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RISK MATRIX IN ACTION: BUILDING SAFER CITIES THROUGH HOLISTIC URBAN SAFETY MODELS

Hong Fei Wang

Shenyang Jianzhu University, Shenyang, China

Abstract: Urban safety serves as the cornerstone for safeguarding the well-being and assets of urban residents, as well as the fundamental prerequisite for the smooth execution of various productive endeavors. Extensive scholarly efforts, both domestically and internationally, have been dedicated to the exploration of urban safety. Existing studies have primarily delved into the facets of urban safety's essence through the lenses of disaster science, sociology, and economics. Furthermore, they have established evaluation frameworks based on sustainability, "pressure," and "response." Innovations in assessment methodologies, incorporating geographic information systems and game theory, have aimed to enhance our understanding of urban safety. Nonetheless, the practical realization of these research findings necessitates government oversight and execution. The government assumes a pivotal role as the foremost steward of urban safety. This paper, drawing inspiration from prior research, undertakes an objective analysis of various risk factors inherent in urban operations, scrutinized through the lens of government supervision. In doing so, it seeks to construct a scientifically sound and rational assessment system model for urban safety indicators. Furthermore, it quantitatively assesses the risks associated with urban safety. This quantitative approach empowers us to propose targeted risk management strategies, thereby effectively enhancing the safety and security of our cities. This research thus presents a comprehensive and actionable framework for advancing urban safety in the modern urban landscape.

Keywords: Urban Safety, Risk Assessment, Government Supervision, Safety Indicators, Risk Management

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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: risk = severity × 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 1.3

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	person/100,000 people

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			rate	
			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	person/km²
			Length of water supply pipelines	km
			Urban gas coverage rate	%
			Average daily power generation	10,000 kWh
			Urban road area	10,000 m²
			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 m²

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

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

(1) (2) Calculating information entropy

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

(3) Calculate indicator weights 3

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

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).

$$A_i = \sum_{j}^{n}\omega_j Z_{ij} \qquad (4)$$

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

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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

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

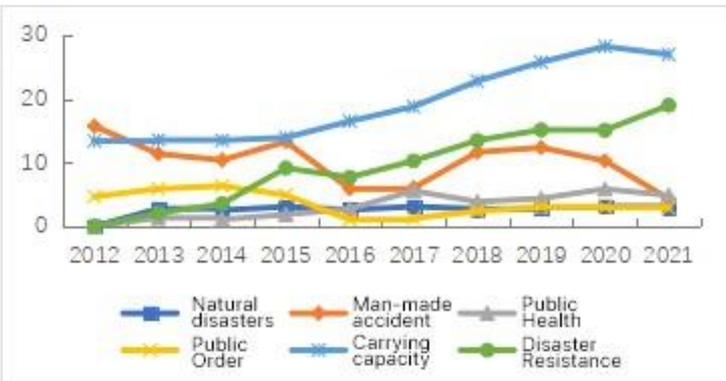

Figure 2 Trend of the safety index of each part over the past 10 years

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].

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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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