, basic characteristics, and main functions after external disturbances. Wilbanks[3] defines urban resilience as the system's ability to respond quickly and recover to its initial state when facing multiple threats, emphasizing the recovery capacity of cities. Bruneau[4] believes that a resilient city must have both the ability to withstand pressure and the ability to recover; it is even more important for an urban system to continuously self-repair during the long-term adaptation process.

With the continuous in-depth research both domestically and internationally, the theoretical framework of urban resilience is becoming increasingly refinement, incorporating the main characteristics of resilient cities [5] and the evaluation system for resilient cities into the research scope [6]; the research scope of urban resilience is gradually expanding to include ecology [7], disaster studies [8], urban planning [9], and economics [10]; in terms of research areas and scales, the current focus is on disaster-prone areas and pilot areas for resilient cities in developed countries and regions, riverine areas, and coastal areas [11]. A research scale of national—urban agglomeration—city has roughly formed.

The measurement of urban resilience is mainly constructed through a multidimensional perspective. Jha[12] decomposes it into four dimensions: infrastructure, economy, society, and institutions, thereby constructing a resilience indicator system. Zhang Mingdou[13] conducts a comprehensive assessment of urban resilience from the perspectives of ecology, economy, society, and infrastructure. On this basis, Zhou Limin[14] introduces five dimensions for evaluation in the comprehensive assessment of urban resilience, but the selected indicators are all qualitative and cannot be measured in detail. According to existing research, there are mainly six research methods for measuring urban resilience levels: Analytic Hierarchy Process[15], Entropy Method[16], Catastrophe Model[17], Resilience Index Method[18], as well as the Moran Index[19] reflecting the spatial-temporal evolution of urban resilience and GIS Spatial Overlay Analysis Method[20].

From a multidimensional perspective, current research on resilient cities can be summarized as follows: the interpretation of related concepts and in-depth theoretical research; measurement and analysis of the resilience levels of individual cities; and measurement and analysis of the resilience levels of large-scale urban agglomerations and metropolitan areas. Existing studies have rarely explored the obstacles to enhancing urban resilience, and there is a lack of understanding of the interactions between multiple subsystems within cities, as well as the relationship between the obstacle levels at the indicator layer and the spatiotemporal development. In light of this, the research directions of this paper are as follows: (1) selecting the southern Jiangsu region, which has a relatively fast economic development speed, as the research object, which is conducive to promoting resilient city construction nationwide; (2) focusing on the internal differences in resilient city construction in economically developed areas at the provincial and urban levels, to guide and lead the resilient cities in central and northern Jiangsu; (3) using the obstacle degree model to analyze the main influencing factors of urban resilience, comparing the obstacle degree at the indicator layer with that at the criterion layer, identifying the patterns and reasons for the differences in urban resilience in southern Jiangsu, which helps the research on urban resilience transition from a hierarchical to a networked

approach, from a closed system to an open system, and provides references for comprehensive, multi-level, and wide-ranging research on urban resilience.

## **2. RESEARCH AREA, INDICATOR SYSTEM CONSTRUCTION AND RESEARCH METHODS**

### **2.1. Overview of the Research Area**

Southern Jiangsu refers to the southern part of Jiangsu Province, located in the center of the southeastern coastal Yangtze River Delta in China, surrounded by cities such as Shanghai, Anhui, and Zhejiang; it is the most economically developed area in Jiangsu, with a very high level of modernization. Southern Jiangsu includes five cities: Nanjing, Suzhou, Wuxi, Changzhou, and Zhenjiang, covering 27.2% of Jiangsu Province's land area. In 2020, the regional GDP reached 5,938.43 billion, with a per capita GDP exceeding 150,000 yuan, comparable to that of developed countries; the urbanization level is relatively high, with an urbanization rate of 82.6% in 2022. Studying the urban resilience of cities in the Southern Jiangsu region can provide valuable references and insights for the construction of resilient cities in other regions.

### **2.2. Data Sources**

The statistical data used in this article are from five cities in the southern Jiangsu Province from 2011 to 2020. The basic city indicator data are mainly from the "Suzhou Statistical Yearbook", "Wuxi Statistical Yearbook", "Nanjing Statistical Yearbook", "Changzhou Statistical Yearbook", "Zhenjiang Statistical Yearbook", and "Jiangsu Statistical Yearbook" from 2011 to 2020. A small amount of data comes from the "National Economic and Social Development Statistical Bulletin", "Environmental Status Bulletin", and Prospective Database. It should be noted that the research cities are all cities. Due to missing data, some indicators are approximated by the municipal district caliber, and missing data in individual years are supplemented by interpolation.

### **2.3. Urban Resilience Evaluation Index System**

Based on the existing evaluation indicators, considering the principles of scientificity, representativeness, and availability of data, the evaluation indicators are screened and modified. From the four subsystems of ecology, economy, society, and infrastructure, 16 indicators that can more accurately reflect the resilience of various cities in Jiangsu Province are selected, collectively forming a comprehensive evaluation index system for urban resilience (see Table 1).

Table 1 Evaluation Index System and Weights of Urban Resilience Levels in the Southern Jiangsu Region from 2011 to 2020

Target Layer	Criteria Layer	Weight	Indicator Layer	Serial Number	Weight
Urban Resilience	Economic resilience X1	0.1870	GDP per capita (Yuan/person)	A1	0.0364
			The proportion of the tertiary industry in GDP (%)	A2	0.0426
			Disposable income of urban residents (Yuan)	A3	0.0372
			General Public Budget Revenue (billion yuan)	A4	0.0707
	Social resilience X2	0.3784	Number of hospital beds per 1,000 people	B1	0.0293
			Number of students in ordinary universities (ten thousand)	B2	0.1096
			Built-up area (square kilometers)	B3	0.0791
			Number of employed persons at the end of the year (ten thousand)	B4	0.0794
	Ecological resilience X3	0.1234	Proportion of days with good air quality in cities (%)	C1	0.0373
			Green coverage rate of built-up areas (%)	C2	0.0593
			Wastewater treatment rate (%)	C3	0.0166
			Rate of harmless treatment of municipal solid waste	C4	0.0101
	Infrastructure Resilience X4	0.3112	Total urban water supply (ten thousand cubic meters)	D1	0.1009
			Electricity consumption of the whole society (100 million kWh)	D2	0.0609
			Road freight volume (10,000 tons)	D3	0.0815
			Actual road length in the city (kilometers)	D4	0.0932

## 2.4. Research Methods and Data Processing

In order to standardize the basic indicator data, this paper adopts the entropy method from the objective weighting evaluation method, using the principle of information entropy to determine the weight of each indicator in the system. Compared to the expert scoring method, the entropy method is more objective and accurate. To facilitate data comparison between different years, provinces, and indicators, this paper optimizes the entropy method by introducing a time variable into the indicator calculation process, making the analysis results more reasonable [17]. The evaluation model of the optimized entropy method is as follows:

Standardized processing of selected indicators: Let there be  $n$  years,  $s$  provinces and cities, and  $z$  indicators, then the value of the  $j$ -th indicator of city in year  $a$  is represented  $X'_{aj}$  as follows:

Calculation method for positive indicators:

$$X'_{aj} = (x_{aj} - x_{j\min}) / (x_{j\max} - x_{j\min}) \quad (1)$$

Calculation method for negative indicators:

$$X'_{aij} = (x_{jmax} - x_{aij}) / (x_{jmax} - x_{jmin}) \quad (2)$$

Determine the weight of the indicators:

$$Y_{aij} = X'_{aij} / \sum_a \sum_i X'_{aij} \quad (3)$$

The entropy value of the j-th indicator is:

$$e_j = -k \sum_e \sum_i Y_{ij} \ln(Y_{aij}) \quad (4)$$

where k is a constant,  $k > 0$ ;

The information utility value of the j-th indicator:

$$g_j = 1 - e_j \quad (5)$$

Weights of each indicator:

$$w_j = g_j / \sum_j g_j \quad (6)$$

The weight of the criterion layer element is:

$$w'_j = \sum_{j=1}^m w_j \quad (7)$$

where m represents the number of indicators included in the subsystem resilience index.

Resilience evaluation values of various subsystems in the city:

$$RES_{ai} = \sum_{j=1}^m (w_j X'_{aij}) \quad (8)$$

Here,  $RES_{ai}$  represents the resilience evaluation value of subsystem i in city a year.

Obtain the comprehensive evaluation value of urban resilience:

$$RES = \sum_{j=1}^m (RES_{ai})_j W_j \quad (9)$$

At the same time, using the resilience barrier model, analyze the barrier factors affecting the resilience level of cities in Jiangsu Province, with the specific calculation formula as follows:

$$m_{tj} = W_j \times P_{tj} / \sum_{j=1}^n (W_j \times P_{tj}) \times 100\% \quad (10)$$

$$M_{tj} = \sum_{j=1}^n m_j \quad (11)$$

In equation (10), the j-th indicator's obstacle degree to the urban resilience criterion layer in year t is  $m_{tj}$ ;  $W_j$  is the weight of each indicator in equation (6), representing the contribution degree to the obstacle factors;  $P_{tj} = 1 - X'_{aij}$  calculates the deviation of each individual indicator from the development target 1,  $X'_{aij}$  which is the value after standardizing each individual indicator;  $M_{tj}$  is the obstacle degree value of the resilience of the criterion layer system in year t.

### 3. THE SPATIOTEMPORAL EVOLUTION LAW OF URBAN RESILIENCE IN SOUTHERN JIANGSU

#### 3.1. Overall Analysis of Resilience Level

The entropy method was used to calculate the comprehensive evaluation values of resilience levels in five prefecture-level cities in the southern Jiangsu region from 2011 to 2021, and the average values of each city were calculated along with the annual average values of the five cities (see Table 2).

Table 2 Comprehensive Measurement of Urban Resilience Levels in Southern Jiangsu Region

City	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
Suzhou	0.399	0.438	0.488	0.506	0.537	0.517	0.617	0.640	0.683	0.728	0.555
	1	5	9	0	8	4	0	6	9	9	8
Wuxi	0.196	0.219	0.241	0.254	0.279	0.294	0.324	0.346	0.383	0.402	0.294
	7	0	6	1	5	1	2	1	0	0	0
Nanjing	0.569	0.603	0.599	0.592	0.642	0.675	0.723	0.751	0.795	0.836	0.678
	1	2	9	4	1	9	1	2	8	7	9
Changzhou	0.143	0.153	0.152	0.176	0.202	0.218	0.233	0.250	0.267	0.292	0.209
	3	4	7	7	5	9	6	2	9	5	2
Zhenjiang	0.063	0.084	0.075	0.079	0.098	0.114	0.127	0.143	0.157	0.178	0.112
	6	8	9	0	4	9	9	0	7	4	4
Annual average	0.274	0.299	0.311	0.321	0.352	0.364	0.405	0.426	0.457	0.487	0.370
	4	8	8	6	1	2	2	2	7	7	1

Based on the existing comprehensive table of resilience levels, it can be seen from the overall urban resilience level composite value (see Table 2) that there are significant differences in the urban resilience levels in southern Jiangsu. The city with the highest average comprehensive resilience level is Nanjing, at 0.5558; while Zhenjiang has the lowest, at 0.1124. The main characteristics are as follows: (1) In terms of average values, the overall resilience level of cities in southern Jiangsu has improved over the past decade. The annual average resilience value of the southern Jiangsu region increased from 0.2744 in 2011 to 0.4877 in 2020, indicating that the urban resilience development level in southern Jiangsu is generally good, showing a positive development trend. (2) However, the differences in values among different cities remain significant. Especially from 2011 to 2015, the comprehensive resilience value of Zhenjiang was consistently below 0.1, which is a large gap compared to the other four cities. Nanjing and Suzhou have always had significant advantages in urban resilience construction, with Nanjing's resilience level composite value consistently above 0.5; Suzhou's urban resilience composite value has been above 0.5 since 2014. The government should strengthen the linkage level between cities to form a resilience development advantage in the southern Jiangsu region.

From the perspective of the temporal development trend, the evolution of urban resilience is shown in Figure 1: (1) Between 2010 and 2021, the overall resilience levels of the five cities have been gradually improving, indicating a positive trend in urban resilience development. (2) In certain years, there has been a decline in urban resilience levels, such as the fluctuation of resilience levels in the Nanjing area from 2012 to 2014; and the fluctuation of resilience levels in the Suzhou area from 2015 to 2016. (3) In terms of development speed, the growth rates of Zhenjiang and Changzhou are relatively flat, indicating a need to strengthen resilience construction and development efforts. (4) Comparing the annual averages with the resilience indices of each city, only Nanjing's comprehensive resilience value is higher than the regional average annual value. The reason may be that the development levels of various tiers in Wuxi, Changzhou, and Zhenjiang are significantly different from those in Nanjing and Suzhou; another possibility is that in the selection of 16 indicators, the

scale of the city was not considered, leading to a somewhat one-sided assessment of the comprehensive resilience value of the city.

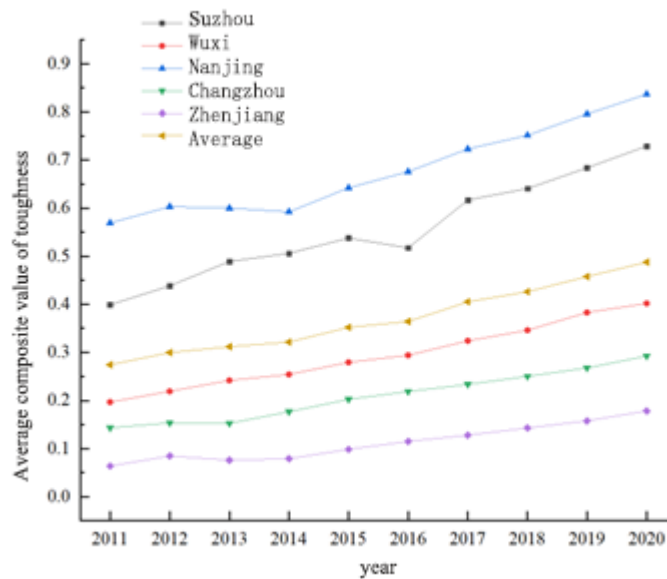


Figure 1: Urban Resilience Development Trends in the Southern Jiangsu Region

### 3.2. Analysis of Resilience Barrier Factors in Southern Jiangsu Cities

Diagnosing and analyzing the obstacle factors of the criterion layer and indicator layer of urban resilience in Southern Jiangsu using the obstacle degree model, calculating the obstacle degrees of different cities and different years for both layers, further exploring the main obstacle factors affecting the improvement of urban resilience in Southern Jiangsu, and conducting a specific analysis.

#### 3.2.1. Barrier Factors at the Guidelines Level

Compared to the barrier factors at the indicator level, the barrier factors at the criterion level are more general. Based on this, we first analyze the impact of the criterion level indicators on urban resilience. We select the barrier degree data of urban resilience at the criterion level for the years 2010, 2015, and 2020, reflecting the changes in the criterion level resilience barrier factors of five cities over three years (see Table 3).

Table 3 The Barrier Levels of Resilience Criteria in Southern Jiangsu Cities in 2011, 2015, and 2020

City	2011				2015				2020			
	X1	X2	X3	X4	X1	X2	X3	X4	X1	X2	X3	X4
Suzhou	0.23	0.39	0.16	0.22	0.19	0.42	0.14	0.25	0.08	0.64	0.17	0.11
Wuxi	0.17	0.41	0.11	0.31	0.15	0.42	0.10	0.32	0.11	0.48	0.08	0.34
Nanjing	0.26	0.24	0.15	0.34	0.27	0.26	0.11	0.33	0.17	0.27	0.11	0.45
Changzhou	0.18	0.41	0.09	0.33	0.17	0.41	0.08	0.33	0.13	0.45	0.17	0.35
Zhenjiang	0.17	0.40	0.10	0.32	0.16	0.41	0.09	0.34	0.15	0.43	0.06	0.37

Analyzing the overall situation of the subsystems, the ranking of barrier levels at the criterion layer is as follows: social resilience subsystem, infrastructure resilience subsystem, economic resilience subsystem, and ecological resilience subsystem. The social resilience subsystem has the greatest impact on the barrier level of cities in southern Jiangsu, with the annual average barrier level of cities approaching 40%, among which Nanjing has the lowest annual average barrier level, around 25%.

The ecological resilience subsystem has the smallest barrier level for cities in southern Jiangsu, with the barrier level values of the five cities ranging from 6% to 17%.

Analyzing the differences in development between subsystems, the social resilience subsystem has the greatest impact on different cities, with the highest value being 45% in Nanjing and the lowest being 11% in Suzhou, a gap of 40%. Infrastructure resilience is at 34%; followed by the economic resilience subsystem and the ecological resilience subsystem, with obstacle levels of 19% and 9%, respectively.

From the perspective of the relationship between subsystem development and temporal changes, the impact of the economic resilience subsystem on urban resilience barriers is gradually increasing; the impact of the social resilience subsystem and the infrastructure resilience subsystem on urban resilience barriers is gradually decreasing; the impact of the ecological resilience subsystem on urban resilience barriers is roughly stable.

In terms of specific cities, there are also differences in the main obstacle factors between different years. Nanjing is relatively special; in 2011, the main obstacle factor was the infrastructure resilience subsystem, while in 2012, it was the economic resilience subsystem. In other cities, the social resilience subsystem remains the primary obstacle factor restricting urban resilience development. The changes in resilience obstacle factors from 2011 to 2012 can reflect potential issues in Nanjing's overall urban planning in 2011, such as insufficient overall planning and a lack of systematic special planning. The imbalance in economic development has affected the obstacle levels of Nanjing's infrastructure resilience subsystem and economic resilience subsystem to some extent.

In the analysis of barrier degree at the guideline level, the impact of ecosystem barrier factors on the study area has been relatively small for two main reasons: first, specific indicators reflecting ecological resilience are difficult to fully encompass all aspects of urban ecological resilience, and the selection of factors has overlooked the impact of natural disasters on the ecology; the second reason is that ecological factors are often neglected in urban development, making it difficult to coordinate economic development with ecological development; many indicators have a relatively small degree of influence, such as sewage treatment rates, which indirectly affect the impact of the ecological subsystem on the overall urban resilience level.

In summary, the analysis of the urban resilience criteria layer in the southern Jiangsu region is consistent with the current development of the economy, society, and infrastructure construction in Jiangsu Province. The economic and social development in the southern Jiangsu region has always been at the forefront of Jiangsu Province's development, and it is necessary to further maintain the momentum of economic development and accelerate the construction of resilient cities. Social and infrastructure barrier factors are increasing year by year. If the southern Jiangsu region wants to improve its urban resilience level, it should strengthen social construction and improve infrastructure construction. The urban construction and development level in the southern Jiangsu region is relatively high, and ecological civilization construction cannot be ignored.

### 3.2.2. Barrier Factors at the Indicator Level

Analyzing only the urban resilience barrier factors at the criterion level cannot reflect the differences in the degree of barriers among individual subsystem indicators. Therefore, analyzing the barrier factors at the indicator level is beneficial for understanding how the urban barrier degree is influenced by specific indicators. Using data from 2020 as a sample, this study delves into the main indicator-level barrier factors affecting urban resilience in southern Jiangsu, selecting the top six high-impact indicators for each city as the main barrier factors of that city (see Table 4).

The data in Table 4 shows that in 2020, the first barrier factor for five cities in the prefecture was the number of students in regular universities, and the second barrier factor was the total urban water supply. Cities need to strengthen talent cultivation and develop university innovation resources into an important driving force for resilient city construction. Jiangsu Province has the highest number of

regular universities in the country; however, the scale and planning rationality of these universities need further improvement. According to data from the Jiangsu Provincial Department of Education, among the 54 undergraduate institutions in Jiangsu, nearly 30 are located in Nanjing; there are a total of 10 centrally-administered universities, with Nanjing accounting for four-fifths. In contrast, other regions in southern Jiangsu have fewer universities, leading to an imbalance in higher education facilities, which also has a significant impact on resilient city construction. During the urban construction process, infrastructure development is often overlooked due to its lack of visible results. When cities encounter sudden disasters such as earthquakes or fires, the normal operation of society relies on lifeline systems such as urban infrastructure, water supply, power supply, transportation, and communication. Urban infrastructure construction should become an important factor that cannot be ignored in urban planning and construction.

Table 4 Ranking of Barrier Factors and Barrier Degree of Urban Indicators in Southern Jiangsu in 2020

City	Project	Importance ranking				
		B2	C2	A2	B1	B3
Suzhou	Barrier factor	B2	C2	A2	B1	B3
	Obstacle Degree	55.19	13.44	7.33	4.61	3.91
Wuxi	Barrier factor	B2	D1	B3	D2	A4
	Obstacle Degree	29.99	12.90	9.94	7.94	6.84
Nanjing	Barrier factor	D2	B4	A4	C2	C1
	Obstacle Degree	33.66	23.17	13.58	5.57	5.42
Changzhou	Barrier factor	B2	D1	B4	B3	A4
	Obstacle Degree	24.9	12.09	9.02	8.26	7.9
Zhenjiang	Barrier factor	B2	D1	D4	B3	C2
	Obstacle Degree	22.4	11.99	11.01	9.20	4.15

In addition, the main obstacle factor for the resilient development of Nanjing, the provincial capital, is different from that of other cities, and the total electricity consumption (D3) is the first obstacle factor. The total electricity consumption reflects the level of urban economic development to a certain extent. It is an important indicator to measure the scale and potential of urban economy[21], the proportion of electricity consumption in the secondary and tertiary industries accounts for 70% of the total electricity consumption, which is the main factor driving the growth of electricity consumption. The provincial capital Nanjing is mainly based on the secondary industry, and the tertiary industry accounts for a relatively low proportion; from the perspective of the secondary industry, the manufacturing industry accounts for a large proportion in the secondary industry, reaching more than 65%. This analysis result is consistent with the analysis result of resilient cities in Jiangsu Province by Sun Yanan [22] et al. In terms of logistics and information industry, Nanjing's industrial scale agglomeration effect is weak, and there is a lack of influential leading enterprises. As pointed out in the "Development Report on the Primacy of Provincial Capital Cities in China" published by Nanjing University of Finance and Economics in 2018, Nanjing ranks behind Suzhou in terms of industrial primacy and scale, and does not have industrial advantages.

The urban office budget revenue (B4), total urban water supply (D1), and built-up area (B3) in the southern Jiangsu region have a significant impact on urban resilience hindrance. Looking at the five cities separately, the hindrance factors in Zhenjiang are greatly influenced by the total urban water supply (D1) and the actual road length (D4). Compared to other cities, Zhenjiang is more constrained by infrastructure and should accelerate infrastructure development. In comparison to the other four cities, Changzhou's indicators in terms of social resilience account for 50%, which include the number of employed people in regular higher education institutions (B2), year-end employment (B4), and built-up area (B3). Changzhou needs to prioritize the above hindrance factors in its resilient city construction, focusing on aligning social development with economic development. In summary, the

supply of infrastructure and social security in southern Jiangsu's cities does not match the demand for resilient cities, with a clear pattern of disparity, and public social investment urgently needs to be increased.

### 3.3. Visualization Analysis of Spatial Differences in Urban Resilience Levels

Evaluate the resilience classification levels of various cities from 2011 to 2020. Cities with values less than the average resilience value over the ten years are defined as low resilience, while cities with values greater than 0.5 are defined as high resilience; moderate resilience falls between the two. By selecting the years 2010, 2014, 2017, and 2020, analyze the visual differences and temporal relationships of resilience values across various dimensions in cities of Southern Jiangsu (see Figure 2), based on the administrative divisions of provinces, cities, and counties in 2022.

As shown in Figure 2, the total number of low-resilience cities in Jiangsu has decreased year by year from 2011 to 2020, while the number of high-resilience cities has increased from 1 to 2. From a regional perspective, the overall resilience level in the southern Jiangsu region has been continuously improving, indicating that the risk resistance capabilities of cities within the region are gradually enhancing. The number of low-resilience cities is decreasing, while the number of high-resilience and medium-resilience cities is gradually increasing. From the perspective of urban agglomerations, the economic level, transportation facilities, and comprehensive support of the central cities in the Nanjing urban agglomeration and the Suzhou-Wuxi-Changzhou urban agglomeration are relatively well-developed, with good resource aggregation capabilities. In future development, attention should be paid to coordinated development with surrounding city clusters and urban agglomerations. From the city level, there are significant differences in resilience patterns among the five cities. Low-resilience and medium-resilience cities still need to accelerate their development pace, and there is still great potential for improvement in urban resilience construction. The uneven characteristics of regional development are evident, so it is necessary to build resilient cities from multiple levels, angles, and comprehensive perspectives.

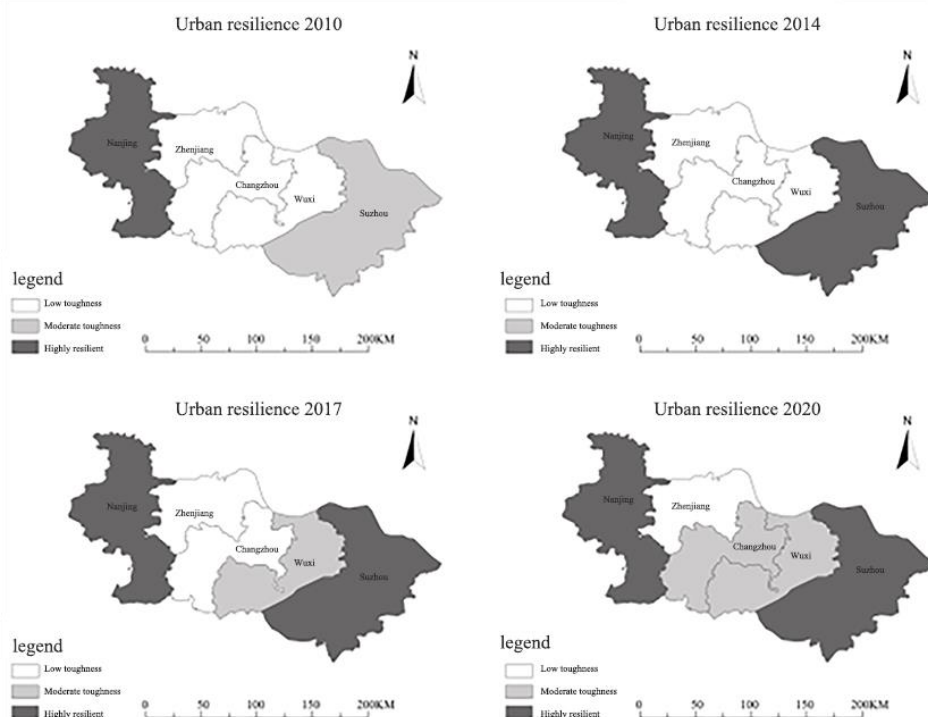


Figure 2 Resilience values of various dimensions in Southern Jiangsu cities from 2011 to 2020

## 4. CONCLUSION AND OUTLOOK

By studying the resilience and spatial correlation characteristics of various cities in Jiangsu using data from 2011 to 2020, it can be found that: (1) In terms of urban comprehensive resilience values, the spatial pattern shows an uneven state among the five cities in southern Jiangsu, specifically high in the east and west and low in the middle; over the time frame, the overall resilience of each city has shown an upward trend compared to the end of 2011 and the end of 2020. (2) From the perspective of average obstacle degree, among the five subsystems, the ecological system is the primary obstacle system for resilience enhancement in the southern Jiangsu region in the near future. Given that the indicators selected for this study do not encompass all aspects of ecological resilience construction, the government should sort out ecological resilience development indicators and formulate practical development plans. (3) From the perspective of obstacle degree indicators, when developing and constructing cities in southern Jiangsu, attention should be paid to the differences in primary obstacle factors among different cities and consideration should be given to the development directions and construction characteristics of different cities. When optimizing resilient cities from the system to the indicator level, it is necessary to propose location-specific urban development strategies.

Based on relevant theories and empirical experiences from the Su Nan region, further insights on urban resilience development are drawn:

Optimize the educational layout structure. All levels of government should actively explore the system and mechanism for co-building universities between provinces and cities, further increase investment in higher education, strive to increase the enrollment numbers of high-level institutions, appropriately expand the scale of student training in universities, and make efforts to balance the uneven education issues in the southern Jiangsu region. Promote the sharing of high-quality educational resources and improve the mechanisms for group-based and district-based schooling. The government should encourage 985 and 211 universities within the province to establish branches or introduce cooperative education projects in areas lacking educational resources, such as Zhenjiang and Changzhou, to expand the reserve of universities. Universities provide talent, technological achievements, and technical support to cities, bringing innovation and vitality to urban resilience construction.

Actively developing advanced manufacturing, industry and manufacturing is the "ballast" of economic development. From the analysis of resilience measurement, Nanjing should strengthen the stable development of industry, focus on developing advanced manufacturing, and promote the development of the real economy. Vigorously improve the development quality and level of backbone industries such as automobile, steel, petrochemical, electronics, and information services. It is necessary to strengthen the manufacturing industry cluster, accelerate the formation of a new system of advanced manufacturing with clear positioning, prominent advantages, and cluster agglomeration, and give full play to the supporting role of strategic emerging industries to truly change the current situation of industrial development without peaks. Suzhou should make full use of its industrial advantages to expand economic cooperation in the southern Jiangsu region; Changzhou, Wuxi, and Zhenjiang need to optimize industrial structure, explore industrial advantages, make up for industrial shortcomings, and enhance their competitiveness in the southern Jiangsu region.

The construction of a resilient city based on the overall situation is an upgrading process from "city" to "city cluster". In the construction of a resilient city, "the overall urban form, networked infrastructure, sustainable resource utilization, digital governance capacity and public participation support" are the five basic elements. In the construction of a resilient city, in addition to focusing on the resilience level of different cities, we should also focus on the development connection between cities and urban agglomerations, and the development connection between metropolises and metropolitan areas. We should adhere to the concept of system, strengthen the overall planning and coordination across industries, fields and regions, use comprehensive means to solve multiple problems more systematically and effectively, optimize and adjust existing standards and norms,

highlight openness and inclusiveness, better integrate resources, and improve the overall and coordinated nature of resilient city construction.

Focus on the resilience disparity patterns in urban development. Southern Jiangsu is the most economically vibrant region in Jiangsu, yet there are still issues such as unbalanced development between cities and mismatches between resilience construction and economic development. The economic, social construction, and infrastructure in Central and Northern Jiangsu have significant gaps compared to Southern Jiangsu. Learning from the advanced experiences of resilient urban construction in Southern Jiangsu, coordinating balanced urban development, and building a resilient urban system are essential to ensure that future urban construction is more scientific. Enhance the radiating and driving role of core resilient network cities. Fully leverage the advantages of regional central cities like Nanjing, Suzhou, and Wuxi to form important support points and power sources for high-quality regional development. In the long run, to improve the overall resilience level of cities, it is necessary to address the shortcomings of basic resilience, optimize systemic resilience solutions, and enhance the benefits of developmental resilience, gradually overcoming obstacles to resilient development and strengthening the ability of cities to withstand risks.

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