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Vulnerability Assessment and Spatial Pattern Analysis of Earthquake Disaster in Hebei Province

Sujie Ji, Jindong Liang, Weihao Xiao, Ziyu Zhang, Miao Liu, Haoran Yu, Yuanda Zhang

Institute of Disaster Prevention, Sanhe, Hebei, China

Abstract: ***To evaluate the vulnerability of earthquake disaster in Hebei Province and analyze the spatial pattern, the aim is to provide theoretical basis for emergency management departments to prevent and respond to disasters. This study uses the subjective and objective evaluation mechanism, through the integration of analytic hierarchy process and entropy weight method to determine the weight distribution of each index. The assessment model is used to assess the vulnerability of earthquake disasters, and the spatial pattern characteristics are studied by global spatial autocorrelation analysis and LISA clustering analysis.The main conclusions are as follows: (1) The area with the greatest vulnerability to earthquake disaster is Shijiazhuang High-tech Zone (0.761); The lowest value is 0.243 in Qian 'an City, Tangshan City, and there are great differences among some regions. (2) The vulnerability of all counties (cities and districts) in Hebei Province has a positive correlation and aggregation with their spatial locations, and the spatial distribution is low in the whole province, high in the local area, high in the southeast and low in the northwest. (3) It is found that measures such as training health workers and expanding professional emergency management team can reduce the overall level of earthquake disaster vulnerability in Hebei Province.***

Keywords: Entropy weight method; GIS; Analytic hierarchy process; Spatial autocorrelation analysis; Aggregation analysis.

1. INTRODUCTION

On a global scale, the risk of natural disasters has attracted the deep concern of many scholars. Internationally, a series of research programs focused on disaster prevention and response have been launched, such as DRI and HotsPot programs, which have promoted in-depth disaster research and produced many academic achievements.At the end of the 20th century, the Scientific and Technical Committee of the International Decade for Disaster Reduction proposed several challenging research directions in the field of international disaster reduction in the 21st century. Among them, four are closely related to vulnerability in disasters and have become the top priority of disaster reduction research. Moreover, many core literatures in the field of disaster research place vulnerability research in a very critical position, and even take it as the center or basis of research to explore and deepen[1-3].In the field of disaster research, vulnerability research has always been a core issue and research focus. At present, China's plate movement is still very active, from 2003 to 2008, 265 earthquakes of magnitude 5 and above, 59 earthquakes of magnitude 6 and above, 6 earthquakes of magnitude 7 and above, in 2008, "5. The 12 "Wenchuan earthquake caused 69,227 deaths, 17,923 people missing, 375,783 people injured, and the direct economic losses caused by the disaster exceeded 852.3 billion yuan[4].

Since the accuracy of earthquake prediction still needs to be improved, we should not only deepen the research of earthquake prediction technology, but also focus more on the exploration and analysis of earthquake disaster vulnerability. Therefore, population vulnerability assessment plays an important role in earthquake emergency response and long-term economic and social development planning[5]. Although vulnerability has been widely recognized as the core component of earthquake risk, the current understanding of vulnerability to earthquake disasters is still in the exploratory stage, and there are many key technical problems to be overcome, such as identification of impact factors, analysis of impact modes, and selection and optimization of modeling strategies such as quantitative methods and mechanism models[6].

In the current research, quantitative analysis has become the main strategy and method to assess the macro vulnerability of earthquake disaster areas[7].Therefore, we need to start from the multiple dimensions and levels of macro vulnerability of earthquake disaster areas, and first identify macro vulnerability indicators matching these dimensions and levels on the basis of qualitative assessment. These indicators are combined with various quantifiable macro-vulnerability indicators that fit the regional scale, and then the comprehensive indicators are summarized.

In view of the frequent occurrence and wide distribution of earthquakes in China, the assessment of earthquake disaster vulnerability is particularly important. To this end, we need to build a sound and easy to operate evaluation methods and models. The required indicator data must be easy to obtain, highly reliable, quickly updated, and easily quantified. Based on the above criteria, this study expands the traditional vulnerability research model, attempts to construct a comprehensive assessment system of earthquake disaster vulnerability from four dimensions: society, population, economy and disaster prevention and reduction capability, and develops a comprehensive assessment model of earthquake disaster vulnerability.This model is used to assess the earthquake disaster vulnerability of each city (county) administrative region in Hebei Province. On this basis, spatial pattern analysis was carried out to find the spatial distribution characteristics of earthquake disaster vulnerability in Hebei Province, and the main ideas were shown in Figure 1.

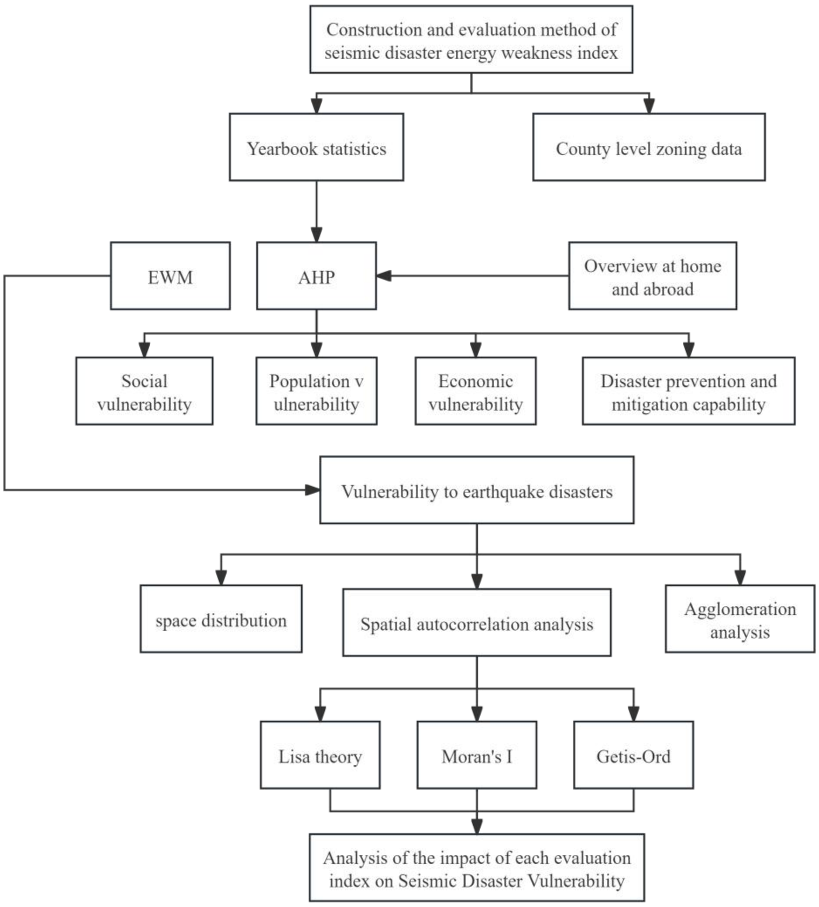

Figure 1: Spatial pattern analysis model based on SPSS and ArcGIS

2. METHODS AND DATA

2.1 Analytic Hierarchy Process

Analytic Hierarchy Process (AHP), as a widely used decision-making tool, assigns weights to different indicators, factors and decision variables, so as to analyze and deal with fuzzy and complex problems effectively. In addition, the influence factors at each level are compared one by one based on different criteria and quantified to form a weight matrix, so as to calculate the weight of each element for this criterion. The main steps are as follows[8].

2.1.1 Construct judgment matrix

The hierarchical structure model is established by using the analytic hierarchy process (AHP), and then the scale method is applied and the importance of indicators is compared by the scores of several experts and the comparison of literature. The judgment matrix is constructed to analyze the factors of indicators in the criterion layer and the judgment matrix (B) is obtained, as shown in formula (1) :

$$B = \begin{pmatrix} 1 & 2 \\ 1/2 & 1 \end{pmatrix} \tag{1}$$

2.1.2 Calculate the weight of criteria layer indicators

Calculate the weight of criteria layer indicators. The eigenvectors of the judgment matrix, namely the weight coefficients of different indicators, are obtained by normalizing the matrix row vectors. The calculation method is shown in formula (2) :

$$w_i = \frac{\sqrt[n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{i=1}^{n} \sqrt[n]{\prod_{j=1}^{n} a_{ij}}} (i = 1，2 \ldots n) \tag{2}$$

Where a_{ij} represents each element in the matrix, and w_i represents the weight coefficients of different indicators.

2.1.3 Index consistency test

First, the largest eigenroot λ_{max} of the matrix is calculated, The calculation method is shown as formula (3), followed by consistency test. The matrix CI(consistency) and CR(consistency ratio) are calculated, and RI is the random consistency index. The calculation formula is shown in equation (3) :

$$\lambda = \frac{1}{n} \sum_{i=1}^{m} \frac{\sum_{j=1}^{n} a_{ij} * w_j}{w_i} \tag{3}$$

RI is a random consistency index, CR = CI/RI = 0.0042 <0.1. Through consistency test, it can be determined that the weight of each first-level indicator is U=(0.423, 0.267, 0.127, 0.123)T. Similarly, the weight of each indicator is calculated.

2.2 Entropy weight method

2.2.1 Calculate the characteristic proportion of the evaluation object under the index

The calculation method is shown in formula (4) :

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{4}$$

2.2.2 Calculate the index entropy

The calculation method is shown in formula (5) :

$$E_j = -(\ln m)^{-1} \sum_{i=1}^{m} P_{ij} \ln P_{ij} \tag{5}$$

2.2.3 Determine the weights of each indicator

The calculation method is shown in formula (6) :

$$V_j = \frac{1 - E_j}{\sum_{i=1}^{n} \left(1 - E_j\right)} \tag{6}$$

2.2.4 The index system based on this research

The calculation method is shown in formula (7) :

$$W_j = \frac{\sqrt{U_j V_j}}{\sum_{j=1}^{n} \sqrt{U_j V_j}} \tag{7}$$

W_j is the weight of indicator j after the integration of the two weighting methods. U_j and U_j respectively represent the weight of indicator j under the weighting of analytic hierarchy process and entropy weight method. Finally, the final weight of the indicator is determined according to formula (7).

2.3 Global spatial autocorrelation analysis

In this study, global Moran's I index tool is used to analyze the global spatial distribution characteristics of earthquake disaster vulnerability among cities. The symbol of Moran's I index reveals the directivity of spatial correlation: the negative value indicates that the vulnerability of earthquake disasters among cities presents a spatial negative correlation, that is, the phenomenon of spatial dispersion; The positive value indicates that there is a spatial positive correlation between earthquake disaster vulnerability among cities, that is, the trend of spatial agglomeration. When Moran's I index approaches 0, it indicates that the vulnerability of cities to earthquake disasters presents an independent distribution in space, that is, there is no significant spatial correlation. In order to visualize the distribution characteristics of this spatial autocorrelation, Moran'sI index scatter plot can be drawn. The specific calculation method of the global Moran's I index can be found in formula (8) :

$$\mathrm{I}=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}\left(X_i-\bar{X}\right)\left(X_{\mathrm{j}}-\bar{X}\right)}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}} \tag{8}$$

Where, S^2 represents the variance, $\bar{X}$ represents the mean value, n represents the total number of selected divisions, X_i represents the regional vulnerability, and w_{ij} represents the adjacent space matrix. (1 when city i and city j are adjacent, 0 when they are not)

2.4 Local spatial autocorrelation analysis

2.4.1 LISA theory

In-depth analysis of Local Spatial features can be achieved by implementing local spatial autocorrelation analysis (LISA). Local spatial correlation is used to represent the characteristics of local spatial heterogeneity, so as to reveal the spatial evolution trend of regional agglomeration with the passage of geography[9].This analysis method is complementary to Moran Index scatter plot. LISA Cluster plot visually presents the positive and negative correlation and significance level of economic growth differences between geographical observation points (such as cities) and their surrounding areas in the form of maps, and becomes an important reference index for evaluating spatial cluster phenomenon. The calculation method is shown in formula (9) :

$$\mathrm{I}_{\mathrm{i}}=\frac{(X_i-\bar{X})^2}{\mathrm{m}_0}\sum\mathrm{w}_{ij}\left(\mathrm{X}_{\mathrm{j}}-\bar{X}\right) \tag{9}$$

Where, $\mathrm{m}_0=\frac{\sum_{i=1}(X_i-\bar{X})^2}{\mathrm{n}}$ and w_{ij} are the adjacent space weight matrix set in this study.

2.4.2 Local$\mathrm{G}_{\mathrm{i}}^{*}$index method

Using Getis-Ord$\mathrm{G}_{\mathrm{i}}^{*}$ in the analysis of hot and cold spots, we can identify the degree of spatial agglomeration of earthquake disaster vulnerability and reveal the spatial distribution pattern of cold spots and hot spots. Its calculation formula is shown in formula (10) : where X_{j} is the attribute value of factor j, W_{ij} is the spatial weight between factor i and j, and n is the total number of factors.

$$G_i^*=\frac{\sum_{j=1}^{n}w_{ij}X_j-\bar{X}\sum_{j=1}^{n}w_{ij}}{S\sqrt{\frac{n\sum_{i=1}^{n}w_{ij}^2-(\sum_{j=1}^{n}w_{ij})^2}{n-1}}} \tag{10}$$

2.5 Data sources

"China City Statistical Yearbook 2021" "China Investment Statistical Yearbook 2021" "Hebei Province Statistical Yearbook 2021"

3. CONSTRUCTION OF EARTHQUAKE DISASTER VULNERABILITY ASSESSMENT INDEX SYSTEM

3.1 Build an index system

On the basis of the existing researches, this study analyzes the multiple factors that affect the vulnerability of earthquake disaster in detail, and selects a total of 13 core indicators to assess the vulnerability of earthquake disaster.

3.1.1 Social vulnerability

The state of social vulnerability refers to the inherent state of a particular region or group before the disaster, which is closely linked to resource scarcity, poverty and social marginalization[10].In addition, social vulnerability is also reflected in the ability of individuals and social groups to adapt to the stress of direct or anticipated disasters, which reveals the potential harm or loss caused by the inadequacy of the natural environment and human society's own adaptive capacity. Scholars such as Tao Peng divided the components of social vulnerability into multiple levels, including individual capital (such as knowledge and experience, skills, economic ability, action ability, gender, age, etc.), social capital (that is, social relationship network), public capital (such as public infrastructure) and natural capital. Based on the current research results, scholars have found that the assessment indicators of social vulnerability are usually closely related to factors such as the degree of exposure, sensitivity and resilience faced by social systems[11].To sum up, this paper selected three key indicators that are negatively correlated with earthquake disaster vulnerability: the number of beds in medical and health institutions, the number of health technology practitioners and the per capita social security funds, so as to assess and analyze social vulnerability.

3.1.2 Population vulnerability

Chinese scholar Ge Quansheng and other scholars[12]on the basis of inheriting the concepts at home and abroad, the population vulnerability is defined as the physical exposure, the inherent sensitivity to resist external shock and the human ability to resist danger accompanying the disaster-bearing body when facing the potential disaster risk due to the role of natural, social, economic and man-made factors[13].Therefore, on the basis of existing studies, this study comprehensively considers the influence of natural, social and economic factors to explore the influence mode of multiple factors on population vulnerability. Therefore, this paper selects three indicators that are positively correlated with earthquake disaster vulnerability, namely population density (person/square kilometer), proportion of unemployed population (%) and proportion of elderly population (%), to analyze population vulnerability.

3.1.3 Economic vulnerability

In exploring the sustainable development of regional economy, the United Nations Development Programme (UNDP) put forward the concept of "economic vulnerability" in 1999[14], and it is regarded as a key indicator to measure the robustness of regional economy. Yuan Haihong and other scholars[15]in his research, he pointed out that economic vulnerability reflects the potential loss that the disaster bearing body may suffer under the influence of disaster causing factors, and this loss is the direct result of the disaster causing factors acting on the disaster bearing body.Su Fei and other scholars[16]it is further emphasized that economic vulnerability is a comprehensive reflection of the interaction between the disaster victim's own sensitivity and recovery ability. Despite the diversity of definitions of economic vulnerability, most studies take into account the three core dimensions of exposure, sensitivity, and resilience. Based on the above research perspectives, this paper defines the economic vulnerability of earthquake disasters as the degree of economic loss shown by the economic system after the impact of earthquake disasters in a specific region, which is jointly affected by the degree of exposure and sensitivity of the economic system to disasters and its post-disaster recovery ability.

In this paper, GDP per capita (yuan), economic density (yuan/square kilometer) and fixed asset investment per capita (ten thousand yuan) are selected as three indicators that are positively correlated with earthquake disaster vulnerability to assess economic vulnerability.

3.1.4 Disaster prevention and mitigation capacity

The ability of disaster prevention and reduction refers to the ability of a city to resolve or withstand external disasters or shocks, maintain its main functions and structures and social life unaffected, and recover quickly after disasters. It can be seen that the capacity of disaster prevention and reduction measures the special capacity of disaster prevention and relief in this region, which can effectively reduce the risk of earthquake disaster in this region, and thus reduce the loss caused by earthquake disaster in this region. In this paper, we selected four key indicators negatively correlated with earthquake disaster vulnerability to assess disaster prevention and reduction capabilities, including the total number of refuge places, the size of social emergency response force, the number of professional emergency response force and the number of practitioners in the field of earthquake preparedness and disaster reduction.

In summary, this study builds an earthquake disaster vulnerability assessment system, as shown in Figure 2:

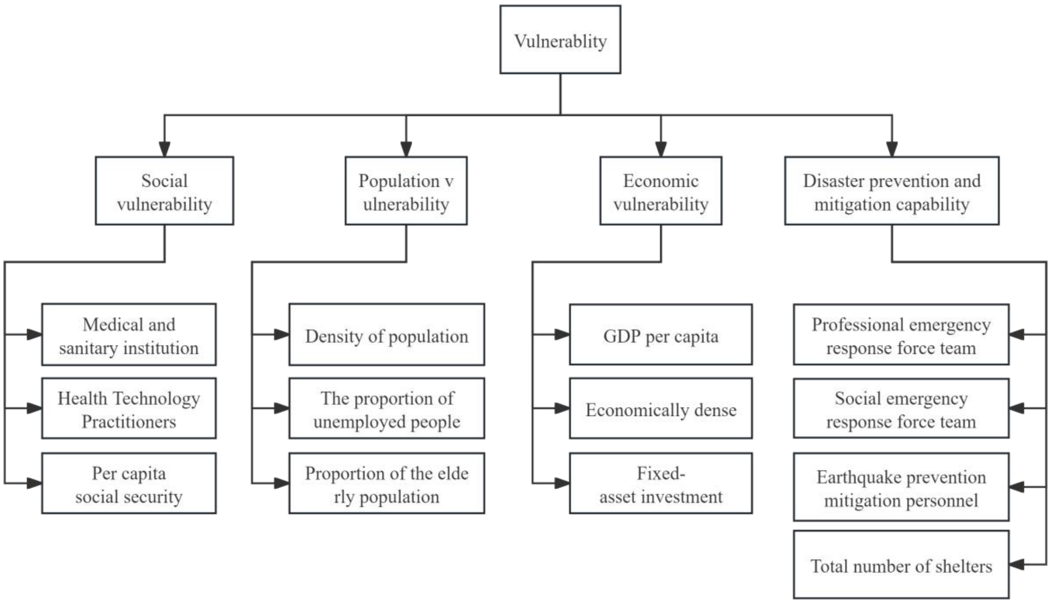

Figure 2: Vulnerability assessment system of earthquake disaster

3.2 Determine index weight

In this paper, we use analytic hierarchy process as an evaluation tool to build a judgment matrix for each indicator through a series of comparison and judgment scoring processes. On this basis, the collected data are calculated according to formula (1) to (3), and the subjective weight of each index is obtained. The entropy weight method is introduced, through which the data itself is deeply processed, and the objective weights of each index are calculated according to formulas (4) to (7). Through the method of combining subjective and objective weights, the influence level of each index on earthquake disaster vulnerability was calculated. The above calculation results are shown in Table 1 below.

Table 1: Weight table of earthquake disaster vulnerability assessment indicators

Decision-making level	Index level	Subjective weight	Objective weight	Comprehensive weight
Economic vulnerability	GDP per capita	0.070	0.116	0.208
	Economically dense	0.025	0.348	0.221
	Fixed-asset investment	0.007	0.116	0.020
Disaster prevention and mitigation capacity	Total number of shelters	0.031	0.034	0.028
	Professional emergency response force team	0.022	0.252	0.142
	Social emergency response force team	0.013	0.024	0.008
	Earthquake prevention and mitigation personnel	0.004	0.009	0.001
Social vulnerability	Medical and sanitary institution	0.261	0.014	0.094
	Health technology practitioners	0.166	0.024	0.104
	Per capita social security	0.035	0.009	0.008
Population vulnerability	Density of population	0.244	0.014	0.091

The proportion of unemployed people	0.085	0.032	0.070
Proportion of the elderly population	0.038	0.006	0.006

According to the data in Table 1, it is not difficult to find that economic density has the greatest impact on earthquake disaster vulnerability, with a weight ratio of 0.221. The number of disaster prevention and mitigation personnel has the least impact, with a weight ratio of 0.001, and the impact of each index on vulnerability is very different.

4. EARTHQUAKE DISASTER VULNERABILITY ASSESSMENT

4.1 Data normalization processing

Since each index has different units, different orders of magnitude, and different impacts on flood disasters, in order to avoid unnecessary errors, the data are standardized in this paper. x_i indicates the value of the indicator, x_{max} indicates the maximum value, and x_{min} indicates the minimum value of the indicator.

For positive correlation indicators, the following formula (10) is adopted:

$$X = \frac{X_i - Xmin}{X_{max} - Xmin} \tag{10}$$

For negative correlation indicators, the following formula (11) is adopted:

$$X = \frac{X_{max} - Xi}{X_{max} - Xmin} \tag{11}$$

4.2 Earthquake disaster vulnerability assessment

The weighted comprehensive evaluation method is used to comprehensively process the data of each index, and the unified quantitative index is used to centrally represent the evaluation results. The formula is as follows (12) :

$$V_i = \sum_{i=0}^{n} Wi * Xi \tag{12}$$

V_i represents the vulnerability of earthquake disaster, W_i represents the weight of each indicator, and X_i represents the indicator data after standardized processing. According to formula (10), the weights of each index were calculated and the data after normalization were processed to obtain the earthquake disaster vulnerability assessment results of 169 counties (cities and districts) in Hebei Province. Taking Shijiazhuang City as an example, Table 2 shows the vulnerability assessment results of each county (city and district) in Shijiazhuang.

Table 2: shows the vulnerability assessment of each county (city and district) in Shijiazhuang

Name	Vulnerability	Name	Vulnerability
Chang'an District	0.499	Xingtang county	0.330
Qiaoxi District	0.457	Lingshou county	0.322
Xinhua District	0.574	Gaoyi County	0.368
Jingxing Mining District	0.569	Shenze county	0.316
Xuhua District	0.311	Zanhuang county	0.317
Gaoxing District	0.761	Wujiang County	0.358
Recycling chemical industry park	0.471	Pingshan county	0.321
Gaocheng District	0.429	Yuanshi county	0.373
Luquan District	0.373	Zhaoxian County	0.388
Luancheng district	0.362	Xinji City	0.392
Jingxing County	0.374	Jinzhou City	0.385
Zhengding County	0.381	Xinle City	0.349

The vulnerability of counties and cities (districts) in Hebei Province was preliminarily explored visually by ArcGIS software, and the distribution results were shown in Figure 4 below.

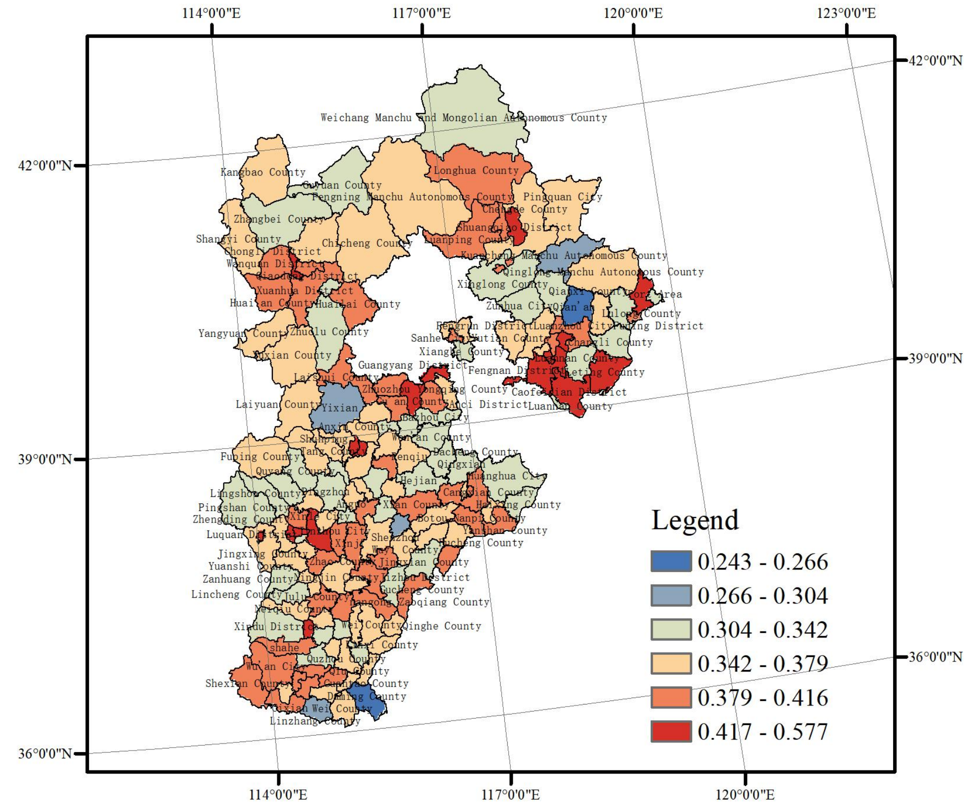

Figure 4: Vulnerability distribution map of counties (cities) in Hebei Province

5. SPATIAL PATTERN ANALYSIS OF EARTHQUAKE DISASTER VULNERABILITY

5.1 The main distribution trend of earthquake disaster vulnerability

In 169 counties (districts and cities) of Hebei Province, the highest vulnerability to earthquake disaster was 0.761, the lowest vulnerability was 0.243, and the vulnerability was lower in the north and higher in the south. The west is low, the east is high. Among them, the vulnerability of 80% counties (districts and cities) is relatively concentrated in the range of 0.378-0.414. It can be found that the distribution of vulnerability index of cities and counties in Hebei Province is relatively concentrated, but the difference is still large in a few areas, and many areas need to continue to carry out reasonable disaster prevention and reduction planning and investment in order to achieve the overall reduction of earthquake disaster vulnerability in Hebei Province. As shown in Figure 5, the X-axis represents longitude, the Y-axis represents dimension, and the Z-axis represents earthquake disaster vulnerability.

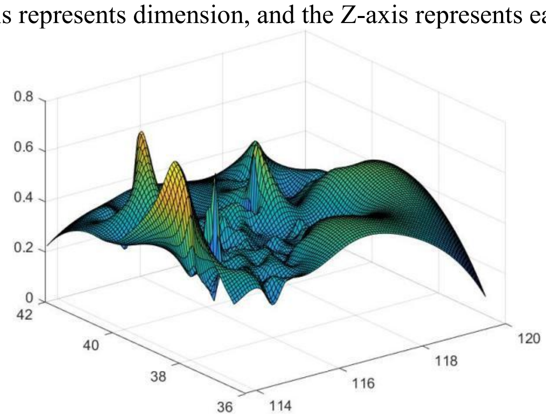

Figure 5: Three-dimensional surface diagram of earthquake disaster vulnerability

5.2 Spatial autocorrelation analysis of earthquake disaster vulnerability

In the field of geography, Tobler's [17] description of spatial autocorrelation is the core content of the first law of geography. He clearly points out that geographical entities and the semantics they carry show a specific correlation in spatial dimension, and the correlation between geographical entities that are close to each other is usually stronger than that of geographical entities that are far away[18].As an important means to explore the distribution pattern of spatial data, the study of spatial autocorrelation is widely used to identify the clustering, discrete and random distribution patterns in spatial data. At the research level of spatial autocorrelation, it can be divided into global and local indexes[19]:Among them, the global autocorrelation index focuses on the whole correlation of a certain attribute in the whole research area. The local autocorrelation index is more refined, which focuses on the spatial correlation of a certain attribute between a unit in the study area and its neighboring units.

5.2.1 Global spatial autocorrelation analysis

When exploring the potential spatial interaction between multiple variables, scholar Anselin proposed the concept of bivariable spatial autocorrelation based on the spatial autocorrelation theory. The purpose is to reveal the intrinsic correlation between an attribute value in a specific spatial unit and other attribute values on neighboring spatial units. As a powerful analytical tool, global spatial autocorrelation has shown excellent applicability and effectiveness in describing the spatial correlation and dependence between two geographic elements. This property is usually quantified and expressed by the global Moran index. At the same time, this study uses GeoDA software to analyze the spatial correlation between geographical space and earthquake disaster vulnerability in the study area. Therefore, different adjacency matrices are studied by using spatial autocorrelation analysis, and the research results are shown in Figure 6-9 below. Through the analysis of Moran 's I index of different adjacency matrices, it is not difficult to find that there is an overall spatial correlation of earthquake disaster vulnerability among counties (districts and cities) in Hebei Province.

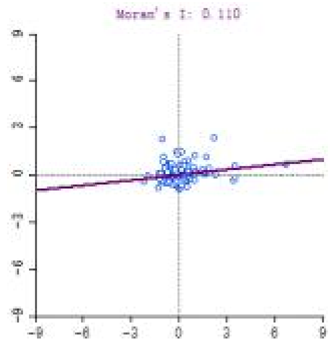

Figure 6: First order Rook adjacency matrix

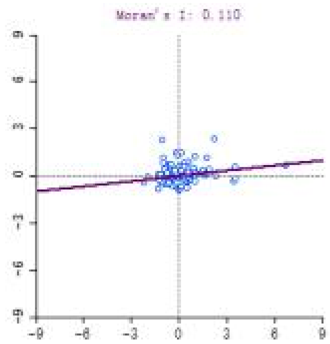

Figure 7: Second order Queen adjacency matrix

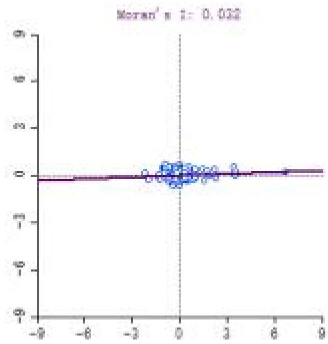

Figure 8: Spatial weight matrix based on Euclidean distance

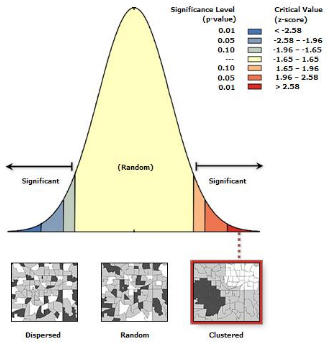

Figure 9: Global Moran's I analysis result graph

5.2.2 LISA clustering analysis

According to the analysis of global spatial pattern autocorrelation in this study, although the global Moran 's I scatter plot can intuitively show the global spatial autocorrelation of vulnerability among cities in Hebei Province, it lacks the relevant description of local spatial correlation analysis. In order to make the results of spatial analysis more comprehensive and specific, this paper used SPSS and ArcGIS software to analyze the local spatial distribution pattern of LISA for earthquake disaster vulnerability in Hebei Province, and showed it in the form of layers, as shown in Figure 10. The agglomeration distribution of earthquake disaster vulnerability in Hebei Province is discrete on the whole, with low or low level in most areas and high or high level in a few areas. Red indicates areas with high vulnerability to earthquake disasters, such as Shijiazhuang, which has a high vulnerability to earthquake disasters; Orange indicates areas with low vulnerability to earthquake disasters, such as Xingtai City.

5.2.3 Local G_i^* index method

Because the local LISA statistic compares the similarity of the value of variable X in A region (set as A) with the value of the same variable in the neighborhood. If the value of the study variable in the neighborhood is similar to the value in region A, a positive local LISA autocorrelation is generated. Negative local LISA autocorrelation occurs if the value of the variable X in the neighborhood is significantly different from the value in A, in which case the difference appears as a difference from the mean in different directions. Therefore, this study further uses the G_i^* local index method to determine whether the districts in the study area whose value of variable X is greater than the mean value are concentrated, or whether the districts in the study area whose value of variable X is less than the mean value are concentrated. As shown in Figure 11. There is no obvious agglomeration in most areas of Hebei Province, but a few areas show agglomeration characteristics, such as the hot spots in various districts of Shijiazhuang City, the hot spots in Wanquan District, Qiaoxi District and Qiaodong District of Zhangjiakou City, the hot spots in Fengnan District, Lunan District and Guzhi District of Tangshan City, but the cold spots in Qinglong Manchurian Autonomous County of Qianxi City.

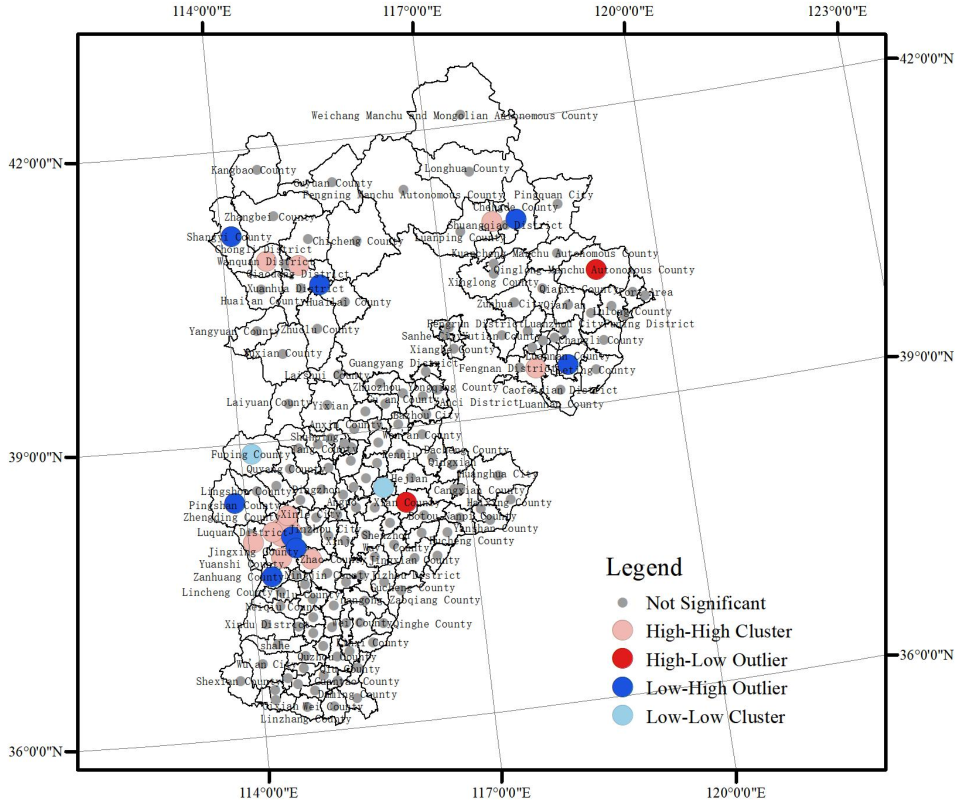

Figure 10: LISA cluster map of earthquake disaster vulnerability in Hebei Province

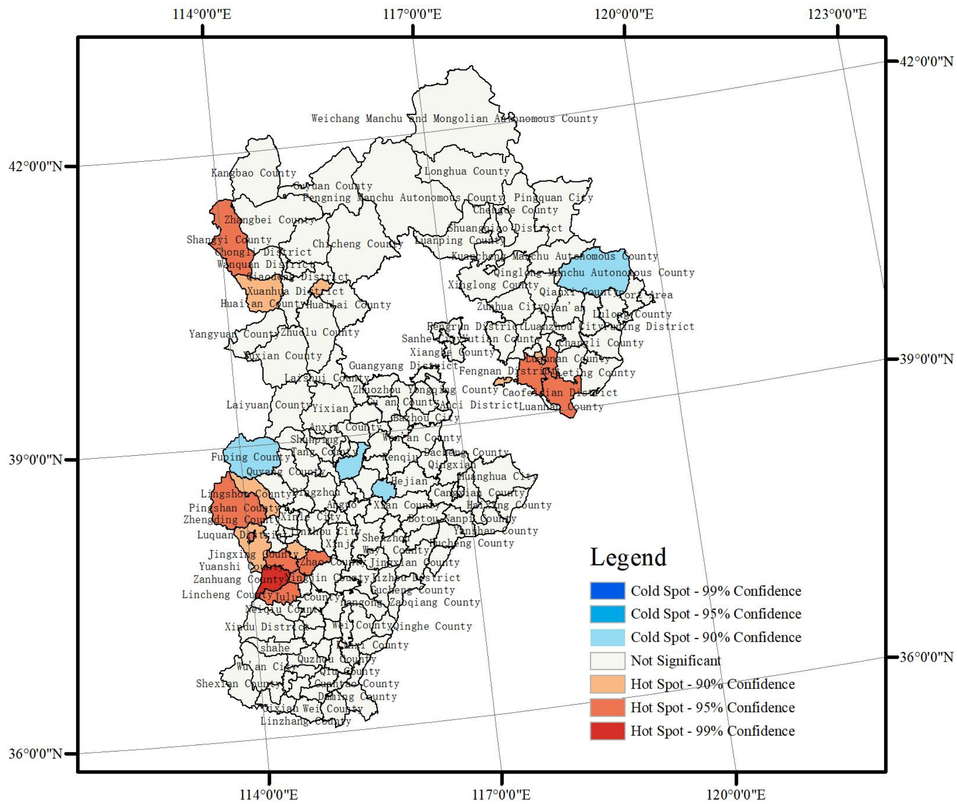

Figure 11: Distribution map of cold hot spots of earthquake disaster vulnerability in Hebei Province

5.3 Cluster analysis of earthquake disaster vulnerability

In order to classify each city in Hebei Province according to earthquake disaster vulnerability, this study uses the method of multivariate analysis - clustering. Cluster analysis was first used by archaeologists in the classification of archaeological objects, and after a long time of development, it has been widely used in biology, climate and other aspects. In this study, three different clustering methods are adopted to analyze the spatial pattern characteristics of earthquake disaster vulnerability in Hebei Province.

5.3.1 k-means clustering

k-means clustering algorithm is a highly respected partitioning clustering method. The algorithm starts from determining the target number k of the cluster and randomly selecting k points as the initial cluster center. The algorithm then calculates the distance from each sample point to each cluster center[20], Euclidean distance is usually used for distance measurement, but other suitable similarity measurement methods can be selected according to the specific situation. Based on these distance calculations, the algorithm classifies each sample point into the category corresponding to the nearest cluster center: After completing the initial classification, the center of each category is updated, usually by calculating the mean of all objects in the category, and then the partitioning and updating steps are repeated until the location of the cluster center becomes stable or the change in the center point is less than a preset threshold, as shown in Figure 12.

5.3.2 K-means ++ clustering

Since k-means clustering is very sensitive to the selection of initial points, improper selection of initial points may lead to serious deviations or errors in clustering results, and it is easy to produce local optimal solutions rather than global optimal solutions. Therefore, an improved algorithm named K-Means ++ is further adopted, and the results are shown in Figure 13.

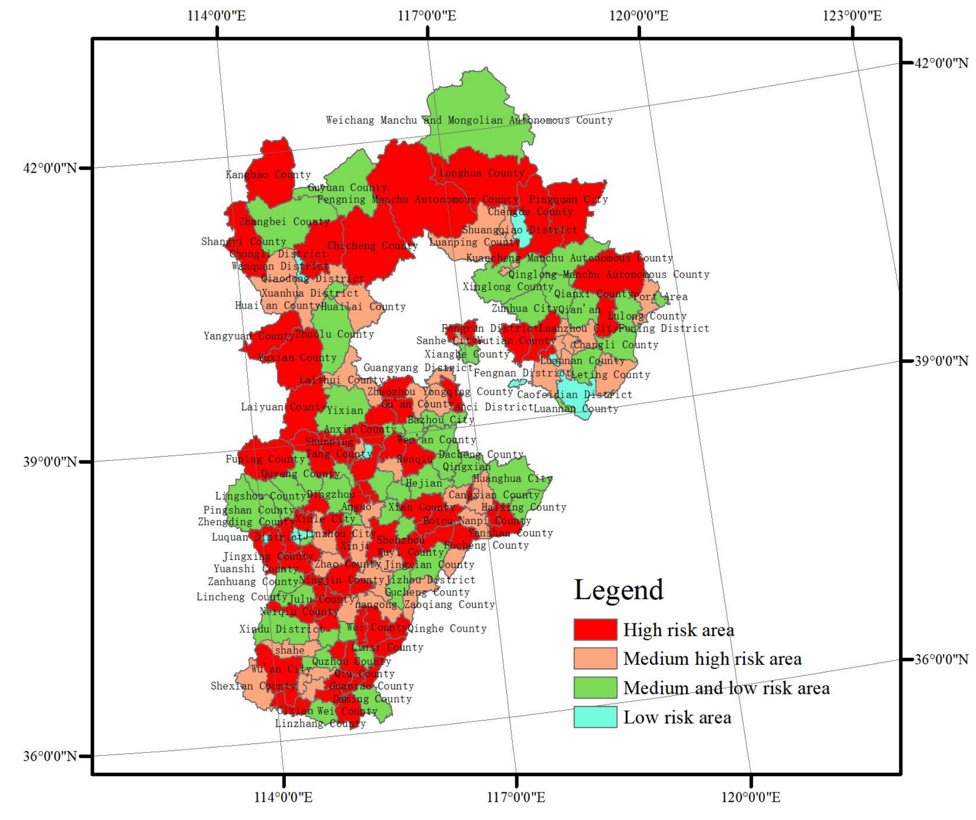

Figure 12: k-means cluster graph

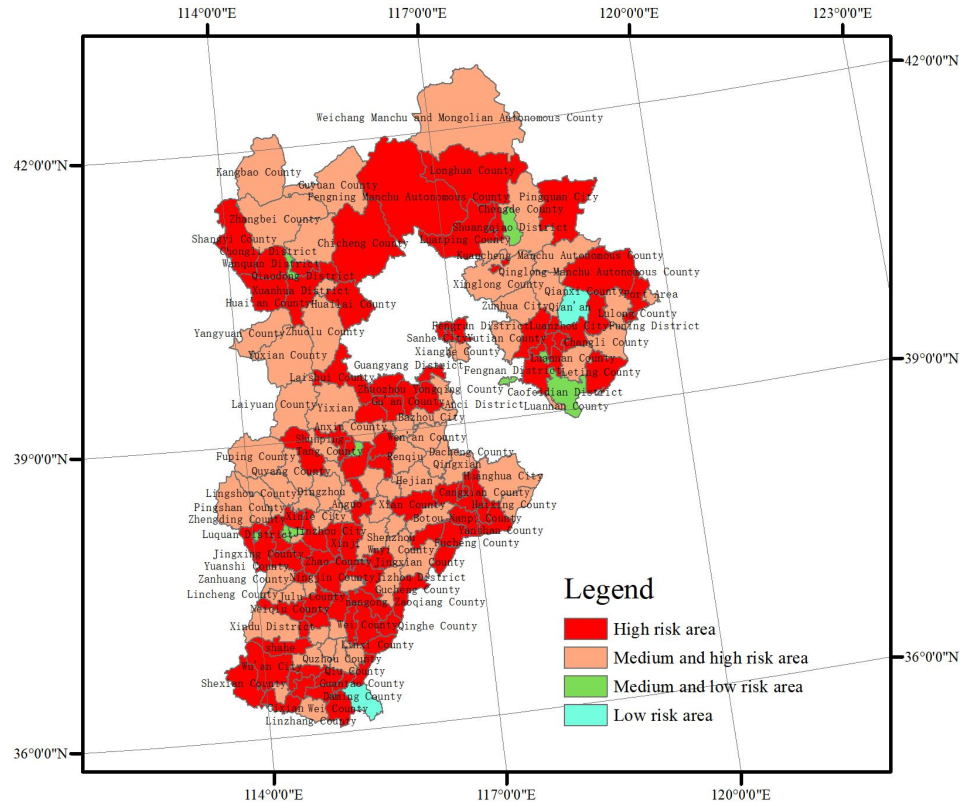

Figure 13: K-means ++ diagram

6. RESULTS AND SUGGESTIONS

The study shows that the area with the greatest vulnerability to earthquake disaster is Shijiazhuang High-tech Zone, which is 0.761. The smallest is Qian 'an City, Tangshan city, 0.243; The overall difference of earthquake disaster vulnerability among cities in Hebei Province is small, but the difference is significant in some areas. In the earthquake disaster vulnerability assessment system, the weight of economic density (positive correlation) is the largest 0.221, and the weight of the number of employees in earthquake preparedness and disaster reduction (negative correlation) is the largest 0.001, and the index weight is different for different decision levels. For disaster prevention and mitigation ability, the number of professional emergency rescue teams has the highest weight (0.142), and for social vulnerability, the weight of health technology practitioners is the highest (0.104). It is not difficult to conclude that for areas with rapid economic development, emergency management departments should pay more attention to the emergency management of earthquake disasters, constantly expand professional emergency management teams, train health technology practitioners, and promote the further development of emergency management system.

At the same time, through the global spatial autocorrelation analysis, it is found that urban earthquake disaster vulnerability in Hebei Province presents obvious spatial autocorrelation. At the same time, the cluster model of urban earthquake disaster vulnerability in Hebei Province is divided into five categories by LISA theory: high, high, medium, low and low, and it is found that the earthquake disaster vulnerability in central and southern Hebei Province is generally low and medium. The eastern and northern areas are higher and high-grade areas, among which the Beijing-Tianjin-Tang Triangle area is the middle grade area. On this basis, the local index method is further used to analyze the cold hot spots, and it is found that a few areas in Hebei Province are hot spots, the whole is not significant, and there are also a few cold spots. The local emergency management department should promote the development of disaster prevention and reduction projects.

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