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Analysis and Evaluation of Urban Vulnerability Based on Entropy Value Method: A Case Study of Bengbu City, China

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Abstract: Bengbu city is an important city in northern Anhui Province, and exploring the degree of urban vulnerability can provide technical reference for sustainable urban development. The index data of three important systems of economy, society and ecological environment of Bengbu City are selected, and the urban vulnerability model is constructed using entropy value method to analyze the vulnerability and comprehensive vulnerability of each subsystem. The results show that: (1) From the change of the comprehensive vulnerability level of the city, the overall urban vulnerability of Bengbu city shows a decreasing trend from 2010 to 2019, basically completing the transition from higher to lower vulnerability, and is in a good and stable development state. (2) From the viewpoint of the vulnerability ratio of each subsystem, the vulnerability ratio of each subsystem in Bengbu city varies more obviously. Social vulnerability occupies a dominant position, economic vulnerability is in the middle, and ecological vulnerability is in a secondary position. (3) In terms of the degree of decline in the vulnerability of each subsystem, all subsystems of urban vulnerability in Bengbu city have declined to different degrees from 2010 to 2019. Among them, the vulnerability of economic and ecological environment subsystems declined more obviously, while the vulnerability of social subsystems generally declined more slowly and moderately.

1. Introduction

Ecosystems are closely related to social, economic, political and cultural development, and the stability and sustainability of ecological environment is an important factor to promote social development [1]. However, the ecological environment of regional society itself has a certain degree of vulnerability, and coupled with the continuous development of urbanization, some unreasonable land and resource use can also exacerbate the vulnerability of cities. Therefore, it is of great theoretical and practical significance to understand the factors that constrain urban development, recognize the ecological vulnerability of urban society, and formulate a stable and good urban sustainable

development strategy to promote regional urban development [2]. Vulnerability restoration of regional cities is an issue that has received increasing attention from scholars in recent years. Currently, most of the vulnerability studies by domestic and foreign scholars take resource-based cities as the object, and mostly adopt the evaluation methods such as the state space method [3], the comprehensive index method [4], and the set-team analysis method [5] to measure the vulnerability of resource-based cities. The representative ones are:Mu Jin, Zhao Cuiwei used GIS technology and AHP hierarchical analysis to evaluate the vulnerability of water system in Guiyang city from 2000 to 2015 [6]; Liu Yanzhong, Song Caifeng, Chen Yong et al. used entropy value method and comprehensive index method to analyze the dynamic evolution of vulnerability of mineral-based resource cities in Huainan, Tongling and Maanshan regions [7]; Sun Pingliang, Xiu Chunliang established a vulnerability evaluation model of major mining cities in Liaoning with the help of principal component analysis and entropy method [8]; Hu, Duan, Dezhong, and Zeng, Juxin used the entropy method to determine the index weights and establish a vulnerability assessment model of Wuhan city circle [9]. This topic takes Bengbu, an important transportation hub city in northern Anhui Province, as the research object, establishes an indicator system, uses the entropy value method to construct the urban vulnerability evaluation model of Bengbu, analyzes the time variation characteristics of its urban vulnerability, and understands its vulnerability degree. This can provide technical support for Bengbu City to turn into an ecological city and a green city and realize sustainable development.

2. Overview of the Study Area

2.1. Physical Geographical Condition

Bengbu is located in East China, west of the Yangtze River Delta and in the middle reaches of the Huaihe River, at 117°12'E longitude and 32°57'N latitude. The terrain here is mainly plain with a relatively flat topography and some hills distributed in the south. The monsoon climate makes the natural profile of Bengbu City affected to different degrees: (1) In terms of precipitation, there are large seasonal differences. The annual precipitation is around 905.4mm; the average summer precipitation reaches 467.4mm, plus there is often a continuous rainy period between the lower part of June and mid-July every year. Therefore, the whole summer rainfall period can last for more than 20 days; the precipitation in winter is significantly less than that in summer, only 77.4mm. (2) In terms of sunshine, the longest sunshine time in summer is 655.9 hours; the annual sunshine is 4429.2 hours. (3) In terms of temperature, the annual average temperature in Bengbu is 15.1℃, which is higher than that in the mountainous areas of Huabei and West Anhui; the average temperature in January is 1℃; the maximum temperature in July reaches 28.1℃. Due to the influence of the natural geography that changes throughout the year, agriculture, production and life in Bengbu City also change.

2.2. Social-Economical Condition

From the economic and social aspects, the GDP of Bengbu area in 2020 was 208.273 billion yuan, an increase of 3% compared with the same period of the previous year. In terms of the proportion of industries, the primary, secondary and tertiary industries have achieved an incremental output of 25.501 billion yuan, 83.519 billion yuan and 99.253 billion yuan respectively; the three industries have grown by 2%, 3.6% and 2.6% compared to last year; the structure of the three industries is 12.2:40.1:47.7. Although the total value of production has risen, it has to some extent made the city vulnerable the degree of vulnerability has increased. In terms of agriculture, due to the industrialization of agriculture, the use of pesticides and fertilizers will only increase and not decrease,

which will inevitably increase the burden on the city. On the other hand, the distribution ratio of industrial and service technology industries in Bengbu City is also unreasonable, with heavy industry dominating, mostly in some electronic, mechanical, chemical and other industrial categories; the development of tertiary industry lacks clear goals and reasonable positioning, resulting in a serious brain drain. In a total area of 5,951 square kilometers of jurisdiction, the resident population is 3,296,400, which is not quite the labor force population, and it is good that the development pattern of Bengbu City is slowly transforming. At the end of 2020, the number of state-owned, collective, joint-stock and Hong Kong, Macao and Taiwan enterprises grew by 20.8%, 2.5%, 3.4% and 8% respectively. In the same year, with the influx of talents, new jobs were added, and 36,000 urban residents were newly employed at the end of the year, and 19,700 unemployed people were re-settled for re-employment. Therefore, the preliminary analysis and evaluation of the natural ecology and economic and social aspects of Bengbu City can provide a basic overview of the study area, which is of practical significance for the subsequent further study of the influence of these information elements on the urban vulnerability of Bengbu City and the promotion of the optimal reorganization of resources and sustainable economic and social development in the region.

3. Research Methods and Data Sources

3.1. Connotation of Urban Vulnerability

Urban vulnerability is based on the enrichment and development of vulnerability, so understanding urban vulnerability first requires an understanding of what vulnerability is. Vulnerability analysis originated from the study of natural disasters [10], which was defined by Cutter [11] and scholars from Clark, USA, who classified vulnerability into three types: first, sensitivity to local natural conditions; second, coping capacity to local social factors, and third, a combination of sensitivity and coping capacity [9]. In the course of this urban vulnerability study, the urban vulnerability of the study area is analyzed in terms of urban environment, economic conditions and social development, combining the positive role of sensitivity in urban vulnerability and the negative role of adaptive capacity in urban vulnerability.

3.2. Determination of the Index System

In selecting indicators, the principles of objectivity, typicality, hierarchy and systematicity are followed [12]. According to the above several principles, Bengbu city vulnerability as the research object, based on the summary and reference of previous experience [4-5], learning and considering the actual situation of the region, 29 research indicators of vulnerability were selected comprehensively, corresponding to three aspects of Bengbu city: economic, social and ecological environment, so as to construct a comprehensive metric system of urban vulnerability in Bengbu city, which is shown in Table 1.

Table 1: Urban vulnerability metrics system

System	Indicator Type	Indicator Variables	Rationale for the selection of indicators
Economic Subsystem	+	The proportion of secondary industry (%)	Reflecting industrial structure
	+	Proportion of people employed in the primary industry (%)	Reflects the impact of natural disasters on the economic system
	+	Energy consumption per unit of GDP (tons of standard coal / ten thousand yuan)	Reflecting the impact of the economy on energy supply
	-	GDP per capita (yuan)	Reflects regional macroeconomics
	-	Total social fixed asset investment (billion yuan)	Reflecting the level of regional investment
	-	Total agricultural output value (ten thousand yuan)	Reflecting the relationship between the state of local agricultural development and the economy
	-	The proportion of tertiary industry (%)	Reflecting industrial structure
	-	Total export commodities (USD million)	Reflecting the external development of the regional economy
	-	Cargo volume (ten thousand tons)	Reflects the adaptive capacity of the regional economy to carry freight volumes
Social Subsystems	+	Urban registered unemployment rate (%)	Social response reflecting unemployment shock
	+	Urban Engel Coefficient (%)	Reflecting the pressure of urban residents' consumption level on social stability
	+	Population density (persons/km^2)	Reflects the demographic pressure on social infrastructure
	+	Total social consumer goods (billion yuan)	Reflecting the level of social consumption
	+	Fertilizer use (tons)	Reflects society's exposure to agricultural consumer goods
	+	Ratio of urban to rural residents' income growth (%)	Reflecting the destabilizing effects of the urban-rural divide on society
	-	Rural per capita net income (yuan)	Reflects society's ability to adjust to urban-rural income imbalances
	-	General secondary school students enrolled (ten thousand people)	Reflects the level of interest in secondary and higher education in the region
	-	Expenditure on science and technology (ten thousand yuan)	Reflecting the level of technological development of society
	-	Number of hospital beds per 10,000 people (pcs)	Reflecting the level of social medical development
	-	Total post and telecommunications business (ten thousand yuan)	Reflecting the level of social courier services
	-	Gas penetration rate (%)	Reflecting the status of infrastructure upgrade for social residents
	-	Natural population growth rate (‰)	Reflects natural population growth in society
	-	Daily domestic water consumption per capita (L)	Reflecting the domestic water consumption of regional residents
Environment Subsystem	-	Forest cover (%)	Reflecting the adaptive capacity of forest resources to cope with the ecological environment
	-	Landscape area (hectares)	Reflects the level of change in regional landscaping area
	-	Greening coverage of built-up areas (%)	Reflects the adaptability of vegetation cover in built-up areas to the regional environment
	-	Harmless disposal rate of domestic waste (%)	Reflecting the city's ability to handle domestic waste
	-	Average annual precipitation (um)	Reflecting the impact of natural factors on urban ecology
	-	Average annual temperature (℃)	Reflecting the impact of natural factors on urban ecology

Note: In this indicator system, the response of each subsystem to urban vulnerability varies in degree. Where "+" indicates the positive effect of the indicator variables on urban vulnerability; "-" indicates the negative effect of the indicator variables on urban vulnerability. The green area, the green coverage rate of built-up area and the harmless disposal rate of domestic waste are important factors reflecting the environmental subsystem, and the greater the proportion, the healthier the ecological environment; the GDP per capita and the ratio of primary, secondary and tertiary industries are important factors reflecting the economic subsystem; the urban registered unemployment rate, population density and science, education, culture and health are important factors reflecting the social subsystem.

3.3. Urban Vulnerability Model

3.3.1. Standardization of Indicators

When analyzing data, a large amount of raw data is usually used to ensure the quality of indicator data, but each of these raw data has its own unique properties. Their individual differences affect the analysis of the data when it is performed. Therefore, raw data need to be standardized in a uniform manner for more objective analysis. The most common standardization methods used in data processing include polarization, vector standardization, standard sample variation, and taking the inverse, among others [13]. Among these methods, the extreme difference standardization method can effectively eliminate the adverse effects of different indicators due to their individual properties, thus making the results of these data more comparable with each other after standardization. In addition, the extreme difference standardization method is widely used in data processing because it is easy to use and practical. Therefore, in this paper, the "extreme difference standardization method" is chosen for the normalization of data.

The indicators in this paper are divided into two categories: positive indicators and negative indicators, and different formulas are selected to standardize the data according to the different impact status of each indicator on the vulnerability of Bengbu city. The calculation formulas are as follows.

Positive evaluation indicator: the higher its value, the greater the vulnerability.

$$Xij = \frac{\mathrm{Xij}-\min(\mathrm{Xij})}{\max(\mathrm{Xij})-\min(\mathrm{Xij})} \tag{1}$$

Negative evaluation indicator: the higher its value, the smaller the vulnerability.

$$Xij = \frac{\max(\mathrm{Xij})-\mathrm{Xij}}{\max(\mathrm{Xij})-\min(\mathrm{Xij})} \tag{2}$$

Where: Xij is the standardized value, xij is the original data, and i is the ith indicator.

3.3.2. Calculation of Index Weights

There are various methods for calculating the analysis of index weights. According to the original source of the weights, they can be divided into subjective assignment method, objective assignment method, and comprehensive assignment method [14]. In general, the commonly used ones are expert consultation method, AHP hierarchical analysis method and entropy method [15]. Here the entropy value method is used as the basis for establishing the entropy value after data standardization. The characteristic of the entropy value method is that the larger the amount of data processed, the greater the certainty and the smaller the entropy; the smaller the amount of data processed, the smaller the certainty and the larger the entropy [16]. However, in fact, the entropy value method is a more objective weight assignment method, and the weight can be determined by the change of the value of each index. Therefore, the entropy method is more accurate and can avoid the various effects of those subjective human factors on the indicator weights, so that the results can be better interpreted. The calculation formula is as follows.

$$e_j = -\frac{\sum_{i=1}^{\mathrm{m}} y_{ij}\ln y_{ij}}{\ln \mathrm{m}} \tag{3}$$

$$w_i = \frac{1-e_j}{\sum_{i=1}^{n}(1-e_j)} \tag{4}$$

The initial values of the indicators of Bengbu city from 2010 to 2019 were normalized by substituting them into equations (1) and (2), and the values obtained were substituted into equations (3) and (4), and the weights were calculated by using SPSS AU, as shown in Table 2.

Table 2: Information values of urban vulnerability indicator weights

Evaluation Indicators	Information entropy value e	Information utility value d	Weighting factor w
The proportion of secondary industry / %	0.916	0.084	2.45%
Proportion of people employed in the primary industry / %	0.8712	0.1288	3.76%
Energy consumption per unit of GDP / (tons of standard coal / ten thousand yuan)	0.894	0.106	3.10%
GDP per capita/yuan	0.9267	0.0733	2.14%
Total social fixed asset investment/billion yuan	0.9037	0.0963	2.82%
Total agricultural output value / ten thousand yuan	0.8871	0.1129	3.30%
The proportion of tertiary industry / %	0.9163	0.0837	2.45%
Total export commodities / USD ten thousand	0.8973	0.1027	3.00%
Cargo volume / ten thousand tons	0.8662	0.1338	3.91%
Urban registered unemployment rate/%	0.9395	0.0605	1.77%
Urban Engel coefficient/%	0.7224	0.2776	8.12%
Population density/(person/km^2)	0.8819	0.1181	3.45%
Total social consumer goods/billion yuan	0.8418	0.1582	4.62%
Amount of fertilizer used/ton	0.9237	0.0763	2.23%
Growth rate of urban and rural residents' income / %	0.9188	0.0812	2.37%
Number of hospital beds per 10,000 people	0.9375	0.0625	1.83%
Total post and telecommunications business / ten thousand yuan	0.879	0.121	3.54%
Gas penetration rate/%	0.6445	0.3555	10.39%
Natural population growth rate/‰	0.954	0.046	1.35%
Per capita daily domestic water consumption/L	0.9348	0.0652	1.91%
Rural per capita net income/yuan	0.9049	0.0951	2.78%
General secondary school students / ten thousand people	0.93	0.07	2.05%
Science and technology expenditure / ten thousand yuan	0.9192	0.0808	2.36%
Forest cover/%	0.8421	0.1579	4.62%
Landscape area/hectare	0.8665	0.1335	3.90%
Greening coverage of built-up area/%	0.9106	0.0894	2.61%
Harmless treatment rate of domestic waste/%	0.7411	0.2589	7.57%
Average annual precipitation/um	0.9408	0.0592	1.73%
Average annual temperature/ ℃	0.868	0.132	3.86%

3.3.3. Vulnerability evaluation model

The comprehensive vulnerability is a weighted sum of the standard values of each indicator multiplied by the weights. The calculation formula is as follows.

$$\mathrm{UVI} = \sum_{j=1}^{n}(w_i \times x_{ij}) \tag{5}$$

Table 3: Grading criteria for comprehensive urban vulnerability assessment

Vulnerability Classification	Level	Level 1	Grade 2	Grade 3	Level 4	Grade 5
		Lower vulnerability	Low vulnerability	Medium vulnerability	High vulnerability	Higher vulnerability
Vulnerability	Index	0≤UVI<0.2	0.2≤UVI<0.4	0.4≤UVI<0.6	0.6≤UVI<0.8	0.8≤UVI<1
UVI Characterization status		Excellent condition	Good Condition	General Status	Alert Status	Crisis Status

After the results of urban vulnerability calculation for the classification, the vulnerability of

Bengbu city was divided into 5 levels of low vulnerability, low vulnerability, medium vulnerability, high vulnerability, and high vulnerability according to the results of vulnerability calculation, and the respective characteristic states were excellent, good, average, alert, and crisis states [7], as shown in Table 3.

3.4. Data Sources

Using Bengbu city as a sample, the historical data information of Bengbu city for 10 years from 2010 to 2019 was collected. The information data are mainly from Anhui Statistical Yearbook, Bengbu Statistical Yearbook, Bengbu Water Resources Bulletin, as well as statistical bulletins on economic and social development of Bengbu city and work reports of the municipal government in previous years.

4. Results and Discussion

4.1. Economic Vulnerability Analysis

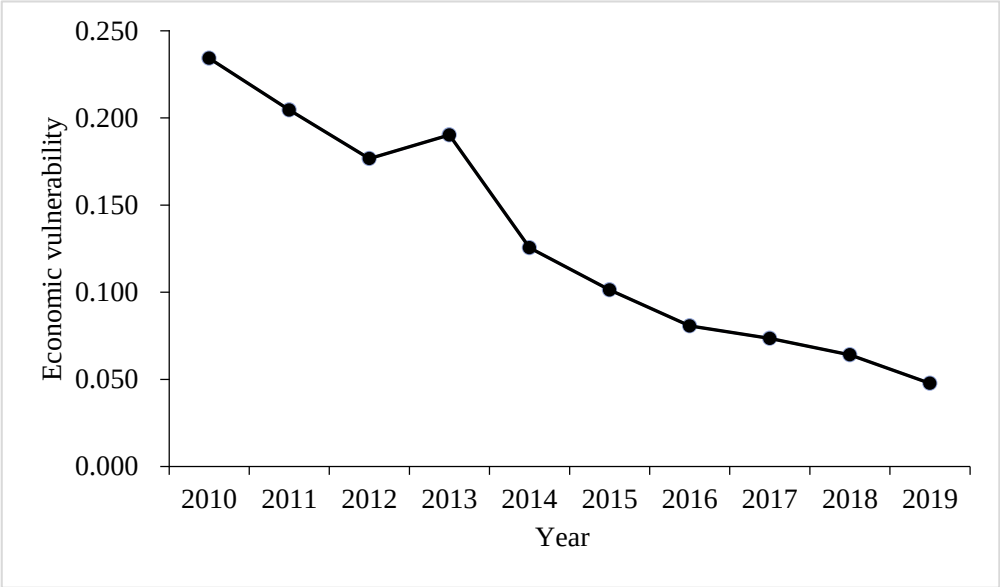

Figure 1: Economic vulnerability

The time series plot of economic vulnerability in Bengbu city (see Figure 1) shows that the overall economic vulnerability of Bengbu city from 2010-2019 shows a fluctuating decline, indicating that the economic vulnerability of Bengbu city is gradually declining and may decline even further in the future. Among these years, the economic vulnerability shows a short-lived increasing trend in 2013 with an increase of 7%, which may be due to the development of supporting industries in Bengbu City during 2012-2013 leading to a larger secondary industry group and an increase in industrial energy supply in Bengbu City, thus causing the secondary industry share and energy consumption per unit of GDP indicators in economic vulnerability to become larger bringing economic vulnerability. So far, after 2013, the economic vulnerability of Bengbu city has been decreasing year by year, and the decreases were 34%, 19%, 20%, 9%, 13%, and 26%, respectively. The biggest decline in 2014 may be due to the fact that Bengbu's development of the secondary industry has led to a forward trend in the economy, resulting in a decline in economic vulnerability due to the increase in per capita GDP and the investment in fixed assets of the whole society; the downward trend after 2014 may be due to the gradual improvement of the economic development order and the stability of the economic

development structure in Bengbu City. In general, the trend of economic vulnerability of Bengbu city from 2010-2019 changes at a faster rate. It can be seen that from the economic vulnerability index of 0.234 in 2010 to 0.048 in 2019, the decline reaches 80%, indicating that the total economic volume of Bengbu city is gradually growing and the economic structure is gradually rationalized, which additionally brings a certain mitigation to the vulnerability of regional cities.

4.2. Social Vulnerability Analysis

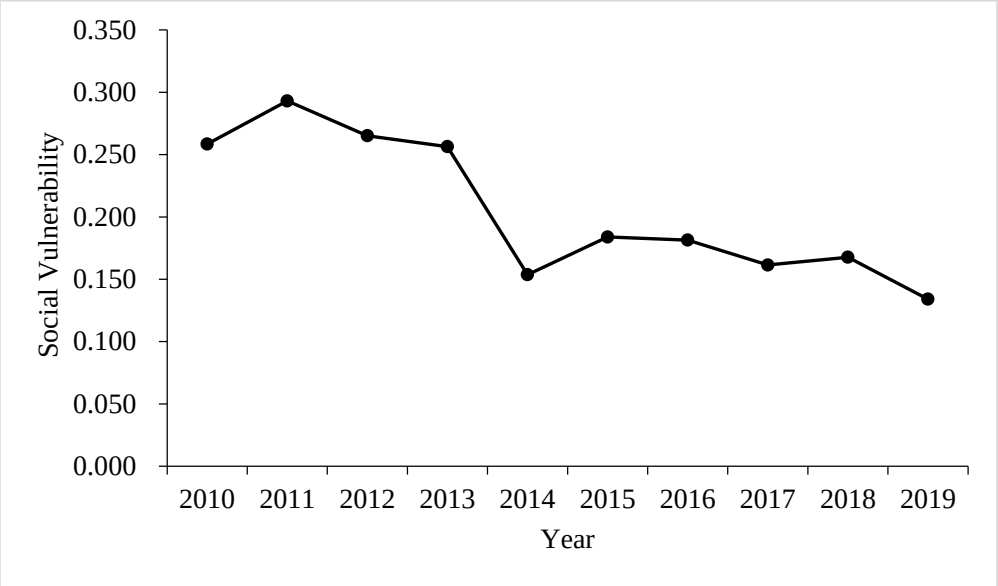

Figure 2: Social vulnerability

From the time series graph of social vulnerability in Bengbu city (see Figure 2), the overall trend of social vulnerability in Bengbu city from 2010 to 2019 is decreasing but fluctuating greatly, indicating that social vulnerability in Bengbu city is in an unstable state and the future trend may further fluctuate and decrease. The social vulnerability of Bengbu city has an upward trend in 2011, with an increase of 13%, probably due to the unstable employment situation in Bengbu city in 2011, which led to the increase of the number of unemployed people and the increase of urban registered unemployment rate, urban Engel coefficient, and total social consumption goods indicators in social vulnerability. From 2012 to 2014, it showed a downward trend year by year, with a decline of 10%, 3% and 40%. In 2014, there was a significant decrease in social vulnerability, probably due to the better economic development of Bengbu city in 2014 and the more stable economic development, which facilitated the municipal government to increase financial expenditures and establish sound social services, resulting in the increase of indicators of social vulnerability such as expenditure on science and technology, the number of hospital beds owned by 10,000 people and gas penetration rate, which to some extent reduced the pressure of social vulnerability. Since then, there was another increase of 20% in 2015. Probably because social security was better established and more functional in 2014 leading to little room for continued improvement in 2015, so there is a rebound state in 2015. From 2016 to 2019, the decline rate from 2016 to 2017 will be 1% and 11%; In 2018, it was on the rise, with an increase rate of 4%; In 2019, it will decrease by 20%. It can be seen that it is basically in a steady decline since 2015, and the rebound of social vulnerability in 2018 may be due to the transient instability phenomenon caused by certain infrastructure upgrades in 2018, or it may be caused by the rise of the population density indicator in social vulnerability since the liberalization of the two-child policy. Overall, the social vulnerability index decreased from 0.258 in 2010 to 0.134 in

2019, a decrease of 48%, indicating that Bengbu City's infrastructure is gradually improving, but the rate of decrease in the social vulnerability index is low compared to economic vulnerability, indicating that there is room for further reduction in the social vulnerability index. It can be seen that Bengbu city still needs a series of measures to reduce the urban social vulnerability index and achieve the long-term development of urban society by improving the social security mechanism, increasing the ratio of social public investment, reasonably building social science, education, culture, health and sports and improving the quality of the labor force.

4.3. Ecological Environment Vulnerability Analysis

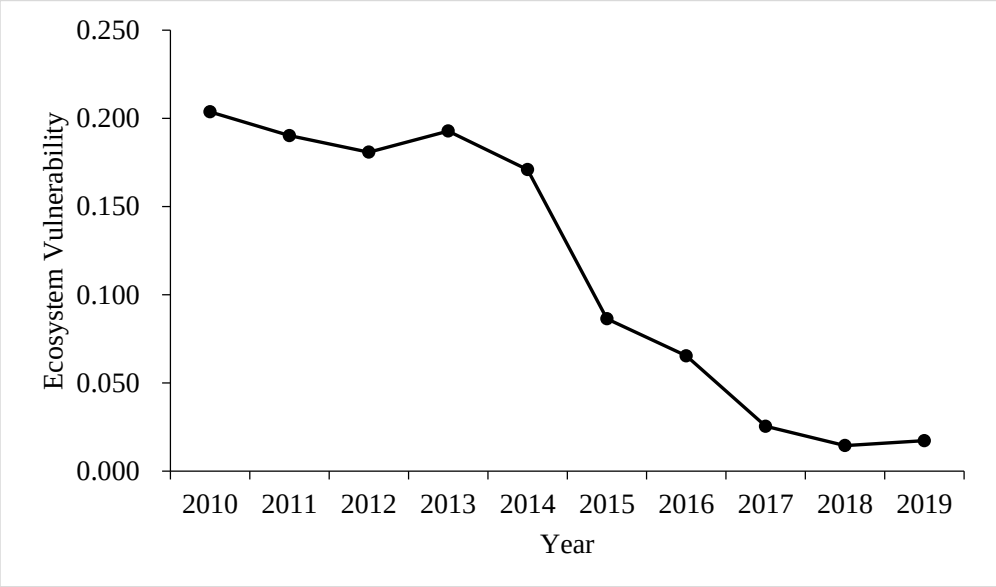

Figure 3: Ecological vulnerability

From the time series graph of ecological vulnerability of Bengbu city (see Figure 3), the overall ecological vulnerability of Bengbu city shows a fluctuating decreasing trend from 2010 to 2019, but the decrease is smaller in the early period and larger in the later period, indicating that the ecological vulnerability of Bengbu city is gradually decreasing and may also decrease in the future. Among them, between 2010 and 2012, the ecological vulnerability of Bengbu city decreased by 7% and 5%. This may be due to the fact that the natural ecological environment of Bengbu was more stable during this period, which caused the increase of the weight of the annual average precipitation and annual average temperature indicators in the ecological vulnerability. In 2013, the vulnerability of the ecological environment increased by 7%, which may be due to the pressure on the environmental carrying capacity of Bengbu City during the economic and social development of Bengbu City in 2013, or because Bengbu City attaches great importance to industrial economic development and infrastructure improvement but neglects the treatment of environmental pollution. From 2014 to 2018, there was a downward trend year by year, with a large decline of 11%, 49%, 24%, 61% and 43%, respectively. This may be because the municipal government recognized the importance of the ecological environment, and increased the environmental remediation, which resulted in the enhanced role of green space area, green coverage rate of built-up areas, and harmless disposal rate of domestic garbage in the ecological environment vulnerability. The ecological environment vulnerability caused by human intervention and governance has decreased significantly. In 2019, the vulnerability of the ecological environment will increase by 19%, which may be due to the weakening of the regulatory role of forest resources on the ecological environment or the large change of climate conditions in the

year. Overall, the ecological vulnerability index decreased from 0.204 in 2010 to 0.017 in 2019, a decrease of 92%, indicating that Bengbu City can be effectively improved by developing environmental policies and embarking on ecological management.

4.4. Urban Vulnerability Analysis

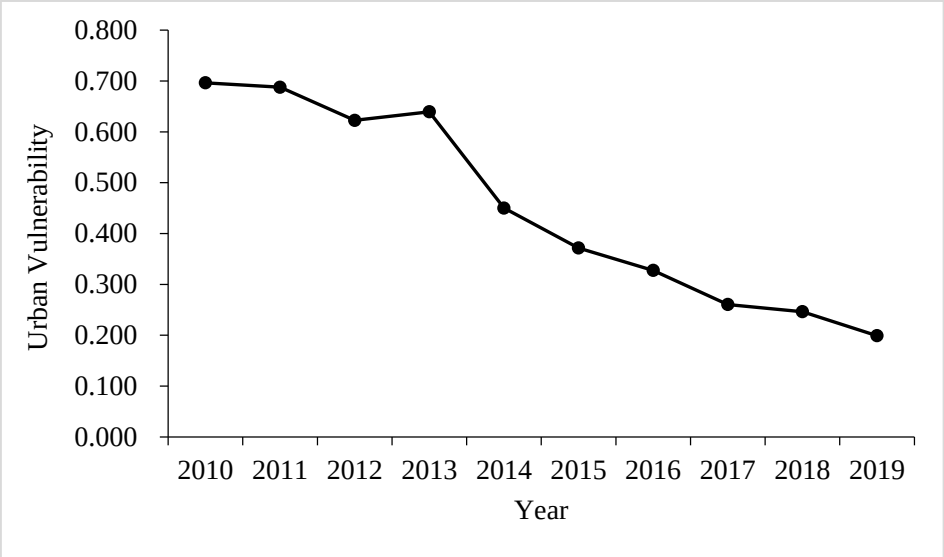

Figure 4: Urban vulnerability

From the time series of urban vulnerability of Bengbu city (see Figure 4) and the change of vulnerability level of Bengbu city (see Table 4), the overall urban vulnerability of Bengbu city from 2010 to 2019 shows a gentle decreasing trend, and the vulnerability level changes from high vulnerability to lower vulnerability. Among them, from 2010 to 2013, the vulnerability of Bengbu City was relatively high, but during this period, the urban vulnerability index of Bengbu City was stable and had a downward trend; By 2019, the urban vulnerability level of Bengbu will become lower, which shows that Bengbu's urban vulnerability has a good development status, and it may further decline in the future. From 2010 to 2012, the urban vulnerability showed a downward trend of 1% and 9%, which may be due to the decline of economic and ecological environment vulnerability, the slight increase of social vulnerability and the slight decline of urban vulnerability caused by it. As a result, Bengbu's vulnerability index continued to be more than 0.6 from 2012 to 2013, and the urban vulnerability was still in a high fragile state. In 2012, the urban vulnerability increased by 3%, which may be due to the slight recovery of the instability of the economic and ecological environment adaptation process. From 2014 to 2019, the urban vulnerability of Bengbu City has decreased significantly in each year, which is 30%, 17%, 12%, 20%, 5% and 19% respectively. This may be caused by the comprehensive adjustment of the economic, social and ecological environment. The biggest reduction in urban vulnerability in 2014 may be due to the largest reduction in the economic, social and ecological environmental vulnerability of Bengbu City in 2014. In addition, the level of urban vulnerability has also changed from medium to low, and urban vulnerability is in a good and stable state. In general, the urban vulnerability index decreased from 0.696 in 2010 to 0.199 in 2019, a drop of 71%. The urban vulnerability level also experienced a process from high brittle to medium brittle to low brittle to low brittle, indicating that Bengbu is now in a good development stage. In addition, it is necessary to adhere to the sustainable development path on the basis of its own development advantages and characteristics, so as to provide Bengbu with the correct direction guide.

Table 4: Change of comprehensive vulnerability index and grade of Bengbu city

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Index	0.696	0.688	0.623	0.639	0.450	0.372	0.327	0.260	0.246	0.199
Grade	High vulnerability				Medium vulnerability	Low vulnerability				Lower vulnerability

4.5. Discussion on the Percentage of Vulnerability of Each Subsystem

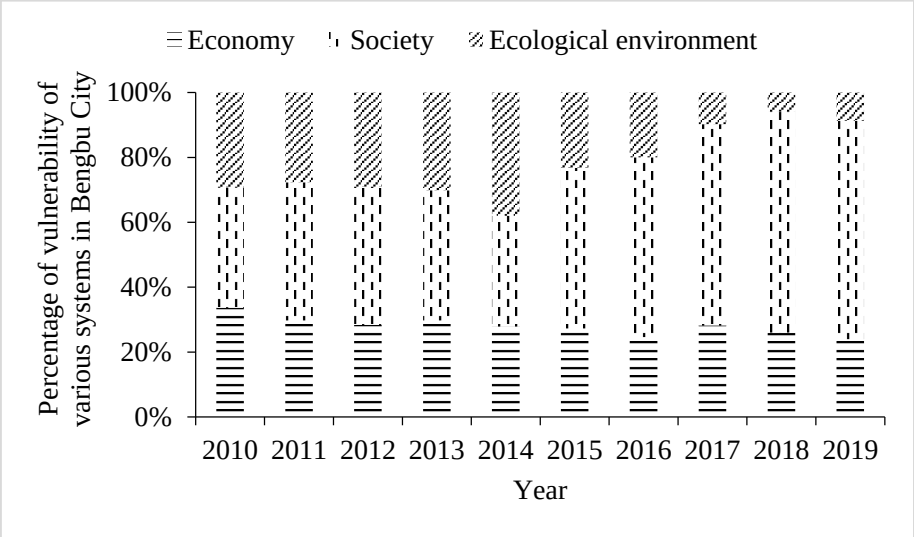

Figure 5: Percentage of urban vulnerability subsystems

From the time series diagram of the proportion of each subsystem of urban vulnerability in Bengbu city (see Figure 5), we can see that the largest proportion of urban vulnerability in Bengbu city from 2010 to 2019 is social, the second is economic, and the ecological environment is at the bottom. It shows that the urban vulnerability of Bengbu city is influenced to a greater extent by the society, less by the ecological environment, and the economic influence on urban vulnerability is more stable, and the urban vulnerability may continue to be influenced by these three in the future and the structural proportion of the influence is basically unchanged. From 2010 to 2013, the proportion of each subsystem of urban vulnerability remained basically stable. Among them, ecological vulnerability is about 29%; social vulnerability is about 41%; and economic vulnerability is about 30%. This indicates that social, ecological and economic vulnerability have a great influence on urban vulnerability in this period; among them, the proportion of social vulnerability has a prominent but not outstanding influence on urban vulnerability. In 2014, the urban vulnerability accounted for 28% of the economy, 34% of the society, and 38% of the ecological environment. The proportion of the ecological environment exceeded the proportion of the society, and the economic proportion remained basically unchanged. This may be due to the fact that the social vulnerability decreased by a large margin of 40% in 2014, 29% higher than the ecological environment vulnerability. From 2015 to 2019, the share of social vulnerability in urban vulnerability is increasing year by year and gradually taking the dominant position; the share of ecological environment is decreasing and gradually becoming less; the share of economic vulnerability is still in the middle position, but it is also slowly withdrawing. Overall, the social share is 60%, the economic share is 26%, and the ecological share is 14% during this period, probably because the social vulnerability index has been stable at around 0.15 after 2015, while the economic and ecological vulnerability indices have been steadily at around 0.05, respectively, resulting in an increase in the social vulnerability share and a decrease in the economic

and ecological shares. Overall it shows that social vulnerability has a strong role in influencing urban vulnerability.

5. Conclusion

Based on the study of urban vulnerability in Bengbu City, the following conclusions were drawn from the economic-social-ecological environment subsystem of Bengbu City, by establishing an index system for the evaluation of urban vulnerability in Bengbu City.

(1) From the change of the comprehensive vulnerability level of the city, the overall urban vulnerability of Bengbu City from 2010 to 2019 shows a downward trend, basically completing the transition from higher vulnerability to lower vulnerability and being in a good and stable development state.

(2) From the viewpoint of the vulnerability ratio of each subsystem, the vulnerability ratio of each subsystem in Bengbu City varies more obviously. Social vulnerability dominates, economic vulnerability is in the middle, and ecological and environmental vulnerability is in the second place.

(3) In terms of the degree of decline in vulnerability of each subsystem, all subsystems of urban vulnerability in Bengbu City have declined to different degrees from 2010 to 2019. Among them, the vulnerability of the economic and ecological subsystems declined more significantly, while the vulnerability of the social subsystem generally declined more slowly and moderately.

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