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Urban Risk Assessment Research of Major Natural Disasters in China*

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Abstract: According to disaster system theory and the natural disaster database of China, this paper builds the urban vulnerability index on the basis of the integrated urbanization level index (CL) of hazard-affected bodies; and considering the structural damage and the influence on traffic of different natural disasters, this paper chooses five major disaster types (including flood, earthquake, debris flow-rock slide, typhoon and dust storm) to build and compute the integrated intensity index of major natural hazards (QC). Then through qualitative analysis and semi-quantitative calculation, the integrated urban risk of major natural disasters in china is divided into five grades, namely very high, high, medium, low and very low grades, and the corresponding assessment map is worked out. At last, some further discussion is done about the integrated risk assessment of natural disaster chains.

Key words: Integrated urbanization level; Vulnerability of natural disasters; Integrated intensity of natural hazards; Integrated risk assessment of natural disasters

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1 Introduction

Since the opening-up and reform, China has been undergoing a rapid urbanization process with the rapid economic development. The urbanization level increased by 23.7% during the past 26 years, from 18% of 1978 to 41.7% of 2004[1]. In the "Urban Development Report of China", it says that the Chinese urbanization level will reach about 75% at the end of the 2050s. This means that there would be 10~12 million rural population per year transferred to the cities in the future[2]. Nowadays, the urban population and wealth is highly centralized in the cities and the city development depends more and more on the infrastructure systems such as traffic, water, electricity systems and so on, which makes the city risk of all kinds of hazards more and more serious. Furthermore, most of the Chinese cities are located in the high-frequency districts of hazards, and 60% of the cities haven't reached the national flood control standard[3]; Among the big cities of

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over 500 000 population, there are 54% lying in the high earthquake intensity (higher than Ⅶ) districts[4]. So it's necessary and urgent to do integrated urban risk assessment of natural disasters, which is not only a basic procedure of integrated urban disaster risk management but also a common requirement of city disaster prevention and sustainable development.

Natural disaster risk assessment is defined as the estimate and assessment of the future possible hazard intensity and losses, through risk analysis method or appearance observation method[5], namely considering the hazard intensity and the vulnerability of hazard-affected bodies to estimate the possible disaster losses; While the classification of natural disaster risk means that the disaster risk is divided into different grades in terms of the regional hazard characteristics and considering regional disaster resistance ability and socio-economic condition. Lerner-Lam *et al*. [6] have done multi-hazard risk assessment research and accomplished the world risk map of major disasters. Many Chinese scholars have also done some useful research on natural disaster risk assessment. For example, Liu Xilin[7] discussed about the algorithm of "Risk = Hazard Vulnerability" in detail and assessed the rock slide risk of the Liangshan county in Sichuan province of China; Ding Yan[8] built a fuzzy risk assessment model of typhoon hazard and assessed the typhoon risk of the 14 cities of Guangdong province of China. Then we can conclude that most present risk assessment work is done to assess a single disaster's risk, which is not the real integrated natural disaster risk assessment. On the basis of the urban natural disaster regionalization of China[9], this paper aims at classifying integrated urban natural disaster risk and dividing the high-risk areas, to provide scientific information and technical support for government emergency management, community security construction and enterprise insurance, which will be beneficial for the urban disaster reduction and sustainable development decision-making.

Table 1 Data sources of integrated urban natural disaster risk assessment in China

Database Name	Data Type	Source	Period	Range	Information Characteristics
Database of Natural Hazards in China	Attribute	Series Maps of Natural Hazards in China (Scale: 1: 4 000 000)	Average value of 1949-1990	Countrywide Except Taiwan, Hong Kong and Macao	County-based information includes hazard types, coverage area index, relative intensity, and integrated index of natural hazards, etc.
Reports Database of Natural Disasters in China		Chinese Provincial Newspapers Reports	Yearly value of 1949-2000	Countrywide	County-based information includes disaster description, lasting time, ending time, intensity, disaster effect and newspaper name, etc.
Database of Disaster Reduction in China		Monthly Records of Disasters on Disaster Reduction in China	Yearly value of 1949-2000	Countrywide Except Taiwan, Hong Kong and Macao	County-based information includes event's starting time, ending time, type, intensity and disaster effect
Database of Natural Disaster Effects in China		Ministry of Civil Affairs	1998	Some Provinces (data is lacked in Tianjin, Liaoning, Shanghai, Sichuan, Shanxi, Xizang, Xinjiang, Taiwan, Hong Kong, Macao)	County-based information includes affected area by natural disasters, disastrous area, building collapsed, food production reduction, livestock death, direct economic loss, relief finance, relief resources etc.
Socioeconomic Database in China		Chinese Provincial Statistic Annuals	2000	Countrywide Except Taiwan, Hong Kong and Macao	County-based information includes over 20 indexes with complete data
Urban Socioeconomic Database in China		Chinese Urban Statistic Annual	2000	663 Cities of China	County-based information includes total population, non-agricultural population, whole area, built-up region area, etc.
Administrative Map Database in China	Spacial data	Related Publications of Sino Maps Press in China	1993 2000	Countrywide	Information includes country boundary, province boundary, district boundary, county boundary, provincial capitals, cities, main rivers and lakes, etc.

2 Data Source

Data source and quality is one of the key points to ensure the precision and objectivity of disaster pattern analysis and disaster risk classification, and also the basic foundation of integrated urban natural disaster risk assessment. The Data Sources of this paper consists of five main parts, including Series Maps of Natural Hazards in China (1949-1990), Natural Disasters Reports on Provincial newspapers in China (1949-2000), Monthly Records of Disasters in Disaster Reduction in China (1990-2000), Chinese Statistic Annual at Provincial Level (2000) and Chinese Administrative Map for regional mapping analysis, *etc.* Table 1 displays the data properties, which contains database name, data type, information source, information period, information range, and information characteristics.

3 Principles and Technical Flow of Integrated Urban Natural Disaster Risk Assessment in China

Integrated urban natural disaster risk assessment is based on the theory of regional natural disaster system, and accorded with the differentiation rules of regional natural hazards. There are five main aspects to be considered in the assessment process:

(1) Take the administrative counties as basic assessment unit.

(2) Design intensity index of urban integrated natural hazard assessment considering the major hazards that could cause structural damage to cities.

(3) Take the urbanization degree that is derived from the counties´ comprehensive economic and social level as the vulnerability degree index of integrated urban natural disaster.

(4) According to the regional disaster system theory, take natural hazard intensity and vulnerability level into account synthetically.

(5) Due to the uncertainty of Risk Degree, classify risk into different degrees by relative risk ordering method.

According to these principles and methods, a technical flow is designed for urban integrated natural disaster risk division in China (Fig. 1).

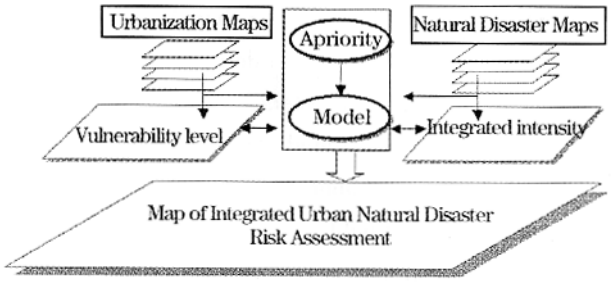

Fig. 1 Technical flowchart of integrated urban natural disaster risk assessment in China

4 Integrated Urban Natural Disaster Risk Assessment in China

4.1 Urban Vulnerability Assessment to major natural disasters in China

Vulnerability is a common socioeconomic phenomenon, which determines the poor and the handicapped is the major disasters victims[10,11]. Integrated Urban Natural Disaster Vulnerability is a state variable of disaster system interaction process among hazards, hazard-affected bodies and hazard-formative environment. It mainly depends on urban economic development degree and community security construction level. Generally speaking, a region with high urbanization level may be likely to have a relative low vulnerability level and high resilience. Therefore, we use the index (CL) (Fig. 2)[9] that reflects integrated urbanization level to assess integrated urban natural disaster vulnerability.

Based on the integrated urbanization level index (CL), the integrated urban Vulnerability index to natural disasters is calculated by the transform formula $e^{-0.5CL}$, and then the Vulnerability index map of integrated urban natural disasters in China (Fig. 3) is worked out. The urban vulnerability level of major natural disasters in china is divided into five grades, namely very high, high, medium, low and very low grades.

4.2 Integrated intensity assessment of major urban natural hazards in China

Considering the structural damage and the influence on traffic of different natural disasters, this paper chooses five major disaster types (including flood,

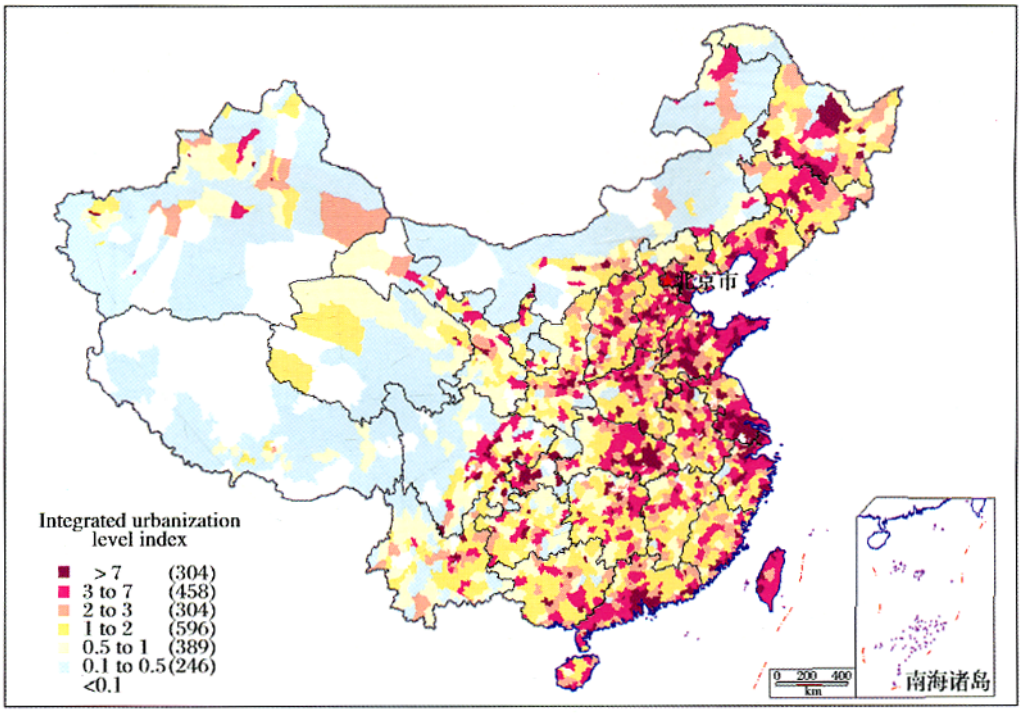

Fig. 2　The integrated urbanization level index (CL) of China

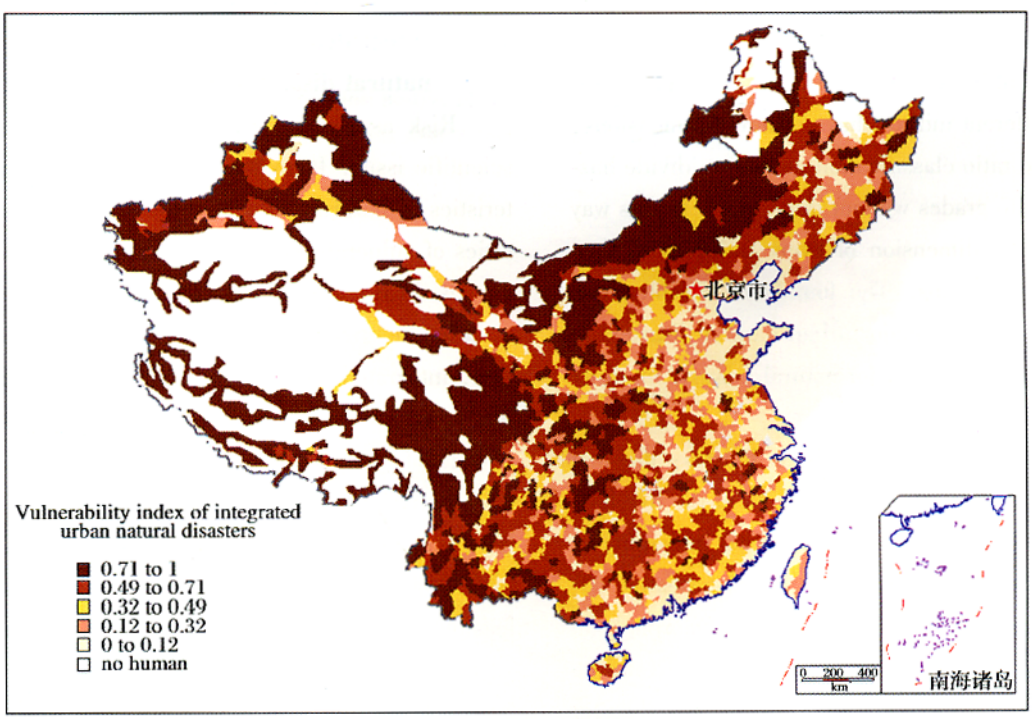

Fig. 3　The integrated urban natural disaster vulnerability assessment in China

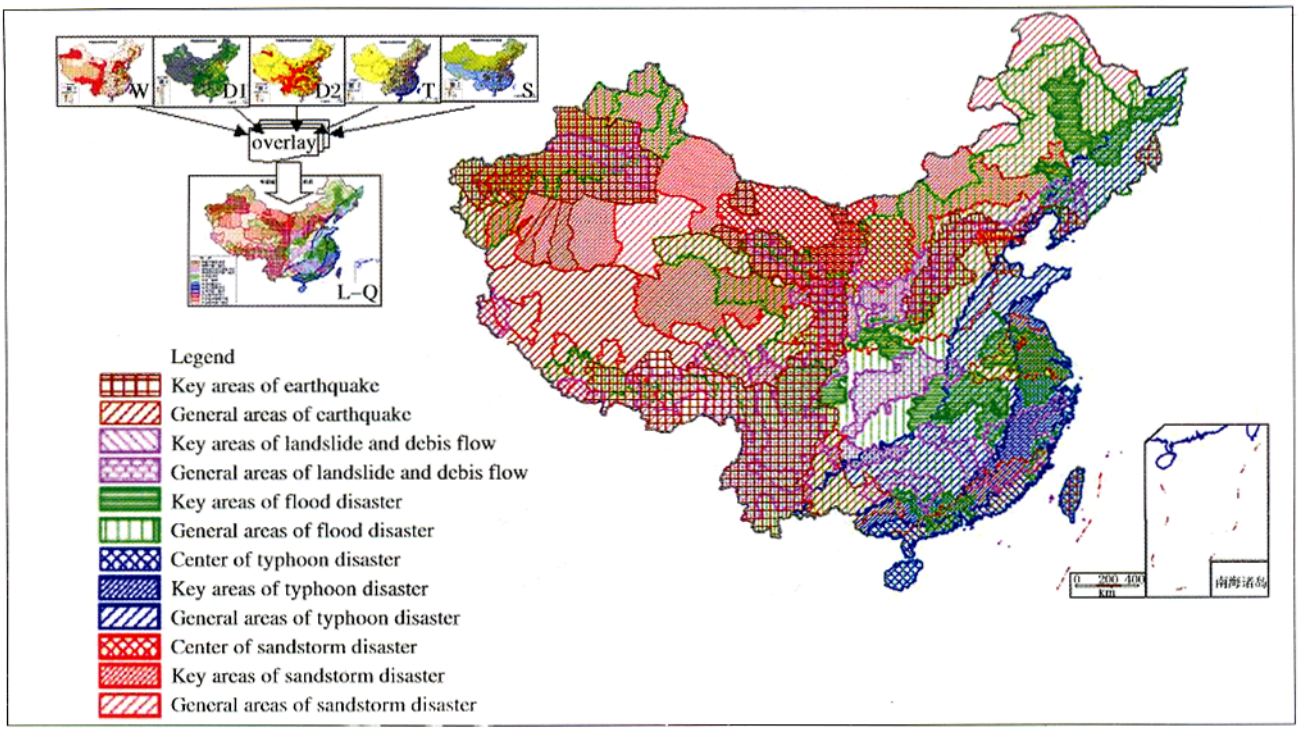

Fig. 4 The major urban natural disaster type – intensity of China

earthquake, debris flow-rock slide, typhoon and dust storm) as urban natural hazard types for risk research. Because different hazards have different quantitative indexes, and different indexes have different dimensions, we have to use ratio classification method to divide hazard intensity into grades without dimension. In this way we can unify the dimension of every index, and then design the digital maps. The foundation of integrated intensity assessment of major urban natural disasters in China is to work out the major natural hazards´ intensity distribution maps.

The assessment procedure is as follows: the first step is to do intensity ratio classification of the five hazards; then considering the administrative integrality of counties and the characteristics of hazard-formative environment, especially the continuity of geomorphologic unit and the evolvement of climate process, we gain the flood disaster intensity map (W), earthquake disaster intensity map (D1), debris flow-rock slide disaster intensity map (D2), typhoon disaster intensity map (T) and dust storm disaster intensity map (S) respectively; at last these five maps are overlaid together, and the major urban natural disaster type-intensity map (L-Q) (Fig. 4) in China is formed[9].

4.3 Integrated urban risk assessment of major natural disasters in China

Risk assessment is a complicated but important scientific issue. It involves not only the natural characteristics of hazards, but also the socio-economic properties of vulnerability. The algorithm of the risk is[13]:

Risk (R) = Hazard (H) × Vulnerability (V)

In the practical process of analysis and application, integrated risk assessment of major natural disasters is mainly to find out the relative risk level and the models of risk assessment are qualitative and semi-quantitative. According to the above risk algorithm, having gained the urban vulnerability index and the integrated intensity index of major natural hazards, it´s feasible to calculate the risk level of every county unit.

Taking county as basic assessment unit, the risk level is classified with regard to both the vulnerability grades of hazard-affected bodies and the integrated hazard intensity grades, which are both divided into five grades in this paper. The matrix of risk level classification are shown as follows (Fig. 5).

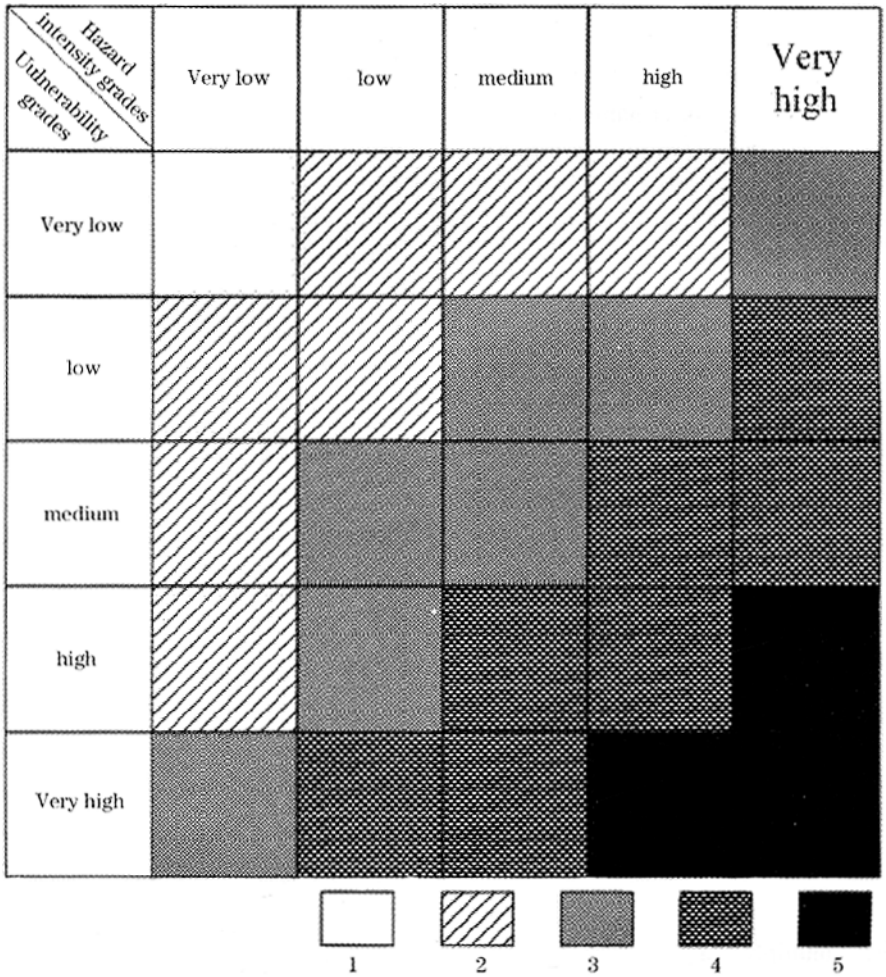

Fig. 5　Classification matrix of urban risk level of natural disasters in China

1. Very low risk level, 2. Low risk level, 3. Medium risk level, 4. High risk level, 5. Very high risk level

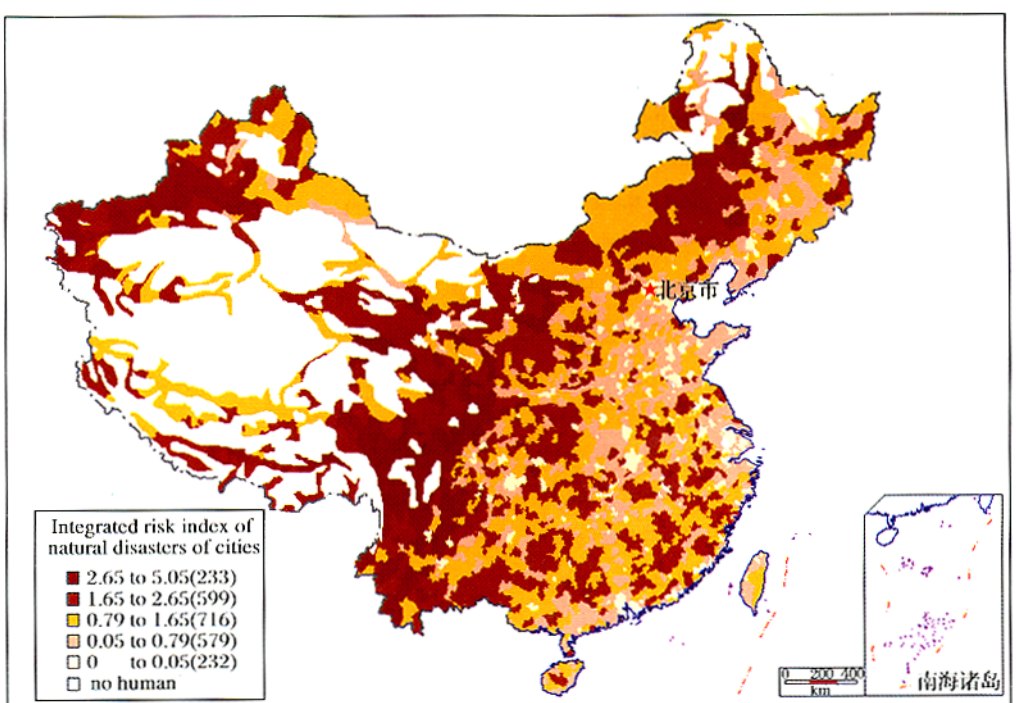

Fig. 6　The integrated urban risk assessment of China

Based on semi-quantitative risk level having been calculated and the qualitative matrix of integrated disaster risk, the integrated urban risk of natural disasters is divided into five sections, namely very low risk section (0 ~ 0.05), low risk section (0.05 ~ 0.79), medium risk section (0.79 ~ 1.65), high risk section (1.65 ~ 2.65) and very high risk section (2.65 ~ 5.05). The involved counties numbers of each grade displays a normal distribution. From the integrated urban risk assessment map (Fig. 6), it 's significant that the natural disaster frequent influenced but economic not well-developed areas, such as the west-east transitional zone and the northwest area of Xinjiang province, are the relatively high-risk centralized regions, some of the coastal areas also have scattered high-risk section distribution.

5 Conclusion and Discussion

On the basis of the urban natural disaster regionalization of China, given the integrated natural hazards intensity level and the integrated urban vulnerability level which is transferred form the urbanization level, this paper uses the " multiply " algorithm to calculate and assess the integrated urban risk level of natural disasters, and the research results accord with the practical situation of China well. Namely, the west-east transitional zone, the southwest mountainous area and plateau area, the northwest area of Xinjiang province, some eastern river-along or lake-along districts are the relatively high-risk centralized region ; the eastern areas, especially the coastal areas of well-developed economy and a natural hazard intensity less than the middle degree, are among the low-risk centralized region.

Nevertheless, the integrated regional natural disaster is not only consisted of multi hazards, but also the disaster chains and groups caused by natural hazards, which makes the integrated disaster risk assessment more difficult. Disaster chains demonstrate a series of disaster phenomena caused by a certain kind of hazard or the change of ecological environments, which can be classified into two kinds of series : disaster chains and simultaneous chains[14]. The former kind means that a certain kind of hazard causes a series of disaster phenomena ; the latter kind means that some certain inducement cause multi-hazard occurrence in a period and correspondingly brings about multi series of disaster phenomena. At present, the integrated disaster chains´ risk assessment is only carried out through the GIS overlay technique and the experts ´ empirical weight-marking to get the integrated natural hazard intensity. So the difficulties that how to choose the indexes and how to estimate the indirect losses of the disaster chains are still there.

Regional disaster system is an important part of earth surface system, and it is also a strong dissimilated system for human development. Its structure system includes hazards, hazard-affected bodies, and hazard-formative environment. Its function system consists threat, risk and vulnerability. Further researches on the structure and function of regional disaster system, and disaster risk assessment are needed for the integrated regional disaster risk management. Namely it´s important to assess the possible risk of disaster system but not just risk of hazards. So integrated regional disaster risk assessment is suggested to aims at establishing the conceptual and modeling methods of disasters system, and with regard to the assessment results to do gradation and regionalization works, which can provide scientific information for integrated regional disaster management. On the basis of integrated regional disaster risk assessment, the construction of integrated regional disaster reduction system should focus on vulnerability reduction and resilience construction, regional public security planning and disaster reduction paradigms construction, which will be effective in improving integrated regional disaster reduction ability and the realization of regional sustainable development.

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中国城市主要自然灾害风险评价研究

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摘　要:本文依据灾害系统理论和中国自然灾害数据库,构建了反映城市承灾体的综合城市化水平(CL)指标,并在此基础上得到城市脆弱性水平指数。考虑对城市具有结构性破坏和易于造成交通灾情的主要灾种,即水灾、地震、滑坡—泥石流、台风、沙尘暴,构建了反映城市主要致灾因子的综合自然灾害强度(QC)指标,并得到城市综合自然灾害强度指数。据此,在定性分析的基础上,通过半定量计算,将中国城市主要自然灾害风险划分为高风险、较高风险、中等风险、较低风险、低风险 5 个等级,编制了中国城市自然灾害风险评价图,并对灾害链的综合风险评价作了进一步的探讨。

关　键　词:综合城市化水平;灾害脆弱性;综合自然灾害强度;综合自然灾害风险评价