Construction of evaluation system and evaluation model of urban environmental engineering geological problems —— a case study of Jinan City

Yunfeng Zhang [1,2], *Ana* Wu [3], *Jianjun* Shen [4], and *Qing* Cao[4*]

[1] Shandong Provincial Geo-mineral Engineering Exploration Instiute, Jinan ,250014, China
[2] Shandong Fifth Institute of Geology and Mineral Exploration, Taian, 250013, China
[3] Shandong GEO-Surveying & Mapping Institute, Jinan, 250002, China
[4] College of Chemical Engineering and Safety, Binzhou University, Binzhou, 256600, China.

Abstract. In order to further study the problems of urban engineering geological environment, taking Jinan as an example, the environmental engineering geological problems are divided into four aspects: primary environmental engineering geological problems, secondary environmental engineering geological problems, the influence of human activities and the restriction of spring water on engineering construction. A multi-level, multi-objective and multi factor evaluation index system suitable for environmental engineering geology is established. The mathematical model is established by using analytic hierarchy process and fuzzy comprehensive evaluation method to evaluate the primary environmental engineering geological problems, secondary environmental engineering geological problems, the impact of human activities and the restrictive effect of spring water on engineering construction. The mathematical model is established by using Nemero index method to comprehensively evaluate the environmental engineering geological problems in Jinan, and the suitability zoning of engineering construction is carried out.

1 Introduction

Environmental engineering geology is a new discipline. Artificial and natural environments jointly shape cities, and urban construction and geological environment promote and restrict each other [1]. Therefore, in urban engineering geology, it is necessary to predict all types of geological engineering problems in cities and suggest corresponding prevention and control strategies [2].

The study of urban engineering geological environment in the modern sense began in the late 1960s when engineering geology in urban planning was gradually realised in practice. With the acceleration of urbanisation and rapid development of economic construction in China, in mining engineering, water conservancy and hydropower, urban construction, geological disasters, water and soil pollution, and other aspects of

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[*]Correspongding author: caoqing526@163.com

environmental engineering geology have carried out a series of research, and achieved a lot of research results. Human engineering activities have accelerated the transformation of the natural geological environment, which has become a driving force keeping pace with natural action. In addition, in big cities with dense populations and frequent economic activities, the consequences are often quite serious once geological disasters or environmental accidents occur. They cause great economic losses and social impact, even causing local social instability [3-6]. Therefore, the study of modern urban environmental engineering geology has essential theoretical and practical significance for correctly understanding the law of environmental engineering geology, revealing, reducing, and avoiding the environmental engineering geology problems, and improving the environmental quality of urban engineering geology.

Taking Jinan city as an example, this paper summarizes the environmental engineering geology problems into four aspects: primary environmental engineering geology problems, secondary environmental engineering geology problems, the effect of human activities and the restriction of spring water on engineering construction. A multi - level, multi - objective and multi - factor evaluation index system suitable for environmental engineering geology is established. The factors affecting environmental engineering geology are quantitatively analyzed and evaluated by analytic hierarchy process(AHP) and fuzzy comprehensive evaluation method. The safety of environmental engineering geological problems in Jinan city is divided into districts.

2 Main contents of urban environmental engineering geology research

With the development of society, the impact of human activities on the engineering geological environment has become increasingly evident, and the environmental engineering geological problems caused by this have become increasingly severe and complex [7-18].

(1) Traditional regional engineering geology problems: It includes soft soil, expansive soil, collapsible loess, liquefied sand, and other special soils, as well as deformation failure of deep and large foundation pits.

(2) Geological disasters: It includes collapse, landslide, debris flow, ground subsidence, ground collapse, ground cracks, and geological disasters caused by mine development.

(3) Seismic geology includes crustal stability and tectonic earthquakes formed by active faults.

(4) Geological problems formed by human engineering economic activities: It includes mine tailings pond, garbage storage yard, artificial water storage reservoir, underground space development, and groundwater overexploitation.

(5) Geochemical and environmental problems include water and soil pollution and heavy metal pollution.

(6) Issues related to land governance: It includes soil erosion and land desertification.

3 Evaluation Methods of urban environmental engineering geology

At present, foreign countries have combined sustainable urban development with engineering geology, and the study of engineering geology has leapt from quantitative change to qualitative change [19-25].

With the development of the economy, standardisation of the construction industry, and gradual attention to engineering geology, urban engineering geology developed into a

specialised discipline [26-36]. Miao selected the grey clustering evaluation model and fuzzy comprehensive evaluation model, adopted the priority relation ranking method and principal component analysis method to screen and optimise each evaluation index, and conducted comprehensive analysis and evaluation on the geological environment quality [37-39].

This paper used analytic hierarchy process (AHP) and fuzzy combined evaluation method to establish a mathematical model to evaluate the primary environmental engineering geology problems, secondary environmental engineering geology problems, the impact of human activities, and the restricting effect of spring water on engineering construction. Nemerow index method was used to establish a mathematical model to comprehensively evaluate the environmental engineering geological problems in Jinan city, and to partition the engineering construction suitability. The evaluation model is shown in Figure 1. The index classification of karst collapse evaluation is shown in Table 1.
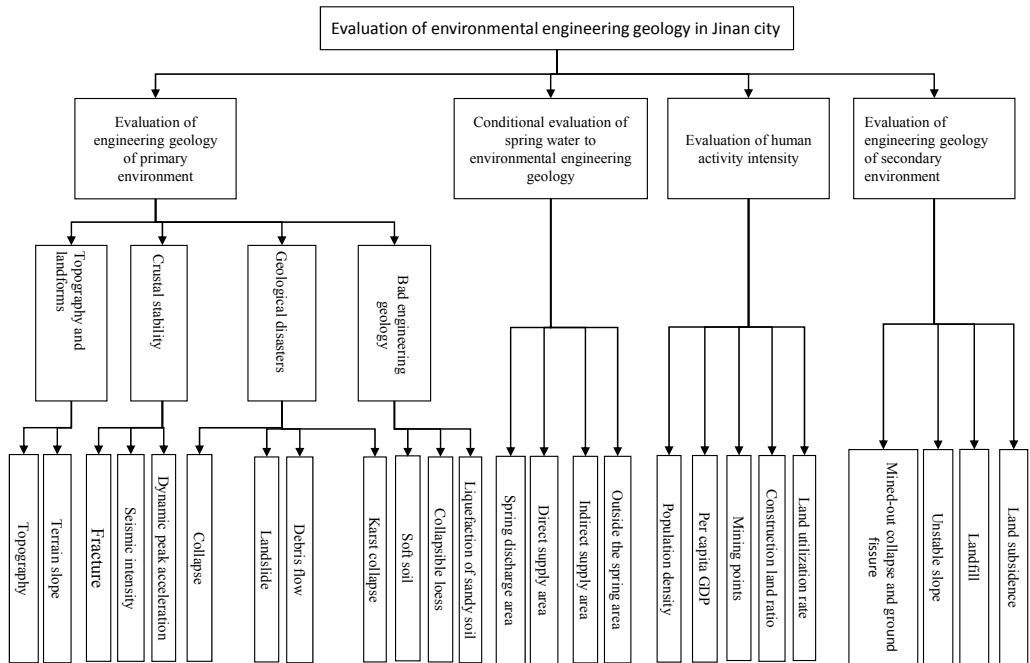

Fig. 1. Evaluation system.

Using the grid division function of the MAPGIS software, the city's grids were named from 1 to 2029 according to the User ID, and a total of 2029 grids are divided. The factors affecting major environmental engineering geological issues are primary environmental engineering geological factors and secondary environmental engineering geological factors. Because the primary environmental engineering geological problems and the secondary environmental engineering geological problems are complementary in affecting the major environmental engineering geological problems of Jinan, the Nemerow index method and the analytic hierarchy process are combined to comprehensively evaluate the two secondary indicators. The results are shown in Figure 2 and Figure 3.

Table 1. Hierarchical classification table of karst collapse evaluation indexes.

Factors of grade four	Factors of grade five	Factors of grade six	Risk level
Karst collapse D_4	Bedrock lithology E13	Dominated by limestone	Ⅰ High risk
		Mixture of limestone and sandstone	Ⅱ Risk

	Dominated by sandstone	Ⅲ Less risk
	Dominated by siltstone	Ⅳ Small risk
Karst development degree E14	Stronger	Ⅰ High risk
	Strong	Ⅱ Risk
	Ordinary	Ⅲ Less risk
	Weak	Ⅳ Small risk
Overburden thickness(m)E15	0-30	Ⅰ High risk
	30-50	Ⅱ Risk
	50-70	Ⅲ Less risk
	＞70	Ⅳ Small risk
Groundwater depth(m)E16	0-15	Ⅰ High risk
	15-30	Ⅱ Risk
	30-45	Ⅲ Less risk
	＞45	Ⅳ Small risk

Figure 2 shows the risk assessment results of engineering geological problems in the primary environment. Figure 3 shows the risk assessment results of engineering geological problems in the primary environment.The factors affecting major environmental engineering geological issues are primary environmental engineering geological factors and secondary environmental engineering geological factors. Because the primary environmental engineering geological problems and the secondary environmental engineering geological problems are complementary in affecting the major environmental engineering geological problems of Jinan, the Nemerow index method and the analytic hierarchy process are combined to comprehensively evaluate the two secondary indicators.
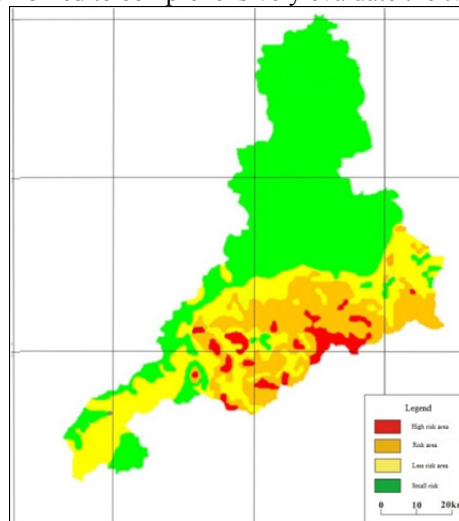

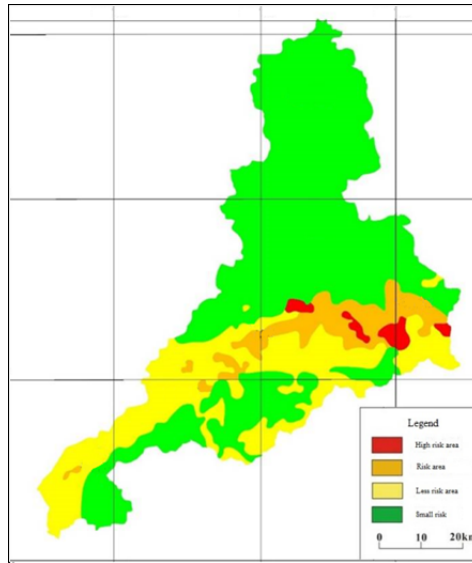**Fig. 2.** Risk assessment results of primary environmental engineering geological problems.

Fig. 3. Risk assessment results of engineering geological problems in secondary environment.

The Nemerow index method was used to calculate the normalized values of primary environmental engineering geological problems index and secondary environmental engineering geological problems index.The primary and secondary environmental engineering geological problems of each grid were calculated according to the formulas. Safety grade and description of major environmental engineering geological indexes are shown in Table 2.

Table 2. Safety grade and description of major environmental engineering geological indexes.

Security level	Level description
Class A [0, 2.5]	This level is the lowest safety level and is not suitable for major environmental engineering construction. Involving primary environmental factors and secondary environmental factors are inappropriate, human activities are strong, and population density is high.
Class B [2.5, 5]	This level is a restricted safety level. When major environmental projects are being constructed, it is more restricted by primary and secondary environmental factors, and human activities are relatively strong.
Class C [5, 7.5]	This level is a selective security level. During the construction of major environmental projects, it is less restricted by primary and secondary environmental factors, and the intensity of human activities is medium.
Class D [7.5, 10]	This level is the highest safety level and is suitable for major environmental engineering construction. Some areas are affected by a single factor, but the impact is relatively small.

$$P_{\mathrm{j}}=\sqrt{\frac{F_{\mathrm{jmax}}^2+\ (\overline{F}_{\mathrm{j}})^2}{2}}$$

(1)

Where: F_{jmax} is the largest single factor environmental quality index.

$\overline{F_j}$ is the average value of each single factor environmental quality index.

The evaluation criteria are shown in Table 2.

The evaluation of the engineering geological problems of the original environment in the grids with ID=1394 and 1395 can be obtained as follows:

$$X_{\text{native 1394}}=\frac{6.5248-5.0075}{8.6808-5.0075}\times10=4.1305, \qquad X_{\text{native 1395}}=\frac{6.2525-5.0075}{8.6808-5.0075}\times10=3.3894$$

The evaluation of engineering geological problems of secondary environment in grids WITH ID=1394 and 1395 can be obtained.

$$X_{\text{secondary 1394}}=\frac{7.4598-4.1895}{8.7500-4.1895}\times10=7.1708, \qquad X_{\text{secondary 1395}}=\frac{6.2525-4.1895}{8.7500-4.1895}\times10=7.8303$$

According to the grading standards, the security level of the grids with ID=1394 and ID=1395 is C. Other grids were graded according to the above evaluation method, and the vector diagram of the comprehensive evaluation zone was obtained, as shown in Figure 3.According to the above figure, the geological safety evaluation of major environmental engineering in Jinan is divided into four grades, namely Grade A, B, C and D.

Table 3. Natural-human environmental engineering geological index calculation table.

Cell	Area(km^2)	Perimeter (km)	Primary environment engineering geology index value	Engineering geological index of secondary environment	Nemerow index method calculated after the value
1394	4	8	4.1305	7.1708	6.4556
1395	4	8	3.3894	7.8303	6.8111

The area of Class A security zone is about 398.46km^2, accounting for 4.97% of the whole city.

The area of Class B security zone is about 1467.52km^2, accounting for 18.30% of the whole city.

The area of Class C security zone is about 1956.53km^2, accounting for 24.40% of the whole city.

The area of Grade D security zone is about 4194.80km^2, accounting for 52.32% of the whole city.
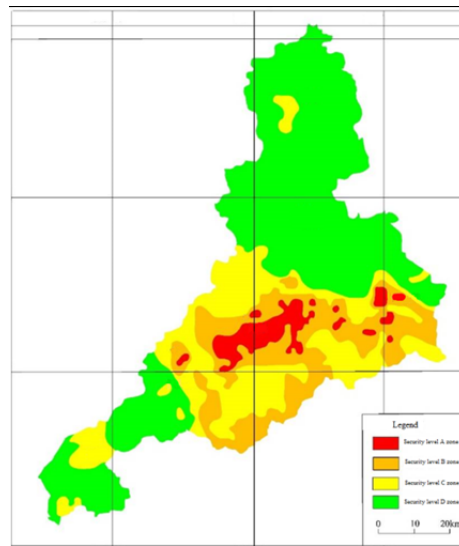

Fig. 4. Safety evaluation results of urban environmental engineering geological problems.

4 Conclusions

Urban environmental engineering geology is the core of environmental engineering geology research. At present, it mainly studies the regional adverse engineering geological effects in urban development, urban geological disasters, seismic, geological problems, geological problems caused by human engineering economic activities, urban water and soil pollution, and heavy metal pollution.The key problems to be solved in urban environmental engineering geology include establishing and improving the database of environmental quality of urban environmental engineering geology and predicting and evaluating the quality of environmental engineering geology in urban three-dimensional space

The nemerow index method is used to comprehensively evaluate the above two problems, and the safety zoning of environmental engineering geological problems in Jinan is obtained. It can be divided into four types: A, B, C and D. The area of grade A safety area is about $398.46km^2$, accounting for about 4.97% of the city's area. The area of grade B safety area is about $1467.52km^2$, accounting for 18.30% of the city's area. The area of grade C safety area is about $1956.53km^2$, accounting for 24.40% of the city's area. The area of grade D safety area is about $4194.80km^2$, accounting for about 52.32% of the city's area. Compared with the original evaluation results, this comprehensive evaluation method of "primary and secondary" environmental engineering geology is more scientific and more consistent with the actual situation.

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