Research on the Coordinated Development of Urban Resilience and Urbanization Level in Sichuan Province

Ma Ke¹, Zhang Tianxu¹, Wei Yali¹, Zeng Fan¹*¹
¹College of Resources, Sichuan Agricultural University, Chengdu, Sichuan, China
*Corresponding author: *email: 14040@sicau.edu.com

Abstract: Urban resilience can reflect the city's ability to cope with crisis and risks, and it is an important guarantee for urban sustainable development. In the process of urban development, attention should be paid to coordinating with urban resilience construction. Taking 21 cities and prefectures of Sichuan Province as the research objects, this paper constructs the evaluation system of urban resilience from the aspects of economy, infrastructure, ecology and society, and the evaluation system of urbanization level from the aspects of population, land and economy. By using Entropy Method, the Coupling Coordination Degree model, coupling coordination between urban resilience and urbanization level is discussed. According to the results, the urban resilience level of cities and prefectures in Sichuan Province presents a pattern of “one city is quite high and the rest are low”, and the urbanization level presents a pattern of “one city is quite high, a few are high and the rest are low”. The coupling coordination degree of most of the cities and prefectures in Sichuan Province are low, and the cities with high coupling coordination are concentrated in Sichuan Basin. Combining with the urbanization level and coupling coordination degree, the cities and prefectures are divided into four types, high-high, high-low, low-high and low-low, in this paper. Corresponding development ideas are put forward so as to provide ideas and suggestions for the coordinated development of various cities and prefectures in Sichuan Province.

1. Introduction
Urban resilience is an important factor to realize the sustainable development of a city, and it interacts with urbanization level. Urbanization is a process in which population concentrates in cities and promotes the urban development, and it is a large project that related to the overall situation of national modernization[1]. The speed and scale of urbanization that China is experiencing is unprecedented in human history. By the end of 2019, China’s urbanization rate has increased from 10.64% in 1949 to 60.60%, with an average annual increase of 0.86%. At the same time, “urban diseases” including population expansion, traffic congestion, environmental pollution and resource shortage have appeared in many cities. With the acute impact of frequent external disasters, the “urban diseases” have brought pressure and challenges to the healthy development of a city[2,3]. The sudden outbreak of the novel epidemic (COVID-2019) has disturbed the normal operation of all walks of life in the city, causing great losses and impacts to the society and the people. How to improve the city’s ability to resist shocks, so that the city can achieve active responding, rapid recovery and self-improvement when facing various uncertainties and risks from itself and external world, has become a hot issue that experts and scholars concerned[4]. Exactly, the proposal of urban resilience provides a solution for the development of a city. Urban resilience gives a city the ability to maintain the original main characteristics, structure and key functions while digesting and absorbing external interference. It is an important method to promote the healthy and sustainable development of a city[5]. Some cities in China have been carrying out the
construction of urban resilience now. For example, in the 2020 Government Work Report of Chengdu, it is proposed to take “patching short boards, strengthening weak points and accelerating the construction of a resilient city” as the annual key work, so as to improve the city’s ability to cope with external interference and promote the sustainable development of the city.

“Resilience” refers to “returning to the original state”, and Holling, an ecologist, gave the term the connotation of ecosystem science for the first time [6,7]. Later, some scholars introduced the idea of resilience into urban construction, which laid an ideological foundation for the theory of urban resilience. At present, the research on urban resilience in China mainly focuses on the connotation analysis [8-10], mechanism of action [9,11], index construction [12-14], etc. Some scholars have also studied relationships between urban resilience and public security [15-16], ecological environment [17-19], urban governance [20] and so on from the perspective of urban composition subsystem. However, there are few researches on the relationship between urban resilience and urbanization level. Based on the relevant models, taking 21 cities and prefectures in Sichuan Province as the research objects, and through constructing the evaluation system of urban resilience and urbanization level, the paper discusses the coupling coordination relationship between urban resilience and urbanization level of 21 cities and prefectures in Sichuan Province, in order to provide some ideas and suggestions for the future regional coordinated and sustainable development.

2. Research Method

Coupling means that two or more systems or motion forms interact with each other and show a certain degree of coordination. From the perspective of synergetics, the coupling effect and its coordination degree determine the order and structure of the system when it reaches the critical region, that is, it determines the trend of the system from disorder to order [21]. Coordination is a kind of healthy correlation between two or more systems or elements, which is a harmonious, consistent, virtuous and cyclic relationship between systems or internal elements [22]. The Coupling Degree is a measurement of the relationship and interaction between the internal elements of the system or between motion forms. The Coordination Degree reflects the benign interaction of the internal elements of the system. The Coupling Coordination Degree can reflect whether the internal system develops in an orderly and sustainable way. The urban resilience system and urbanization system affect each other through their respective coupling elements. Based on this, the paper defines such affect as “Urban Resilience - Urbanization Level Coupling Coordination Degree”, and reflects the relevant degree between urban resilience and urbanization.

2.1 Calculation Method

2.1.1 Standardized Processing of Index Data

The data of each index should be standardized. Suppose that the number of the cities is “n” and the number of the indexes is “m”. Use “uij” to describe the index, “j”, in the system, “i”. The value is “xij”(i = 1,2; 1 ≤ j ≤ m). The standardized processing formula is as follows:

\[
\begin{align*}
\text{if } x_{ij} & \text{ is a positive index} \\
\text{if } x_{ij} & \text{ is a negative index}
\end{align*}
\]

In the formula, i = 1,2; j =1,2..., m; max(xij) and min(xij) are the maximum value and minimum value of xij.

2.1.2 Determination of Index Weight

In order to minimize and avoid the subjective factors and some objective limitations in the process of weight determination, referring to relevant research [23,24], this paper uses Entropy Method to determine the weight of each evaluation index. In order to eliminate the influence of “0” and negative numbers, the standardized data should be translated. This paper takes + 0.0001 as the translation distance. The value is Zij after translation:
\( Z_0 = u_0 + 0.0001 \)  

Under the index, \( j \), calculate the proportion of index, \( i \), in the sum, get \( p_{ij} \):

\[
p_{ij} = \frac{Z_0}{\sum_{i=1}^{n} Z_i}
\]

Calculate the entropy value of the index, \( j \), get \( e_{ij} \):

\[
e_{ij} = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij}, k = 1/\ln n
\]

Calculate the differential coefficient of the index, \( j \), get \( d_{ij} \):

\[
d_{ij} = 1 - e_{ij}
\]

Calculate the weight of the index, \( j \), get \( W_{ij} \):

\[
W_{ij} = d_{ij} \sum_{i=1}^{n} d_{ij}
\]

2.1.3 Determination of System Evaluation Index

Use Weighted Summation Method to get the evaluation index in the system, \( i \), in the city, \( n \):

\[
U_i = \sum_{i=1}^{n} W_{ij} Z_j
\]

2.1.4 Coupling Coordination Degree Model

Based on the evaluation indexes of the two systems of urban resilience and urbanization, and according to the relevant coupling model\(^{[21,25,26]}\), the coupling degree model is obtained as follows:

\[
C = \left[ u_1 u_2 / (u_1 + u_2)^2 \right]^{1/2}
\]

In the formula, \( C \) is the coupling degree between urban resilience and urbanization level; \( u_1 \) is the evaluation index of urban resilience; \( u_2 \) is the evaluation index of urbanization level.

Coupling degree can only judge the consistency of the evaluation index scores of the two systems. In order to prevent the situation that the scores of the evaluation indexes of the two systems are at a low level but the coupling degree is at a high state, the coupling coordination degree model is introduced to reflect the level of coupling coordination between the two systems\(^{[7]}\). The formula is as follows:

\[
D = \sqrt{CT}, T = \alpha u_1 + \beta u_2
\]

In the formula, \( D \) is the coupling coordination degree, \( T \) is the coordination index, and \( \alpha, \beta \) are the undetermined coefficients, representing the contribution coefficient of urban resilience and urbanization. This paper holds that both urban resilience and urbanization are equally important factors for the healthy development of cities, and their contributions should be consistent. So \( \alpha = \beta = 0.5 \).

2.2 Data Sources

The research data of this paper mainly comes from the 2019 Statistical Yearbook of Sichuan Province\(^{[27]}\), and some of the data are from the 2019 Statistical Yearbook of various cities and prefectures, and the 2019 National Economic and Social Development Bulletin of various cities and prefectures.

2.3 Construction of Evaluation System

Based on relevant researches\(^{[12,15]}\), this paper takes four dimensions as the standard layer, and selects 21 secondary indexes as the index layer to construct the evaluation system of urban resilience. According to the connotation of urbanization development, this paper takes three dimensions as the standard layer, and selects six secondary indexes to construct the evaluation system of urbanization level (Table 1).
### Table 1 The evaluation system of urban resilience and urbanization level

| Target Layer | Standard Layer | Index Layer | Weight | Attribute |
|--------------|----------------|-------------|--------|-----------|
| Economic resilience (0.3354) | | GDP | 0.1233 | + |
| | | Per capita GDP | 0.0440 | + |
| | | GDP growth rate | 0.0289 | + |
| | | Per capita savings balance | 0.1039 | + |
| | | The urban unemployment rate | 0.0353 | - |
| | | Per capita urban road area | 0.0222 | + |
| Infrastructural resilience (0.1815) | | Drainage pipe density | 0.0486 | + |
| | | Gas penetration rate | 0.0292 | + |
| | | The number of cars per ten thousand population | 0.0570 | + |
| | | Mobile phone penetration rate | 0.0246 | + |
| | | Per capita green area | 0.0494 | + |
| | | Urban sewage treatment rate | 0.0173 | + |
| | | Days of good air quality | 0.0217 | + |
| | | The coverage of green land in built-up areas | 0.0148 | + |
| | | The capacity of municipal solid waste (MSW) | 0.1663 | + |
| | | Industrial energy consumption index | 0.0158 | - |
| Ecological resilience (0.2853) | | The number of hospital beds per thousand population | 0.0197 | + |
| | | Average life expectancy | 0.0306 | + |
| | | The number of college students per thousand population | 0.0773 | + |
| | | The participation rate of pension insurance | 0.0395 | + |
| | | The natural population growth rate | 0.0308 | + |
| | | The Urbanization rate | 0.107 | + |
| | | The proportion of employment in secondary and tertiary industries | 0.070 | + |
| | | The proportion of built-up area | 0.331 | + |
| | | The built-up area per thousand population | 0.158 | + |
| | | The proportion of the second and tertiary industry | 0.109 | + |
| | | Per capita industrial output value | 0.225 | + |

The attribute "+" means that the index is a positive index, and the attribute "-" means that the index is a negative index.

### 3. Evaluation Analysis of Urban Resilience and Urbanization Level

#### 3.1 Evaluation Analysis of Urban Resilience

According to the evaluation system of urban resilience, the resilience scores of 21 cities and prefectures in Sichuan Province are obtained, which range from 0.1543 to 0.8576. Using Jenks Natural Breakpoint Method, the 21 cities and prefectures can be divided into four types: low level, medium and low level,
medium and high level, and high level (Fig. 1).

![Spatial distribution of urban resilience in Sichuan Province](image)

Fig.1 Spatial distribution of urban resilience in Sichuan Province

The skewness coefficient and kurtosis coefficient are calculated by SPSS25.0. The results show that the skewness coefficient of resilience scores, $g_1$, is higher than 0, which indicates that the overall level of urban resilience development in Sichuan Province is low. There are 15 cities and prefectures whose resilience scores are below the middle and low level, accounting for 71.43% of the total. The kurtosis coefficient of resilience evaluation scores, $g_2$, is higher than 0, which indicates that there is a huge gap between cities and prefectures in urban resilience construction, and the overall pattern of resilience level presents a pattern of “one city is quite high and the rest are low”. The urban resilience scores of Chengdu is as high as 0.8576, far higher than that of Mianyang, which has the second highest score of 0.4172, and is 5.56 times higher than Bazhong, which has the lowest score. This is consistent with the fact that Chengdu pays great attention to the development of urban resilience and enjoys preferential policy and social resources as a key development city of Sichuan Province.

3.2 Evaluation Analysis of Urbanization Level

According to the evaluation system, the evaluation scores of urbanization level of 21 cities and prefectures in Sichuan Province are calculated, which range from 0.0073 to 0.9751. According to Jenks Natural Breakpoint Method, the urbanization level of the 21 cities and prefectures can be divided into four types: low level, medium and low level, medium and high level, and high level (Fig. 2).
The skewness coefficient and kurtosis coefficient are calculated by SPSS25.0. The results show that the kurtosis coefficient of the evaluation scores of urbanization level, $g_1'$, is higher than 0, which indicates that there are great differences in the urbanization level of cities and prefectures in Sichuan Province. The score of Chengdu is 0.9751, which is not only much higher than that of Panzhihua, which is at the second place, but also 133 times higher than that of Ganzi, which is at the last place. The skewness coefficient of the evaluation scores of urbanization level, $g_2'$, is higher than 0, which indicates that urbanization levels of most cities in Sichuan Province are low, and 90.48% of the total cities are below the medium and high level. The pattern of urbanization level presents a pattern of “one city is quite high, a few are high and the rest are low”. As the provincial capital city, Chengdu has superior location, large population, convenient transportation and high level of urban development. However, the low development level of the other cities has become an important factor restricting the regional social and economic development of Sichuan Province.

### 4. Evaluation Analysis of Coupling Coordination Degree

#### 4.1 Classification of Coupling Coordination Degree

In order to better evaluate the coupling coordination degree of each city and prefecture, the 21 cities and prefectures can be divided into five types according to the relevant classification standards [26,28], and the classification results are as follows:

| Coupling Coordination Score | Type               | City and prefectures | Coupling Coordination Score | Type                | City and prefectures |
|-----------------------------|--------------------|----------------------|-----------------------------|---------------------|----------------------|
| 0.0 ～ 0.2                  | High disorders     | None                 | 0.5 ～ 0.6                  | Mild coupling coordination | Leshan, Suining, Luzhou, Yibin, Guangan, Meishan, Yaan, Neijiang, Nanchong Panzhihua, Zigong, Mianyang, Deyang |
| 0.2 ～ 0.4                  | Moderate disorders | Bazhong, Liangshan, Ganzi | 0.6 ～ 0.8                  | Moderate coupling coordination |                       |
4.2 Evaluation Analysis of Coupling Coordination Degree

In this paper, the Moran’s I index is used to analyze the coupling coordination scores through Arcgis 10.6. The results show that the index is 0.033 (the score of Z is higher than 1.96), indicating that the coupling coordination degree of 21 cities and prefectures in Sichuan Province has the characteristics of spatial agglomeration. From the classification results, the coupling coordination degree of urban resilience and urbanization level in Sichuan Province in 2018 presents a pattern of “high in the east and low in the west” (Fig. 3). Except Panzhihua, over half of the cities with coupling coordination are concentrated in the Sichuan Basin. The cities with disorders are mainly located in Western Sichuan Area and Northeastern Sichuan Area.

| Coupling Coordination | Cities |
|------------------------|--------|
| 0.4~0.5 Mild disorders | Guangyuan, Ziyang, Dazhou, Aba |
| 0.8~1.0 High coupling coordination | Chengdu |

Fig.3 Spatial distribution of coupling coordination degree in Sichuan Province

Among them, Chengdu with high coupling coordination has strong ability of sustainable development. As the central city in Western China, Chengdu's coupling coordination score is as high as 0.9563, which benefits from its introduction of Park City concept into urban construction while developing economy vigorously in recent years. The concept pays attention to the improvement of human settlement environment and urban operation efficiency, improves the city’s anti-risk abilities, and promotes the coordinated development of urban resilience construction and urban construction. The cities with moderate coupling coordination include Panzhihua, Deyang, Mianyang and Zigong. These four cities are important industrial bases in Sichuan Province, owing strong strength and resources, which can provide support and guarantee for the construction of urban resilience. The cities with mild coupling coordination include Leshan, Suining, Yibin, etc. These cities are rich in natural resources. In recent years, they pay more attention to the governance and protection of ecological environment and the overall arrangement of urban and rural areas and to developing low-carbon economy, and their abilities of sustainable development has been increasing. The cities with mild disorders include Guangyuan, Dazhou, Ziyang and Aba. The industrial foundation of these four areas is weak, and the economic structure is relatively simple. The economic development and urban construction level of them are in the middle state in Sichuan Province, and they pay a little attention to urban resilience construction. The cities and prefectures with moderate disorders include Bazhong, Ganzi and Liangshan.

The common characteristics of the three areas are underdeveloped economy, obvious urban-rural dual
structure, low level of urbanization development, and lack of urban resilience construction for a long time.

4.3 Classification of “Urbanization Level - Coupling Coordination Degree”

According to the evaluation indexes of urbanization level and coupling coordination degrees, taking the average value of the two, using Jenks Natural Breakpoint Method, the “urbanization level - coupling coordination degree” of cities and prefectures in Sichuan Province can be divided into four types (Fig. 4).

![Fig.4 Spatial distribution of “Urbanization Level - Coupling Coordination Degree” in Sichuan Province](image)

4.3.1 High Urbanization - High Coupling Coordination

This type of city includes Chengdu and Panzhihua, whose urbanization and coupling coordination are at a high level, and the urbanization level is compatible with the coupling coordination degree. Internal economic development, infrastructure construction, ecological environment protection and social governance are coordinated and unified. Besides, these cities have strong abilities to resist external interference and keep good coordinated and sustainable development. In the future, such cities should continue to maintain the existing development mode, and at the same time play a regional radiation role to drive the development of surrounding areas.

4.3.2 High Urbanization - Low Coupling Coordination

This type of cities includes Deyang, Zigong, Mianyang, etc, which are characterized by high urbanization level and relatively low coupling coordination degree. Such cities should pay attention to the construction of urban resilience, so as to match the level of urban development and improve the quality and sustainable capacity of urban development.

4.3.3 Low Urbanization - High Coupling Coordination

This type of cities mainly includes Nanchong, Yaan, Meishan, etc, which are characterized by low urbanization level and relatively high coupling coordination degree. Such cities should continue to construct urban resilience while developing cities and towns. Make urban resilience as an important guarantee for urban development and urban development as an important support for urban resilience construction, and form a virtuous circle in the end.

4.3.4 Low Urbanization - Low Coupling Coordination
This type of cities includes Dazhou, Bazhong, Aba, etc, whose urbanization and coupling coordination degree are both at a low level. In future development, it is necessary to increase the support for such cities in policies and resources, change the rough development in the past, and realize the coordinated development of urbanization and urban resilience.

5. Summary
Taking 21 cities and prefectures in Sichuan Province as the research objects, the paper reflects the coupling coordination degree between urban resilience and urbanization level through coupling coordination model. The conclusions are as follows:

(i) The overall level of urban resilience in Sichuan Province is relatively low, with serious regional differentiation. The urban resilience level of the whole province presents a pattern of “one city is quite high and the rest are low”.

(ii) The differences of urbanization level are large, and the overall level is relatively low, presenting the pattern of “one city is quite high, a few are high and the rest are low”. Restricted by the natural conditions and social and economic conditions, most of the cities and prefectures develop slowly and have insufficient stamina for development.

(iii) The coupling coordination level of 21 cities and prefectures in Sichuan Province shows a pattern of “high in the east and low in the west”. Except Panzhihua, over half of the cities with coupling coordination are concentrated in Sichuan Basin. The cities with disorders are mainly located in Western Sichuan Area and Northeastern Sichuan Area.

In view of the above main conclusions, following suggestions are put forward in this paper:

(i) Insist on regional coordination and suitable development path. Based on the special situation of great regional differences in Sichuan Province, each area should formulate their own development path according to local conditions, actively promote city transformation, actively carry out inter-city cooperation, and reduce regional differences.

(ii) Ask for key breakthroughs and right measures. Identify the problems in regional development, analyze the development bottleneck of each city, make breakthroughs in key issues, fully consider the differences of social and economic development foundation and natural environment in different regions, and improve the development quality and efficiency.

(iii) Achieve concept establishment and coordinated development. The concept of urban resilience construction should be established in all cities and prefectures, and it should be integrated into the regional development, so as to improve the city’s ability to response, recover and improve in the face of various factors and risks, and achieve sustainable and coordinated development in the region.

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