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Research on social vulnerability evaluation of urban fringe based on street scale—Taking Chang'an district of Xi'an as an example

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Abstract. Vulnerability theory is an important tool for analyzing the degree, mechanism and process of human-land interaction, and provides a new perspective for sustainability assessment research. The interference factor of this study is rapid urbanization, and the entry point is the street space scale. Taking the northwestern part of Chang'an District of Xi'an as an example, the social vulnerability assessment index suitable for the study area is selected, and the social vulnerability theoretical framework and the index evaluation method are combined. The RS/GIS spatial statistical analysis method analyzes the social vulnerability assessment and its influencing factors of the street units in the study area. The research results show that: (1) The spatial distribution of social vulnerability is unbalanced and the contradiction between human and land is prominent. The spatial unit is highly correlated with the system in which it is located. (2) Changes in land use patterns and landscape fragmentation are the direct causes of the vulnerability of social systems in urban fringe areas, while the social system transition and urbanization in urban fringe areas are dislocated to aggravate the negative impact of urbanization.

1. The introduction
In recent years, the area of urban built-up areas in China has increased year by year, the urban fringe area is the main area of urban spatial growth with outstanding instability and sensitivity characteristics[1]. At the same time, a series of social ecological and environmental problems have been formed due to population explosion and polarization of social forms [2]. Residents in the fringe area are also unable to enjoy the social security system they deserve. In short, rapid urbanization has made urban fringe areas a spatial entity with more prominent social contradictions. Therefore, it is of great significance to evaluate the social vulnerability of urban fringe areas for formulating adaptive countermeasures.

Early research in the field of vulnerability focused primarily on natural disasters[3]. In recent years, scholars' research focus has gradually changed from the vulnerability of natural systems to the focus on people and society, and the positive coping ability of people and society as the core issue of vulnerability evaluation[4-5]. Foreign scholars' research results mainly focus on the conceptual framework of social vulnerability, time and space evolution, assessment and influencing factors[6-7], spatiotemporal evolution of social vulnerability[8], governance of social vulnerability[9]. In contrast, China's research results on social vulnerability are mainly based on the...
background of resource decline and natural disasters [10-12], the assessment of social vulnerability and the analysis of influencing factors [13-15].

In summary, current scholars have already had richer results in the study of social vulnerability, but there are few studies on the space of human activities, especially for the smallest spatial units such as streets and neighborhoods, it is necessary to study the urban social vulnerability of small-scale streets. This study takes the impact of rapid urbanization on the structure of the social system as an entry point. Taking the northwestern part of Chang’an District as an example to select the social vulnerability assessment index of the appropriate research area, and then using the social vulnerability theoretical framework and index evaluation method, combined with RS/GIS spatial statistical analysis method evaluates the social vulnerability assessment of the street unit scale in the study area, and analyzes its social vulnerability from the perspective of spatial differentiation, aiming to provide practical theoretical basis and reference for its sustainable development.

2. Conceptual Connotation and Evaluation Framework of Social Vulnerability

2.1 The concept of social vulnerability
Based on the definition of scholars at home and abroad, this paper argues that social vulnerability is a social system that is susceptible to internal and external factors [16-17]. It lacks the ability to cope with unfavorable disturbances and easily puts the system itself at risk.

![Figure 1: framework of social vulnerability assessment in urban fringe areas](image)

2.2 Social vulnerability assessment framework
In the analysis of social vulnerability, exposure, sensitivity and resilience are considered as exponential functions, and rapid urbanization is a key disturbance factor in their social systems (18). Through the vulnerability assessment framework, the degree of urbanization affected by urbanization is analyzed (Figure 1). The social vulnerability of each street scale space unit is evaluated so as to the urban fringe area in the northwest of Chang’an District.

3. Overview of the research area and research methods

3.1 Overview of the research area
Chang'an district is located in the hinterland of Guanzhong plain, the process of urbanization is accelerating. The 25 streets in Chang'an District are affected differently in the process of urbanization.
This paper uses the fuzzy comprehensive judgment method to identify the marginal zone of Chang'an District. The proportion of urban land use, proportion of arable land use and landscape fragmentation of each street are reclassified by the natural fracture method in GIS spatial analysis method for superposition analysis. Determining the scope of the study area: Ziwu street, Guodu street, Doumen street, Weiqu street, Luanzhen street, Wangsi street, Xinglong street, Huangliang street, Duqu street, Wangqu street, Dazhao street, Yanzhen street and Paonli street are 13 streets in total.

3.2 Social vulnerability evaluation index system

The evaluation index construction index system is selected from three aspects: exposure, sensitivity and adaptability. Combined with the framework of the evaluation of social vulnerability in urban fringe areas and the available data, a total of 17 evaluation indicators were selected to establish a comprehensive evaluation index system, estimation of the vulnerability of social systems in the urban fringe of the northwestern part of Chang'an District.

| Rule layer | Index layer | The data source | Index properties | Indicator description |
|------------|-------------|-----------------|-----------------|-----------------------|
| Exp-su -   | B1 The distance from the city center (km) | Measured by arcgis | - | Reflect the proximity of space |
|             | B2 Shannon diversity index | Calculated by fragstats4.2 | + | Reflect the heterogeneity of landscape |
|             | B3 Patch density (a/km²) | Same as above | + | Reflects the comparison of different sizes of landscape in unit area |
|             | B4 Landscape fragmentation index | Same as above | + | Reflect the degree of human interference with |
B5 Proportion of construction land area (\%) 
Remote sensing image compilation (Xi’an Chang’an district statistical yearbook 2016) + Reflect the level of urban development 

M1 Proportion of agricultural population (%) 
Same as above + Reflect the sensitive state of population structure 

M2 Gross output value of primary industry (Ten thousand yuan) 
Same as above + Reflect the sensitive state of landuse 

S1 Industry above designated size (Mu/person) 
Same as above + Reflect the state of economic development 

S2 Wholesale and retail above designated size (Ten thousand yuan) 
Same as above + Reflect the living consumption condition 

S3 Qualified construction industry (a) 
Same as above + Reflect the state of urban construction 

S4 Service industry above designated size (a) 
Same as above + Reflect the state of economic development 

S5 The proportion of non-agricultural industry population (%) 
Same as above + Reflect the diversity of employment of local villagers 

S6 The proportion of junior high school or higher education population (%) 
Xi’an “sixth population census” data + Reflect the population affected by education level 

S7 The proportion of illiterate population (%) 
Same as above - Reflect the population affected by education level 

S8 The proportion of households with more than seven persons (%) 
Same as above - Reflect the size of family economic pressure 

3.3 Determination of the weight of evaluation indicators 

3.3.1 Data source and standardization The data in this paper are mainly composed of two parts, namely, socio-economic statistics data, RS and GIS remote sensing image data. The socio-economic data were standardized, and the normalized dimensionless values of exposure, sensitivity and adaptability indexes were obtained by the range standardization method. The specific formula is as follows:

Positive indicator: \[ Y_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} \] (1)

Negative indicator: \[ Y_{ij} = \frac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}} \] (2)

Where \( i = 1, 2, 3, \ldots, n \), \( j = 1, 2, 3, \ldots, m \), \( Y_{ij}, x_{ij}, x_{j\max}, x_{j\min} \) respectively refer to the normalized value, initial value, maximum and minimum of the \( J-th \) index of the \( I-th \) level.

3.3.2 Determining indicator weights After standardizing the original data, the data is translated and then the calculation of the index weights is mainly divided into the following steps: Calculate the value of the \( J-th \) indicator in the \( i-th \) study of the street space unit:

\[ P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \] (3)

Calculate the entropy of the \( J-th \) indicator \( e_j \):

\[ e_j = -k \sum_{i=1}^{n} P_{ij} \log(P_{ij}) \] (4)

Where \( k > 0 \), \( ln \) is the natural logarithm, let \( k = \frac{1}{\ln m} \), and the constant \( k \) is related to the number of research units \( m \).
Calculate the difference coefficient of the J-th index $g_j$:

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

Calculate the weight of the J-th index $w_j$

$$w_j = \frac{\sum_{j=1}^{m} g_j}{\sum_{i=1}^{n} g_j}, j = 1, 2, \ldots, m$$ \hfill (6)

3.4 Social vulnerability assessment model

Exposure and sensitivity are positively correlated with social vulnerability. The higher the exposure or sensitivity, the higher the vulnerability and the lower the adaptability. Using the social vulnerability index to calculate the vulnerability of the marginal zone is expressed as:

$$V = (E + S) - A$$ \hfill (7)

Where: $V$, $E$, $S$, and $A$ represent vulnerability, exposure, sensitivity, and adaptability, respectively. Among them, $E$, $S$, and $A$ are respectively obtained by the following formula weighted summation method. Taking exposure as an example:

$$E = \sum_{i=1}^{5} W_{ej} Y_{ej}$$ \hfill (8)

Where: $E$ represents the exposure index, The value range is distributed in $(0, 1)$; $W_{ej}$ is the exposure index weight; $Y_{ej}$ is the standardized value of the exposure index.

4. Social vulnerability assessment results

Substituting the processed data into the publicity (7) to calculate the exposure, sensitivity index and adaptability index of each street space unit in Chang'an District. The public vulnerability (9) will be used to calculate the 2015 Social Security Index of Chang'an District (Table 2). The arcgis10.2 software was used to visualize the indicators spatially, and the spatial differentiation pattern of exposure, sensitivity, adaptability, and social vulnerability in Chang'an District was obtained.

| The street | exposure | resilience | sensitivity | sensitivity |
|------------|----------|------------|-------------|-------------|
| Weiqu      | 3.185    | 12.327     | 1.845       | 0.476       |
| Guodu      | 3.114    | 11.437     | 1.806       | 0.445       |
| Luanzhen   | 2.356    | 8.183      | 2.955       | 0.851       |
| Yinzhen    | 2.283    | 8.578      | 2.818       | 0.750       |
| Wangsi     | 2.822    | 9.751      | 1.984       | 0.633       |
| Doumen     | 2.544    | 9.037      | 2.768       | 0.779       |
| Ziwu       | 2.575    | 8.952      | 2.366       | 0.680       |
| Xinglong   | 2.425    | 8.360      | 2.635       | 0.764       |
| Dazhao     | 2.400    | 8.807      | 2.951       | 0.804       |
| Duqu       | 2.434    | 8.955      | 2.972       | 0.807       |
| Paoli      | 2.361    | 7.992      | 2.890       | 0.853       |
| Wangqu     | 2.290    | 8.199      | 2.552       | 0.713       |
| Huangliang | 2.488    | 8.176      | 2.677       | 0.814       |
4.1 Spatial distribution of social vulnerability in the study area

4.1.1 Exposure It can be seen from Figure 5 that the exposure of Chang'an District is high in the northwest and low in the southeast with obvious aggregation characteristics. The high-level exposure space unit mainly includes 2 streets of Guodu and Weiqu. These two streets are close to the core area of the city, the landscape has a high degree of fragmentation. The medium-level exposure space units are mainly distributed in Wangsi Street, Doumen Street and Ziwu Street. Among them, Wangsi and Doumen Street units are close to Fengdong New City and the city center. Ziwu Street is rich in tourism resources, the economic development speed is relatively fast; The low-level exposure space units are concentrated in the outer edge areas of the towns such as Qizhen Street Unit. The main reason is that the outer edge area is far from the city center and the mode of utilization is mainly based on agriculture, and the expansion of urban space is relatively slow.

4.1.2 Sensitivity From the spatial distribution of sensitivity index (Figure. 6), it can be seen that the distribution of low-sensitivity and medium-sensitivity street units is relatively gathered and the distribution of high-level sensitivity is relatively scattered. The middle-level streets are mainly distributed between high-level and low-level spatial units. The spatial units of high sensitivity have a wide distribution range and are relatively dispersed. However, the outer edge of the city is still in the rural system, and the rural nature is relatively significant. It is more sensitive and responsive to the pressure brought by urbanization.

4.1.3 Adaptability It can be seen from the spatial distribution of adaptive capacity (Figure. 7) that the distribution of high-level adaptive capacity spatial units is mainly in Guodu Street and Weiqu Street; the low-level adaptive capacity spatial units are mainly distributed in the central and southern areas. The middle class streets of adaptability are scattered and embedded in the high and low class streets, and the spatial distribution regularity is not strong. However, in the field investigation, it was found that the streets with relatively high adaptability, such as Guodu Street and Weiqu Street, were transformed from the rural system to the urban system relatively early, and the process of urbanization was almost freed from the urban-rural dualization system; Street towns far from the urban core area are still in the process of transition and adaptation due to the late development, and some towns and streets are still in the rural system, unable to cope with the interference of urbanization, and have low adaptability and transformation ability.

4.1.4 Social vulnerability As can be seen from figure 8, Chang'an district has 2 high-class social vulnerability streets, 9 middle-class streets and 2 low-class streets, and the spatial distribution of social vulnerability is unbalanced. The eight streets close to the high-tech industrial zone belong to the spatial units of vulnerability of high-level society; Guodu and Weiqu, which are closer to the city center, are low-level social fragility spaces, and middle-level streets are scattered around high-grade streets. From the spatial distribution of social vulnerability, by synthesizing the common components of the three dimensions, the middle and low grade vulnerable streets are distributed in a concentrated way and the high grade streets are distributed in a scattered way.
4.2 Influencing factors of social vulnerability

4.2.1 Change of landscape pattern of land use The change of land use pattern and the change of landscape fragmentation are the most direct manifestation of urban fringe interference, and also the direct influence factor of social vulnerability[18]. The continuous loss of agricultural land has become the most intuitive landscape change in urban fringe areas. The replacement of agricultural land by urban construction land makes the urban fringe landscape in a dynamic process of continuous fragmentation, and the whole system is very unstable.

4.2.2 Land space transformation and social system transformation are dislocated Compared with the social system, the transformation of land space is relatively rapid, resulting in a large number of social conflicts. Most of the street units are dominated by rural system, and the transformation of social system is out of step with the urbanization process to a certain extent. The social system is extremely unstable throughout the process.

4.2.3 Unfair distribution of social resources The imperfection of social and political systems leads to the unfair distribution of interests in urban fringe areas. After being disturbed by urbanization, each street space unit began to play a self-organizing function, adjusting the internal structure and function of the social system to adapt to its negative impact. The different ability of self-organization leads to the different ability of streets to adapt to disturbances.
5. Conclusion and discussion

Taking the social fragility of urban fringe as the starting point, this paper uses various landscape indicators, spatial analysis and statistical analysis techniques to describe the spatial layout of urban whole and urban fringe, and conducts in-depth research on its influencing factors, and draws the following conclusion:

(1) The exposed spatial distribution of the study area is high in the northwest and low in the southeast with obvious aggregation characteristics. The distribution of low sensitivity and middle sensitivity street units is relatively concentrated and the distribution of high sensitivity is relatively dispersed. The distribution of high and low grade adaptive spatial units is relatively concentrated; The spatial units of middle level adaptability are distributed in a scattered way.

(2) The spatial distribution of social vulnerability of each street spatial unit in Chang 'an district is unbalanced. The spatial location of units with prominent contradiction between human and land relationship is highly consistent with the center of urban social and economic activities.

(3) The change of land use pattern and landscape pattern is the direct cause of the instability and fragility of the social system in urban fringe areas. Urban fringe areas should adapt to the disturbance of urbanization by optimizing the internal structure and functions of the system.

In the future, rapid urbanization will still promote the development of urban fringe areas. Therefore, urban fringe areas should reduce the negative impact of urbanization and other disturbance factors by improving adaptability and establish corresponding policies to improve the adaptability of urban fringe areas on the basis of reducing exposure. The following measures should be taken to deal with the risk of social vulnerability within urban fringe areas: Reduce exposure, avoid urbanization caused by urban disorderly expansion, and pay more attention to the reduction of social vulnerability of rural communities, taking targeted measures to reduce the sensitivity of urban and rural street communities, so as to improve the adaptability of street communities and promote the sustainable development of marginal areas.

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