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Study on the Evaluation of Environmental Cost for Coal Resource Development Based on the Improved Fuzzy Mathematics

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Abstract: The evaluation of environmental cost for coal resource development is the foundation of the environmental impact compensation for coal resource development. The evaluation index system of the environmental cost for the coal resource development was constructed from three aspects, including the impact on natural environment, impact on ecological environment, as well as the impact on social environment. The environmental cost evaluation model for the coal resource development was constructed on the basis of improved fuzzy mathematical model.

Key words: Evaluation of environmental cost, coal resource development, improved fuzzy mathematics

INTRODUCTION

The evaluation of environmental cost for coal resource development aims to evaluate the possible influence on the environment from the coal resource development, so that the favorable influence can be utilized and the unfavorable influence can be reduced or improved, which will provide scientific basis for the decision of the impact compensation for the col resource development. Therefore, when evaluating the environmental cost for the coal resource development, it should analyze the possible influence on the environment of this activity according to the characteristics of the environmental cost evaluation for coal resource development (Johst *et al*., 2002).

As for the coal resource development, since it can influence a lot of environmental factors, it will influence the environments at the same time. As a result, when carrying out the specific evaluation of environmental cost for the coal resource development, the environmental factors influenced by the coal resource development should be integrated and it will provide basis for the environmental impact compensation in the coal resource development (Bienabe and Hearne, 2006).

During the process of environmental cost evaluation for coal resource development, a significant problem confronted by the coal resource development is the evaluation model and determination of the index weight (Tang *et al*., 2013). For the comprehensive evaluation model of the environmental impact, the evaluation model should be selected respectively during the process according to the data provided by the environmental condition investigation, including the basic data, precision of environmental impact forecasting, as well as the degree of environmental impact. In this study, the traditional fuzzy mathematical model would be improved to evaluate the cost of coal resource development.

CONSTRUCTION OF THE EVALUATION INDEX SYSTEM OF THE ENVIRONMENTAL COST FOR COAL RESOURCE DEVELOPMENT

During the process of evaluating the environmental cost for coal resource development, the first problem was the construction of environmental cost evaluation index system for coal resource development, namely constructing an index system that could reflect the environmental cost for the coal resource development completely (Ma *et al*., 2007).

The effect of environmental influence in coal resource development is mainly reflected in three aspects, namely the influence on natural environment, ecological environment and social environment. Therefore, the construction of environmental cost evaluation index system for the coal resource development should be carried out from the three aspects. And the influences on the natural environment, ecological environment and social environment are also reflected in different aspects, in which, the influence of coal resource development on the natural development is mainly reflected in the atmospheric environment, water environment, noise, geology, etc., the influence of coal resource development on the ecological environment is mainly reflected in the damages to the biological resources, influence on the ecological integrity, influence on the water and soil loss, influence on the desertification of land, etc. and the

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Table 1: Environmental cost evaluation index system for coal resource development

Target layer	First-class index	Second-class index	Third-class index
Environmental cost evaluation for coal resource development	Natural environmental cost X_1	Atmospheric environment X_{11}	Annual mean concentration of SO_2 ($\mu g\ m^{-3}$) X_{111}
			Annual mean concentration of NO_2 ($\mu g\ m^{-3}$) X_{112}
			Annual mean concentration of PM10 ($\mu g\ m^{-3}$) X_{113}
			Annual mean concentration of PM2.5 ($\mu g\ m^{-3}$) X_{114}
			Annual mean concentration of TSP ($\mu g\ m^{-3}$) X_{115}
		Water environment X_{12}	Total hardness (calculate in $CaCO_3$, mg L^{-1}) X_{121}
			Sulfate (mg L^{-1}) X_{122}
			Nitrate (calculate in N, mg L^{-1}) X_{123}
			Nitrite (calculate in N, mg L^{-1}) X_{124}
			Total bacterial count (PCs mL^{-1}) X_{125}
		Noise X_{13}	Daytime noise in A type of room (dB (A)) X_{131}
			Night noise in A type of room (dB (A)) X_{132}
			Daytime noise in B type of room (dB (A)) X_{133}
			Night noise in B type of room (dB (A)) X_{134}
		Geology X_{14}	Loss in geological environmental capacity (in thousand) X_{141}
	Ecological environmental cost X_2	Biological resources X_{21}	Loss in terrestrial plant (in thousand) X_{211}
			Loss in peculiar vegetation (in thousand) X_{212}
			Loss in key protective plant species and precious wood (in thousand) X_{213}
			Loss in terrestrial animal (in thousand) X_{214}
			Loss in aquatic organism (in thousand) X_{215}
		Ecological integrity X_{22}	Loss in 'three fields' of fish (in thousand) X_{221}
			Loss in habitat of terrestrial animal (in thousand) X_{222}
			Loss in diversity of species (in thousand) X_{223}
		Water and soil loss X_{23}	Loss in water and soil loss (in thousand) X_{231}
		Desertification of land X_{24}	Loss in desertification of land (in thousand) X_{241}
	Social environmental cost X_3	Entertainment X_{31}	Loss in entertainment (in thousand) X_{311}
		Communication and transportation X_{32}	Loss in communication and transportation (in thousand) X_{321}
		Human health X_{33}	Loss in human health (in thousand) X_{331}
		Human landscape X_{34}	Impact on the local customs (%) X_{341}
			Impact on the local life style (%) X_{342}
		Economic development X_{35}	Loss in primary industry (in thousand) X_{351}
			Loss in the secondary industry (in thousand) X_{352}
			Loss in the tertiary industry (in thousand) X_{353}

influence of the coal resource development on the social environment is mainly reflected in the influence on cultural and recreational facilities, influence on the communication and transportation, influence on human health, influence on human landscape, influence on economic development, etc.

Based on the above analysis, the environmental cost evaluation index system constructed for the coal resource development was shown in Table 1.

It can be seen that the constructed environmental cost evaluation index system for the coal resource development reflect the influence on the coal resource development on the environment from three aspects, namely the natural environment, ecological environment and social environment. It is relatively comprehensive and it can provide relatively good support for the construction of environmental impact compensation for the coal resource development.

ENVIRONMENTAL COST EVALUATION METHODS FOR THE COAL RESOURCE DEVELOPMENT BASED ON THE IMPROVED FUZZY MATHEMATICAL MODEL

After constructing the environmental cost evaluation index system for the coal resource environment, the next problem confronted is the design of the environmental cost evaluation for the coal resource development.

The traditional fuzzy mathematical model has certain advantage in solving the visualization and comprehensive evaluation of complicated problems and it also plays a vital role in studying the changing rules and solving problems. However, the traditional fuzzy mathematics has certain shortages in solving the problems about multi-person decision and multi-layer index weight. On that basis, the determination of the multi-person decision and multi-layer weight is improved based on the traditional fuzzy mathematical model and then it is applied into the environmental cost evaluation for coal resource development (Ren, 2009).

The procedures for constructing the environmental cost evaluation model for the coal resource development based on the improved fuzzy mathematical model are shown as follows:

- **Step 1:** Determining each of the third-class index characteristic value in the environmental cost evaluation index system for the coal resource development

As for the environmental cost evaluation index system for the coal resource development, the

determination for each third-class index characteristic value should be analyzed properly according to the types of different indexes.

It can be seen that in the environmental cost evaluation index system for the coal resource development, for all the indexes, the smaller they are, the better they will be. Meanwhile, when determining the characteristic value of the third-class index, it will be determined according to the with-and-without comparison method and three specific numbers will be involved, namely the current value of the index, the normal value of the index and the maximum value of the index. The specific calculation method for each value is shown as follows:

- Estimation for the current value for the index, marked as $V_{present}$. The current value of the index refers to the current value of each index in the environmental cost evaluation index system for the coal resource development. As for the estimation of the current value, each expert shall endow each index in the environmental cost evaluation index system with an interval value in table 5-1 by combining the current status and data. Suppose the number of the expert is K and the interval value for each index given by each expert is:

$$[v_{1p}^{(k)}, v_{2p}^{(k)}]$$

(k is the expert, k = 1, 2,…, k):

$$v_{2p}^{(k)} \geq v_{1p}^{(k)}$$

Then:

$$V_{present} = \frac{1}{2}\sum_{k=1}^{K}[(v_{2p}^{(k)})^2 - (v_{1p}^{(k)})^2] / \sum_{k=1}^{K}[v_{2p}^{(k)} - v_{1p}^{(k)}]$$

- Estimation for the normal value of the index, marked as V_{normal}. The normal value of the index refers to the normal value of each index if without the coal resource development according to the with-and-without comparison method. As for the estimation of the normal value, each expert will endow each index with an interval value respectively of the environmental cost evaluation index system for the coal resource development in Table 1 by combining with the current situation, historical data and data in similar region. Suppose the number of the expert is K and the interval value for each index given by each expert is:

$$[v_{1n}^{(k)}, v_{2n}^{(k)}]$$

(k is the expert, k = 1, 2,…, k):

$$v_{2n}^{(k)} \geq v_{1n}^{(k)}$$

Then:

$$V_{normal} = \frac{1}{2}\sum_{k=1}^{K}[(v_{2n}^{(k)})^2 - (v_{1n}^{(k)})^2] / \sum_{k=1}^{K}[v_{2n}^{(k)} - v_{1n}^{(k)}]$$

- Estimation for the maximum value of the index, marked as V_{max}. The maximum value refers to the possible maximum value of each index in the environmental cost evaluation for coal resource development when satisfying the normal production and normal life. As for the estimation of the maximum value, each expert will endow each index with an interval value, respectively of the environmental cost evaluation index system for the coal resource development in Table 1 by combining with the current situation, historical data and data in similar region. Suppose the number of the expert is K and the interval value for each index given by each expert is:

$$[v_{1m}^{(k)}, v_{2m}^{(k)}]$$

(k is the expert, k = 1, 2,…, k):

$$v_{2m}^{(k)} \geq v_{1m}^{(k)}$$

Then:

$$V_{max} = \frac{1}{2}\sum_{k=1}^{K}[(v_{2m}^{(k)})^2 - (v_{1m}^{(k)})^2] / \sum_{k=1}^{K}[v_{2m}^{(k)} - v_{1m}^{(k)}]$$

Step 2: Determining the weight of the environmental cost evaluation index system for the coal resource development: When determining the weight of the environmental cost evaluation index system for the coal resource development, GAHP is adopted. Specifically speaking, each expert is invited to carry out the determining of weight for each class of index according to the procedures and requirements of AHP and the average value of the weight of the index system waiting to be evaluated for the coal resource development determined by each expert is taken as the final weight of each index in the environmental cost evaluation index system for the coal resource development.

Step 3: Determining the result of the environmental cost evaluation for the coal resource development: According to the characteristic value of each third-class index in the environmental cost evaluation index system for the coal resource development, the environmental cost value for the coal resource development is determined by combining with the weight determined for the environmental cost evaluation index system for the coal resource development.

The matrix formed by the characteristic value of the third-class index in the environmental cost evaluation index system for the coal resource development is marked as B_V, the matrix formed by the weight of the third-class index is W_V and the result of the environmental cost evaluation for the coal resource development is O_V:

$$O_V = B_V \otimes W_V$$

The O_V calculated is the result of the environmental cost evaluation for the coal resource development.

CONCLUSION

During the coal resource development process, it is inevitable to bring influence to the environment. Therefore, in order to guarantee the sustainable development of the diggings, it is required to establish the environmental impact compensation mechanism for the coal resource development. The establishment of the coal resource compensation mechanism should be carried out on the basis of comprehensive comparison of the environmental capacity and environmental cost of the coal resource development. Therefore, it is quite significant to establish the environmental cost evaluation system for complete and proper coal resource development. On that basis, the environmental cost evaluation index system is constructed from three aspects, including the natural environment, ecological environment and social environment and the environmental cost evaluation model for the coal resource development is proposed on the basis of the improved fuzzy mathematics, which provides supports to the scientific launch of the environmental impact compensation for the coal resource development.

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