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The socio-economic attribute of geo-hazard made us distinguish it from the traditional engineering geology study. It will get more social benefit from the analysis of the geo-hazard in the socio-economic attribute. The hazard and the vulnerability of the element controls the risk level of the regional geo-hazard. The risk analysis supported by GIS in geo-hazard study is one of the most important directions. Based on the author´s studies in recent years, a risk analysis system of regional geo-hazard (RiskAnly) has been developed on the basis of software MAPGIS. The paper introduces the train of system design, the structure and the workflow of RiskAnly. As a case study, the paper also deals with the risk zonation of the regional landslide hazard of China.

Risk analysis system of geo-hazard based on GIS technique ZHU Liangfeng1, ZHANG Guirong1, YIN Kunlong1, ZHANG Liang2 (1. Faculty of Engineering, China University of Geosciences, Wuhan 430074, China; 2. China Research Institute of Land Resources and Economy, Beijing 101149, China) Abstract: The socio-economic attribute of geo-hazard made us distinguish it from the traditional engineering geology study. It will get more social benefit from the analysis of the geo-hazard in the socio-economic attribute. The hazard and the vulnerability of the element controls the risk level of the regional geo-hazard. The risk analysis supported by GIS in geo-hazard study is one of the most important directions. Based on the author´s studies in recent years, a risk analysis system of regional geo-hazard (RiskAnly) has been developed on the basis of software MAPGIS. The paper introduces the train of system design, the structure and the workflow of RiskAnly. As a case study, the paper also deals with the risk zonation of the regional landslide hazard of China. Key words: geo-hazard; GIS; risk analysis; landslide CLC number: P642.2 1 Introduction Generally speaking, geo-hazard is not only a kind of natural phenomenon, but also a kind of socioeconomic phenomenon. So, it has either natural or socioeconomic attribute, which is the comprehensive reflection of both antagonistic and unified relationships. Relatively, for the study of geo-hazard, it is essential to search for the elementary rule from two basic attributes, which makes us distinguish it from the traditional Engineering Geology study. However, the current study of geo-hazard at home and abroad mainly considers its natural attribute, and prediction also begins with the inner and outer factors that affect it, and the emphasis is put on the formative mechanism and evocative condition, and the indexes are mainly stability factor, stability degree, etc. (Xiang and Huang, 2000). Although this study is necessary to the single geo-hazard, it does not apparently allow for the socioeconomic attribute of geo-hazard and ignores the regional evaluation study of geo-hazard from a deeper respect. The final aim of mankind preventing geo-hazard does not extirpate the geological phenomenon or accident of geo-hazard (it is also obviously impossible from the current social and economic development level), but assure which do not cause unacceptable hazard to mankind. So speaking from the significance of hazard reduction and prevention, we will get more socio-economic benefit from the analysis of geo-hazard in the socioeconomic attribute. It requires us to explore the systemic theory and method from the prediction of regional geo-hazard, mid- and long-term forecast to risk evaluation of geo-hazard, and which will provide scientific evidence for more effective geo-hazard reduction. 2 Concepts and composition of geo-hazard risk The early study of hazard risk, which was developed from the insurance risk assessment, was served for the insurance. With the development of the society and economy, the requirement of hazard reduction gradually magnified, and not only the insurance required mastering the hazard risk, but other enterprises and government required for making the hazard reduction plan and carrying on preventive projects. In this case, the study of hazard risk booms and rapidly develops. There are miscellaneous understandings about geo-hazard. In a study plan of UNESCO, Varnes (1994) put forward the term definition of natura

l hazard and risk, then which was generally recognized by the field of international geo-hazard study and became the elementary style of evaluation of the hazard and vulnerability of geo-hazard and risk (Yin and Zhu, 2001). The geo-hazard risk can be defined: within the limit of a certain region and time, probable risk of special geo-hazard to life, finance, economic activity, etc. It can be expressed: R = f (H, E, V) (1) Generally, formula (1) can be further expressed: R = H×E×V (2) where R (Risk) is the geo-hazard risk, which refers to the probable loss of specially geo-hazard causing; H (Hazard): within the range of a region, the probability of occurring potential geo-hazard phenomenon, that is the hazard of geo-hazard; E (Element): the objects by special geo-hazard threatening in a given region, including population, possession, facilities, economic activity, etc. V (Vulnerability): the loss degree to the threatened objects of special geo-hazard that occurs at a intensity, that is the vulnerability of threatened objects, which is expressed by 0-1 (0 expresses no loss, 1 expresses hundred-percent loss). From formula (2), we can see that the hazard (H) of geo-hazard and the vulnerability (V) of threatened objects co-determine the loss degree of geo-hazard, which are the basic conditions to control the geo-hazard risk, and the analysis and evaluation to them are called the hazard evaluation of geo-hazard and the evaluation of socioeconomic vulnerability. Figure 1 shows the detailed contents. For the hazard analysis of geo-hazard, there are a few studies, and the theories are relatively complete, and forms the widely used expert analytic models, such as information value model, fuzzy evaluation model, model based on artificial neural network and genetic arithmetic, etc. To the analysis of socioeconomic vulnerability of threatened objects, because it involves so many factors and it is difficulty to collect information, it only stays at the theoretical exploring stage and has few applied model. For the complexity of practical condition, it is difficult to precisely quantitatively express H, E and V in the evaluation of geo-hazard (sometimes it is not necessary to do it). In this case, we can use "grade" to firstly classify the hazard of geo-hazard and socioeconomic vulnerability, and then adopt proper method to conduct final risk evaluation. 3 The risk analysis system of geo-hazard based on the GIS technique As one of the core technologies of the Digital Earth, the GIS technique provides us a novel style of knowing and understanding geosciences information, and it was widely used in the investigation of land and resource, environmental quality evaluation, regional planning design, facilities management, etc. In the field of geo-hazard study, the application of GIS technology has been from data management, multi-resource data collection, digital input and drawing output to the use of digital elevation model and digital terrain model, the extended analysis of GIS combining with hazard evaluation model, the integration between GIS and decision-making supported system, the application of virtual geographical environment, etc., has progressively developed (Shen et al., 2000). Various geo-hazards all occur within the definite spatial range and time limit. Though different geo-hazards and different units of the same geo-hazard have different shape and different formative mechanism, they are the results of hazard gestating environment and triggering factor co-work, which are closely related with spatial information. Using GIS technology can not only manage various geo-hazards and their related information, but also analyze the statistical relations between the geo-hazard occurrences and environmental factors from different space and time, and evaluates probability and probable hazard consequences of various geo-hazards. GIS can manage not only data and attribute information like traditional database management system, but also spatial information. By using various methods of spatial analysis, GIS can comprehensively analyze different information, look for the interrelation of spatial entities, and analyze and handle distributed phenomena and processes in a definite region. The way of today´s GIS is developing toward the intellectual GIS of providing abundant and all-round spatial analysis function (Guo, 2000). Intellectual GIS has strong spatial modeling function, construct various professional geosciences models of speciality, synthesis and integration, which can accomplish practical work, and solve the problems that are depended on geosciences experts. Generally, GIS tools offer the basic spatial analytic tools, such as region overlapping analysis, buffer analysis, the transition of vector and grid data, inquiring searches of attributively, digital elevation model, digital terrain model analysis, but it is not reality to analyze the geo-hazard risk only directly using these basic tools. So, by combining special condition, it is required to develop analytic model combined with various professional geosciences models on the GIS tools. For example, we can combine information value models, expert analytic model, and artificial neutral network model with GIS and apply them into the risk analysis of geo-hazard. After years of study, we have developed the risk analysis system of geo-hazard on the basis of GIS tools. The system conducts development supported by MAPGIS, combines various analytic models of professional geosciences, which can do hazard analysis and vulnerability analysis and final risk evaluation to various geo-hazard (such as landslide, debris flow, karst slump, etc.). The system progresses design with the work requirement. According to the element attribute of geo-hazard and combining the characteristic of GIS software, the system adopts the design train of blocking program. Its main flow chart is showed in Figure 2. The risk analysis system of geo-hazard (RiskAnly) on the basis of the GIS technique preferably has carried out the combination of GIS techno

logy with the risk analysis model of geo-hazard, and can sufficiently use the advantages of GIS, such as graphic editing, attribute management, spatial analysis, digital elevation model, etc, to rapidly and conveniently solve the problems that common analytic methods have difficulty to do. In light of the changed condition and information, RiskAnly can carry out the risk analysis of geo-hazard, and further reduces the illegibility and non-definition of the risk analysis. 4 Application examples: risk analysis of the landslide hazard in China 4. 1 Landslide hazard analysis of China 4.1.1 Hazard analysis of historical landslide There are serious landslide hazards in China. Recent scores of years, serious landslides frequently occur and cause great loss and negative social effect, but at the same time, it accumulates rich landslide hazard information for us. According to historical information and combining the active frequencies and scales of landslide hazard, the paper analyzes the landslide historical hazard and draws the zonation map of historical landslide hazard. In light of different densities of historical landslides, the map is divided into five grades of region (1. super-high density region; 2. high density region; 3. middle density region; 4. low density region; 5. few active region), which basically reflects the regional distribution characteristic of historical landslides of China. 4.1.2 Main influencing factors analysis of landslide hazard The occurrence of landslides is subject to the factors of the combination of rock and soil, the terrain and the physiognomy, the geological tectonisms, the grade of earthquake intensity, the engineering activities of human being, etc., so the hazard analysis of landslide should begin with these factors. According to the requirement of the characteristics of various factors affecting hazard occurrence and of the subsequent analysis, the paper respectively draws the zonation of each factor (Table 1). 4.1.3 Hazard evaluation and zonation Information value model is the valid method for analyzing the risk of regional geo-hazard (Zhu and Yin, 2001), and the hazard analysis of geo-hazard is set up on the basis of information model. By the spatial analysis function of GIS, it can overlay the zonation map of historical landslide to the zonation map of affecting factor, then calculate the information value, finally classify the hazard grade according to the information value and draw the zonation map of landslide hazard (Figure 3). The area in Figure 3 is divided into four grades: 1. super-high hazard, 2. high hazard, 3. medium hazard, 4. low hazard. 4.2 The analysis of socioeconomic vulnerability Relating to describing the natural attribute hazard of geo-hazard, it has more changes and difficulties to describe the socioeconomic vulnerability of threatened objects´ social attribute(Chen et al,2000). Regional vulnerability not only changes with space, also changes with time. It is the function of space and time (Lin et al., 2001). When progressing the regional socioeconomic vulnerability analysis, on the basis of casualty and social and economic loss by the historical landslide hazard, the paper synthetically allows for the distribution and developing condition and anti-hazard ability of region population, facilities, building, human economic activities and structure, and progresses the analysis of regional population vulnerability and land vulnerability, and draws the zonation map of vulnerability of China (Figure 4). The vulnerability is divided into four grades: 1. high vulnerability; 2. middle vulnerability; 3. low vulnerability; 4. super-low vulnerability. 4.3 Landslide risk analysis It is unrealisic to calculate nationwide risk directly using formula (2), and it is necessary to classify the risk according to "grade". The paper carries on final zonation of landslide risk by adopting the classified standard of Table 2. According to the combinatorial characteristic of landslide risk grade and vulnerability grade, the landslide risk is divided into four grades: 1. high risk region, 2. middle risk region, 3. low risk region, 4. super-low risk region. Figure 5 shows the specific distribution. 5 Conclusions The application potentiality of GIS in the geo-hazard is progressively extending, and the GIS technique provides the valid technical support for the risk evaluation of geo-hazard under various models. At home and abroad, the risk analysis of geo-hazard is a new question for discussion, and the theoretical significance and practical importance on risk analysis of geo-hazard will get the general agreement of the whole society. With the development of new round country resource plan and the construction of western development, it is essential to have the risk evaluation of large-range regional geo-hazard. The geo-hazard risk analysis on the basis of the GIS technique has not only available method, also advanced technology, and it represents the directions of risk analysis of geo-hazard. References Chen Yaning, Chen Lijun, 2000. The distribution of environment disasters of Xinjiang line in New Eurasian Continental Bridge, Acta Geographica Sinica, 55(1): 82-90. (in Chinese) Guo Renzhong, 2000. Spatial Analysis (2nd edn.). Wuhan: The Press of Wuhan Technical University of Surveying and Mapping, 8-9. (in Chinese) Jin Xiaomei, Liu Jintao, 1999. Hazard condition evaluation of landslide in Wanxian City. Journal of Engineering Geology, 7(1): 25-29. (in Chinese) Li Xianhua, Lin Hui, Chen Xiaoqing et al., 2000. GIS-aided study and numerical simulation of initiation mechanism of landslide due to precipitation. Journal of Engineering Geology, 9(2): 133-140. (in Chinese) Liu Xilin, Mo Duowen, Wang Xiaodan. 2001, Regional vulnerability assessment of debris flows. The Chinese Journal of Geological Hazard and Control, 12(2): 11. (in Chinese) Shen Fang, Huang Runqiu, Miao Fang et al., 2000. Geographic information system and geoenvironmental evaluation. Journal of Geological Hazards and Environment Preservation, 11(1): 7. (in Chinese) Xiang X

iqiong, Huang Runqiu, 2000. Risk assessment and risk management for slope geohazards. Journal of Geological Hazards and Environment Preservation, 11(1): 38. (in Chinese) Yin Kunlong, Zhu Liangfeng, 2001. Landslide hazard zonation and application of GIS. Earth Science Frontiers, 8(2): 280. (in Chinese) Zhang Liang, Zhang Jianjun, 2000. The theory and method of risk zonation of geo-hazard. Journal of Geological Hazards and Environment Preservation, 11(4): 323. (in Chinese) Zhu Liangfeng, Yin Kunlong, 2001. Information analysis system of geo-hazard supported by GIS. The Chinese Journal of Geological Hazard and Control, 12(3): 81. (in Chinese)

关键词： geo-hazard; GIS; risk analysis; landslide

