Evaluation of Heavy Metal Pollution Prevention Technology based on AHP—FCE

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Abstract—AHP—FCE model was introduced to carry out evaluation of heavy metal pollution prevention technology. AHP was used to determine the weights of various evaluation indices, and FCE was used to evaluate heavy metal pollution prevention technology. The paper took HDS technology. as an example, to introduce technology assessment process.

Keywords—Analytical Hierarchy Process (AHP); Fuzzy Comprehensive Evaluation (FCE); High Density Sludge (HDS)

I. INTRODUCTION

The technology evaluation often is decided by several factors, but analyzed from qualitative analysis or quantitative analysis only nowadays. Its result is single, not overall and accurate enough. Because evaluation object factors have often fuzziness, the FCE adopted to carry out the evaluation is superior to the other traditional method. Meanwhile, in order to avoid the error which is brought by fuzzy uncertainty, analytical hierarchy process (AHP) is used to confirm its weights. This paper will apply AHP—FCE to evaluate heavy metal pollution prevention technology.

II. ANALYTICAL HIERARCHY PROCESS (AHP)

A. Judging Matrix

AHP starts by performing a sequence of pair wise comparisons of criteria with respect to a goal by using original (crisp) 9-point scale[1-2].

TABLE I. NINE-POINT INTENSITY OF IMPORTANCE SCALE AND ITS DESCRIPTION.

Definition	Intensity of importance
Equally importance	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate valuse	2,4,6,8

(Source: Adapted from Saaty(1994))

B. Consistency Check

The pairwise comparison data are translated into the absolute values and the normalized weight vector. $W=(W1,W2,...,Wn)$ is obtained by solving the matrix equation:

$$AW = \lambda_{\max} W \quad (1)$$

where A is the pairwise comparisons matrix, W is the $\lambda_{\max}$'s normalized weight vector and $\lambda_{\max}$ is the maximum eigenvalue of the matrix A (used to calculate the consistency index).

$$\lambda_{\max} = \sum_{i=1}^n \frac{(AW)_i}{nW_i} = \frac{1}{n} \sum_{j=1}^n \frac{\sum_{i=1}^n a_{ij}W_j}{W_i} \quad (2)$$

In order to control the result of the method, the consistency ratio for each of the matrices and overall inconsistency for the hierarchy calculated. The deviations from consistency are expressed by the following equation CI, and the measure of inconsistency is called.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

The consistency ratio (CR) is used to estimate directly the consistency of pairwise comparisons. The CR is computed by dividing the CI by a value obtained from a table of Random Consistency Index (RI).

$$CR = \frac{CI}{RI} \quad (4)$$

If the CR less than 0.10, the comparisons are acceptable, otherwise not. RI value is showed in table II.

TABLE II. THE RI VALUE OF 1-10 ORDERS MATRIX

orders	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

III. FUZZY COMPREHENSIVE EVALUATIONS

A fuzzy evaluation system can be represented as: $U = \{u_1, u_2, \dots, u_m\}$, where $u_1, u_2, \dots, u_m$ is one of the indexes in the evaluation factors. Designated evaluation standard can be represented as: $V = \{v_1, v_2, \dots, v_n\}$, where $v_1, v_2, \dots, v_n$ is one of the indexes in the designated evaluation standard[3-4].

A. Membership Degree Function Establishing

Firstly, we develop the membership degree function of index and build the fuzzy inference matrix R.

$$P = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \quad (5)$$

In the matrix, r_{ij} is the degree of U_i belongs to V_j .

B. Fuzzy Comprehensive Evaluations Models

In order to consider the different influences of factors, the weight matrix W was applied.

$$W = [W_1, W_2, \dots, W_n] \quad (6)$$

This leads to a fuzzy inference matrix B which has the form:

$$B = W \cdot R \quad (7)$$

$B = (b_1, b_2, \dots, b_n)$ is the fuzzy evaluation results.

IV. HEAVY METAL POLLUTION PREVENTION TECHNOLOGY EVALUATION

A. Multi-Level Evaluation Index System

Because the evaluation have multi-index and multi-level characteristics. All the indexes on certain attributes can be divided into several aspects, known as norms. Therefore, taking V (comprehensive evaluation) as the goal, the P1 (heavy metal discharge), P2 (economical costing) and P3 (technology) as the norms. For particular technology, the evaluation index system may be appropriately adjusted. More than 80 points' technology were determined as advanced pollution control technology.

B. Evaluation Example

The paper took HDS technology. as an example, to introduce technology assessment process.

TABLE III. HEAVY METAL DISCHARGE EVALUATION

							evaluation			
secondary index				3 nd the index						
							3 nd the index	secondary		
index	weights	index	weights	index	Copper and cobalt nickel industrial pollutants emission standards		score	actual value	scoring	scoring
					Water pollutants concentration limit new enterprises	Special water pollutants emission limits				
Heavy metal discharge	0.4	Water pollutants indicators	1	Hg	0.05	0.01	20	<0.01	20	32
				Cd	0.1	0.02	20	<0.05	10	
				Pb	0.5	0.2	20	<0.2	20	
				As	0.5	0.1	20	0.14	10	
				Cu	0.5	0.2	20	<0.05	20	

TABLE IV. ECONOMICAL COSTING EVALUATION

								evaluation					
secondary index		3 rd the index	four-level index		five-level index			five	four	third	two		
index	weights	index	weights	index	metewand	score	index	metewand	score	scoring	scoring	scoring	scoring
Econo- mical costing	0.3	cost of invest-ment	1	Investmen	<2000yuan	20							
				t of per	3000yuan>	10				10	10		
				ton waste	or>2000yuan	0							
				water	>3000yuan	15							
				electric	<1yuan	10				10			
				charge per	1.5yuan> or	0							
				ton waste	1yuan	15							
				water	>1.5yuan	10							
				medicame	<2.5yuan	15							
				nt expense	2.5yuan< or	10							
	operat	ing	1	per ton	<3yuan					15	35		
	cost	waste	>3yuan	0									
		water											
		maintenan	<1yuan	10								19.5	
		ce cost per	1yuan< or	5						10			
	ton waste	<1.5yuan	0										
	water	>1.5yuan											

TABLE V. TECHNOLOGY EVALUATION

secondary index	3 nd the index	four-level index	evaluation			
			four	third	two	
technology	0.3	Advancement	advanced	15		
			ordinary	10	15	
			backward	0		
			advanced	10		
			ordinary	5	10	
			backward	0		
			large	10	50	
			ordinary	5	10	
			small	0		
			no	15		
			ordinary	10	15	
			seriousness	0		
			yes	15	15	
			no	0		
			yes	15		
		Reliability	generalize	5	10	45
			no	0		
			yes	20	20	
			no	0		

As can be seen through the accounting, "HDS technology scored 28.5 on technical indicators, scored 32 on heavy metal discharge, scored 19.5 on the economic costs, evaluation score of 80, the technology is feasible, economic and reasonable.

V. CONCLUSIONS

In view of uncertainty in heavy metal pollution prevention technology, AHP-FCE model were introduced. Compared with the above methods, the model can more objectively reflect the comprehensive influence of system elements, provide a aid evaluation tools for the heavy metal pollution prevention.

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Figure 1. The evaluation index system centered.