

# Establishment and Application of City Safety Assessment Model Based on Risk Matrix

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**Abstract:** Urban safety is a common concern in the world, and it is important to evaluate the safety of cities. Based on the existing research results and China's national conditions, this paper establishes an urban safety evaluation model based on "risk matrix" and verifies the scientific validity of the model by using examples. This paper provides a reference for future urban safety management.

**Keywords:** Urban safety; comprehensive evaluation; risk matrix; entropy weight method

## 1. Introduction

Urban safety is the basis for the safety of life and property of urban residents, and it is also the basic guarantee for the normal conduct of various production activities. Many scholars at home and abroad are devoted to the study of urban safety, and the existing studies mainly explore the connotation of urban safety from the perspectives of disaster science [1], sociology, and economics; establish the assessment system from the perspectives of sustainability, "pressure" and "response", and so on; improve the assessment methods by using geographic information systems and game theory. The implementation of various research results requires government supervision and implementation, and the government is the first person in charge of urban safety. This paper draws on the existing research results to objectively analyze various risk factors in the process of urban operation from the perspective of government supervision, so as to establish a scientific and reasonable evaluation system model of urban safety indicators; quantitative assessment of urban safety risks, so as to propose targeted risk management measures to effectively improve the safety of cities

## 2. City Safety Assessment Model

### 2.1. Expanded Application of Risk Matrix

The risk matrix is not only a common risk assessment method but also an effective risk management tool, as it can assess the potential impact of systemic risks and combine qualitative and quantitative analysis. The risk matrix can be defined as:  $\text{risk} = \text{severity} \times \text{vulnerability}$ . The traditional risk matrix model is extended to derive an urban safety evaluation model, in which the severity of urban safety risk is described by natural disasters, man-made accidents, public health, and social security; the vulnerability of urban safety risk is influenced by the disaster-bearing capacity and resilience [2].

### 2.2. Indicator System

According to the principles of establishing the index system [3] and the existing research results, the urban safety evaluation index system is established. Specifically, this system takes the safe city as the overall goal, and the two dimensions of severity and vulnerability are used as the system layer to select the first-level indicators respectively. Severity includes four secondary indicators of natural disasters, man-made accidents, public health events, and social security events and the corresponding 12 tertiary indicators; vulnerability includes two secondary indicators of carrying capacity and disaster resilience and the corresponding 16 tertiary indicators. The specific selection can be seen in Table 1.

Table 1 Selection of Indicators

| Goal Level  | System Level                                     | Primary Indicator                                | Secondary Indicator  | Unit                  |
|-------------|--|--|--|-----------------------|
| CITY SAFETY | Seriousness                                      | Natural Disasters                                | Natural disaster affected population                                       | 10,000 people         |
|             |  |  | Direct economic losses from natural disasters                              | 100 million yuan      |
|             |  | Man-made accidents                               | Mining and industrial enterprise production safety accident mortality rate | person/100,000 people |
|             |  |  | Number of road traffic accidents   | case                  |
|             |  |  | Number of deaths from road traffic accidents                               | person                |
|             |  |  | Number of fires  | case                  |
|             |  |  | Number of deaths from fires  | person                |
|             |  |  | Direct economic losses from fires  | 10000 yuan            |
|             |  | Public Health                                    | Incidence rate of Class A and B infectious diseases                        | 1/100,000             |
|             |  |  | Pass rate of key food safety monitoring and sampling                       | %                     |
|             |  | Social Security                                  | Number of criminal cases filed   | case                  |
|             |  |  | Number of criminal cases solved  | case                  |
|             |  | Vulnerability                                    | Disaster-bearing capacity  | Population density    |
|             | Length of water supply pipelines                 |  |  | km                    |
|             | Urban gas coverage rate                          |  |  | %                     |
|             | Average daily power generation                   |  |  | 10,000 kWh            |
|             | Urban road area                                  |  |  | 10,000 m <sup>2</sup> |
|             | Urban green coverage rate                        |  |  | %                     |
|             | Urban sewage treatment rate                      |  |  | %                     |
|             | Industrial solid waste generation                |  |  | 10,000 tons           |
|             | Per capita GDP                                   |  |  | yuan/person           |
|             | Per capita disposable income of residents        |  |  | yuan/person           |
|             | Number of participants in unemployment insurance |  | person   |                       |
|             | Disaster Resilience                              |  | Number of healthcare institutions  | unit                  |
|             |  |  | Number of hospital beds  | 10,000 beds           |
|             |  |  | Number of healthcare professionals   | person                |
|             |  |  | Cumulative number of earthquake emergency shelters                         | unit                  |
|             |  | Cumulative area of earthquake emergency shelters | 10,000 m <sup>2</sup>  |                       |

### 2.3. Calculation of the security index

Comparing various types of weight calculation methods, the entropy weight method was selected to calculate the weights of each index. This method is sensitive to differences in indicators and is suitable for evaluation of small samples [4]. The final urban safety index is calculated using the weighted composite scoring method commonly used in multiple indicator evaluation:

- (1) Evaluate m years of data of cities with n evaluation indicators and construct a judgment matrix

$$X = (x_{ij})_{m \times n} \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n) \quad (1)$$

- (2) Calculating information entropy

$$H_j = -k \sum_{i=1}^m p_{ij} \ln p_{ij} \quad \text{among them, } p_{ij} = z_{ij} / \sum_{i=1}^m z_{ij}; \quad k = 1 / \ln m \quad (2)$$

- (3) Calculate indicator weights

$$\omega_j = \frac{1 - H_j}{\sum_{j=1}^n (1 - H_j)} \quad \text{among them, } \omega_j \in [0,1], \sum_{j=1}^n \omega_j = 1 \quad (3)$$

After calculating the weights of each indicator using the entropy weighting method, the urban safety index was evaluated based on the weighted composite score method common in multiple indicator evaluations (4).

$$A_i = \sum_j \omega_j Z_{ij} \quad (4)$$

### 3. Application of Urban Safety Assessment Model

In this paper, City A is selected for the case study, and the data of each indicator in City A from 2012 to 2021 are collected by consulting the statistical yearbook and other channels, and the weights of indicators at all levels can be obtained by using the entropy weighting method, among which the results of the weights of primary indicators are shown in the following table 2.

*Table 2 The results of the weights of primary indicators*

| Primary Indicator | Natural Disasters | Man-made accidents | Public Health | Social Security | Disaster-bearing capacity | Disaster Resilience |
|-------------------|-------------------|--------------------|---------------|-----------------|---------------------------|---------------------|
| Weights           | 0.0315            | 0.1836             | 0.0811        | 0.0751          | 0.4323                    | 0.1964              |

The comprehensive safety index of each year is calculated according to the constructed urban safety evaluation model in Table 3, and the safety index of each component is shown in Table 4 and the corresponding change trends in Figures 1 and Figures 2.

*Table 3 Combined safety index by year*

|      | Comprehensive Safety Index | Severity index | Vulnerability index |
|------|----------------------------|----------------|---------------------|
| 2012 | 33.8                       | 20.4           | 13.4                |
| 2013 | 37.0                       | 21.4           | 15.6                |
| 2014 | 37.4                       | 20.4           | 17.1                |
| 2015 | 46.3                       | 23.2           | 23.1                |
| 2016 | 36.5                       | 12.3           | 24.2                |
| 2017 | 45.1                       | 16.0           | 29.1                |
| 2018 | 57.0                       | 20.6           | 36.3                |
| 2019 | 63.8                       | 22.8           | 41.0                |
| 2020 | 65.6                       | 22.3           | 43.4                |
| 2021 | 61.0                       | 14.9           | 46.0                |

*Table 4 Safety index by component*

|      | Natural Disasters | Man-made accidents | Public Health | Social Security | Disaster Bearing Capacity | Disaster Resilience |
|------|-------------------|--------------------|---------------|-----------------|---------------------------|---------------------|
| 2012 | 0.0003            | 15.7336            | 0.0008        | 4.6681          | 13.4156                   | 0.0020              |
| 2013 | 2.7766            | 11.3998            | 1.3261        | 5.8932          | 13.5640                   | 2.0853              |
| 2014 | 2.5346            | 10.4072            | 1.0877        | 6.3435          | 13.5099                   | 3.5451              |
| 2015 | 3.0789            | 13.3076            | 1.8485        | 4.9295          | 13.9541                   | 9.1622              |
| 2016 | 2.6058            | 5.8871             | 2.7524        | 1.0331          | 16.5193                   | 7.7122              |
| 2017 | 3.0990            | 6.0294             | 5.5776        | 1.2794          | 18.8153                   | 10.2886             |
| 2018 | 2.7450            | 11.6559            | 3.8651        | 2.3704          | 22.8313                   | 13.5143             |
| 2019 | 3.0283            | 12.3835            | 4.3851        | 3.0419          | 25.8026                   | 15.1625             |
| 2020 | 3.1431            | 10.2971            | 5.8702        | 2.9492          | 28.2702                   | 15.0992             |
| 2021 | 2.8872            | 4.3179             | 4.8715        | 2.8430          | 27.0012                   | 19.0318             |

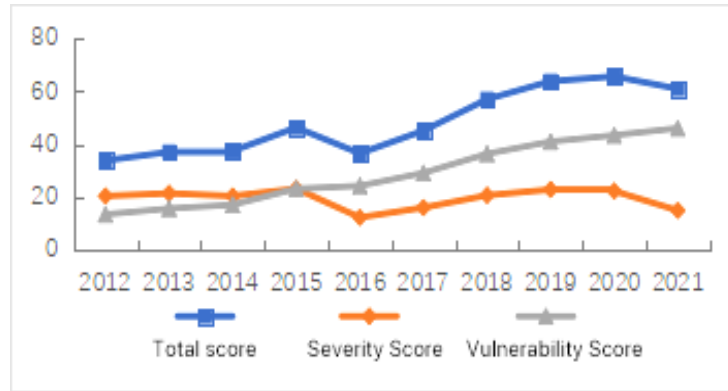


Figure 1 Trend chart of the 10-year safety index scores

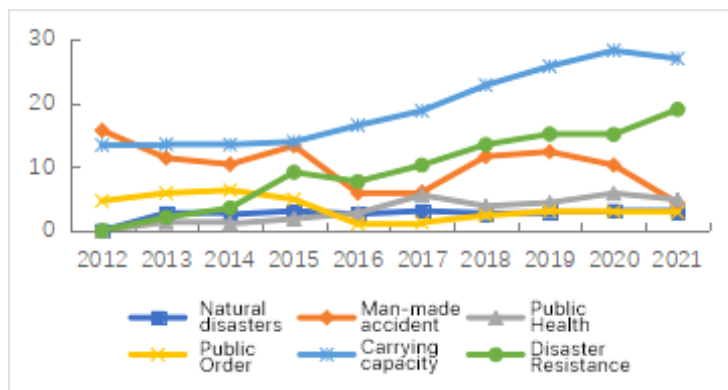


Figure 2 Trend of the safety index of each part over the past 10 years

#### 4. Analysis

As a whole, this article assesses the safety situation of City A and proposes a model and index system for evaluating the safety of the city based on several factors. The model is based on the actual historical situation of the city and reflects the safety situation of City A in a reasonable and scientific way. The evaluation results of the model show that the factors affecting the safety of City A are, in order, disaster-bearing capacity, disaster-resisting capacity, man-made accidents, public safety, social security, and natural disasters. All of these factors have an important impact on the safety level of the city, and therefore need to be paid attention to in the city safety management. Among them, disaster-bearing capacity and disaster-resistance capacity are very important factors because City A is located in a natural disaster-prone area and needs to have the ability to deal with natural disasters. Human accidents, public safety and social security are directly related to the safety of citizens' lives and properties, and have an important impact on the safety level of the city[5]. Therefore, in order to improve the safety of cities, it is necessary to start from several aspects, including strengthening the city's disaster prevention, mitigation and emergency management capabilities, improving emergency rescue and recovery and reconstruction capabilities, enhancing the prevention and management of man-made accidents, strengthening public safety and security, and maintaining social security. Only by improving the capacity and level of these aspects in an integrated manner can we effectively improve the safety level of City A and allow citizens to live and work in peace and happiness[6].

#### 5. Conclusion

This article aims to explore the issue of urban safety evaluation, establish a "risk matrix" based urban safety evaluation model, and provide an example to verify its scientificity. By drawing on existing research results and practicing based on China's national conditions, this article establishes a comprehensive, scientific[7], and operable urban safety evaluation index system. The system uses the risk matrix method to assess urban safety risks and proposes corresponding risk management measures, providing important references for urban safety management. The research results of this article are not only of great significance for government supervision of urban safety but also can provide similar

evaluation models and methods for other fields to improve the overall level of security in society.

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