Evaluation Model of Rural Drinking Water Project Based on Entropy Weight and Fuzzy Comprehensive Evaluation Method

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Abstract Based on *Measures for Assessment of Rural Drinking Water Standard Raising Action in Zhejiang Province*, this study established an evaluation system for rural drinking water project in Zhejiang Province, covering three primary indicators of project construction, project management and project performance, and 18 secondary indicators. It proposed an evaluation model based on entropy weight and fuzzy evaluation method. It solved the problems of the objectivity of the indicator weight and the quantification of the indicators, and can well achieve the coordination and unity of fuzziness and accuracy. Using this model, it evaluated a rural drinking water project in a county and concluded that both accuracy and feasibility of the model are high.

Key words Entropy weight method, Fuzzy comprehensive evaluation method, Rural drinking water

1 Introduction

In recent years, Zhejiang Province has vigorously promoted the improvement of rural drinking water standards, and counties and cities in the province also have gradually established agricultural drinking water systems with large-scale development, standardized construction, market-oriented operation, and professional management. Due to the geographical characteristics of Zhejiang Province, the drinking water projects generally have problems such as small scale, scattered distribution, imperfect facilities, and non-standard management. These bring a certain difficulty to objectively evaluate the agricultural drinking water work in various areas. The existing evaluation system is not very objective in determining the weight of each evaluation indicator, which prejudices the credibility of the results. In addition, because the evaluation of rural drinking water is a non-linear process with unclear goals, it presents certain fuzzy characteristics in terms of indicator content, expression form and evaluation results. Therefore, it is urgently necessary to establish a scientific and practical evaluation system[1]. Combining the entropy weight method and the fuzzy comprehensive evaluation method not only solves the objectivity problem of the indicator weight, but also solves the fuzziness problem of the indicators. It can make the evaluation work professional, scientific and standardized, bring the incentive effect of the assessment, and provide decision-making basis and reference for the follow-up project construction.

2 Establishment of the evaluation indicator system

Rural drinking water project involve many factors. Apart from the project construction situation, it is also necessary to consider the daily management and operation work and overall benefit. Taking a county in Zhejiang Province as the research object, based on *Measures for Assessment of Rural Drinking Water Standard Raising Action in Zhejiang Province*, with the reference to the existing research results, following the principles of science, application and operability[2], we divided the rural drinking water project into three primary indicators, namely construction management, operation management and performance management, and then subdivided into 18 secondary indicators. Because the provincial standard of Zhejiang Province is higher than the national standard, we complied with the following principle when formulating the scoring standard: Those that meeting the national standards were rated as Level I (90 points), and those not meeting the national standards were rated and scored by scoring experts according to the actual situation. The evaluation system and criteria are shown in Table 1.

3 Construction of evaluation model based on entropy weight-fuzzy comprehensive evaluation method

The entropy weight method is an objective weighting method and it only depends on the discreteness of the data itself. Compared with the subjective weighting method, the entropy weighting method is more objective and has higher precision. Fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy mathematics. It transforms qualitative evaluation into quantitative evaluation according to the membership degree theory of fuzzy mathematics, that is, to use fuzzy mathematics to make a general evaluation of things or objects restricted by many factors. It is characterized by clear results and strong systematicness. It can better solve fuzzy problems that are difficult to quantify, and is suitable for solving various non-deterministic problems.

In the evaluation of agricultural drinking water projects, there are many indicators that are difficult to quantify, such as so-

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cial benefits, *etc*. It is difficult to make quantitative analysis, but have to make qualitative analysis, and it is necessary to avoid relying too much on the subjectivity of experts in determining the weight of indicators. In this study, through combining the characteristics of the entropy weight method and the fuzzy comprehensive evaluation method, we not only identified the differences between the evaluation results under equal weight and unequal weight[3], but also solved the evaluation factors that are fuzzy and difficult to quantify. We transformed qualitative evaluation into quantitative evaluation to achieve the unity of fuzziness and precision[4].

Table 1 Evaluation indicator system and criteria of rural drinking water project in Zhejiang Province

Primary indicators	Secondary indicators	Evaluation criteria				
		Level I	Level II	Level III	Level IV	Level V
Project construction management (u_1)	Project basis (u_{11})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Planning and design (u_{12})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Construction process (u_{13})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Project acceptance quality (u_{14})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Archives and data (u_{15})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
Project operation management (u_2)	Management system construction (u_{21})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Management personnel level (u_{22})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Water supply capacity (u_{23})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Production process and equipment (u_{24})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Environmental sanitation (u_{25})	≥90	90 – 75	75 – 60	60 – 40	60 – 0
	Information technology utilization (u_{26})	≥90	90 – 75	75 – 60	60 – 40	40 – 0
	Emergency maintenance capability (u_{27})	≥90	90 – 75	75 – 60	60 – 40	60 – 0
Overall benefit management (u_3)	Water quality qualification rate (u_{31})	≥85	85 – 75	75 – 60	60 – 40	40 – 0
	Water supply guarantee rate (u_{32})	≥90	90 – 75	75 – 60	60 – 40	60 – 0
	Water charges collection rate (u_{33})	≥90	90 – 75	75 – 60	60 – 40	60 – 0
	Economic benefit (u_{34})	≥20	20 – 15	15 – 10	10 – 5	5 – 0
	Social benefit (u_{35})	≥8	7 – 6	5 – 3	2 – 1	0
	Project sustainability (u_{36})	≥20	20 – 15	15 – 10	10 – 5	5 – 0

3.1 Determination of the weight of evaluation indicators using entropy weight method[5-6]

3.1.1 Establishment of the original data evaluation matrix K.

$$K=\begin{bmatrix} k_{11} & k_{12} & k_{13} & \cdots & k_{1m} \\ k_{21} & k_{22} & k_{23} & \cdots & k_{2m} \\ k_{31} & k_{32} & k_{33} & \cdots & k_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ k_{n1} & k_{n2} & k_{n3} & \cdots & k_{nm} \end{bmatrix}$$

where k_{ij} denotes the final evaluation score of the j^{th} evaluation indicator of the i^{th} sample. According to Table 1, there are 18 evaluation indicators, so $m=18$.

3.1.2 Normalization processing. Normalization is to convert the absolute value of the initial evaluation matrix of indicators into relative values, so as to solve the homogeneity problem of various indicators of heterogeneous indicators. Using the formula (1), we processed the K matrix and obtained the normalized standard matrix. The calculation formula is as follows:

$$k'_{ij}=\frac{k_{ij}-\min(k_{1j},\cdots,k_{nj})}{\max(k_{1j},\cdots,k_{nj})-\min(k_{1j},\cdots,k_{nj})} \tag{1}$$

3.1.3 Calculation of the evaluation criteria matrix P. This is to calculate the proportion of the i^{th} sample value under the j^{th} indicator to the indicator, and the evaluation standard matrix P is:

$$P=\begin{bmatrix} p_{11} & p_{12} & p_{13} & \cdots & p_{1m} \\ p_{21} & p_{22} & p_{23} & \cdots & p_{2m} \\ p_{31} & p_{32} & p_{33} & \cdots & p_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & p_{n3} & \cdots & p_{nm} \end{bmatrix}$$

where $$p_{ij}=\frac{k_{ij}}{\sum_{i=1}^{n}k_{ij}},\ i=1,\cdots,n,\ j-1,\cdots,m \tag{2}$$

3.1.4 Calculation of the information entropy of each indicator. The information entropy of the j^{th} indicator is calculated by the formula (3):

$$e_j=-\frac{1}{\ln(n)}\sum_{i=1}^{n}p_{ij}\ln(p_{ij}),\ j=1,\cdots,m,\ satisfying\ e_j\geqslant 0 \tag{3}$$

3.1.5 Calculation of the weight of each indicator. The weight of the j^{th} indicator is calculated by the formula (4):

$$w_j=\frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)},\ j=1,\cdots,m \tag{4}$$

3.2 Determination of the evaluation score using the fuzzy comprehensive evaluation method[6-7]

3.2.1 Determination of the evaluation indicator set. We determined the evaluation indicator set U according to the evaluation factors of the evaluation indicator system. $U=\{u_1, u_2, u_3, \cdots, u_m\}$.

3.2.2 Determination of the finite set V of evaluation levels. According to actual needs, we divided the evaluation into n levels. $V=\{v_1, v_2, v_3, \cdots, v_n\}$. According to the actual situation such as the operability of the evaluation of rural drinking water projects, we divided the evaluation into 5 levels, namely very good v_1, good v_2, general v_3, poor v_4 and very poor v_5. The score ranges are: [90, 100], [80,90), [70,80), [60,70), [0,60). Then, we assigned the scores from high to low, $V=\{v_1, v_2, v_3, v_4, v_5\}$, if the score is 90 – 100, it means that the evaluation is very good, and other score levels can be obtained in the same way.

3.2.3 Determination of the membership degree evaluation indicator. We made a statistic of the number of experts whose indicator factors belong to five levels: very good, good, general, poor and very poor. Then, we divided the number of experts at each evaluation level by the total number of experts as the membership degree value $r_m u_i$ of the evaluation factor u_i to the evaluation level v_n (n = 1, 2, 3, 4, 5). The membership degree matrix R of each factor is expressed as:

$$R = \begin{bmatrix} r_1(u_1) & r_2(u_1) & r_3(u_1) & \cdots & r_5(u_1) \\ r_1(u_2) & r_2(u_2) & r_3(u_2) & \cdots & r_5(u_2) \\ r_1(u_3) & r_2(u_3) & r_3(u_3) & \cdots & r_5(u_3) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ r_1(u_m) & r_2(u_m) & r_3(u_m) & \cdots & r_5(u_m) \end{bmatrix}$$

3.2.4 Evaluation of fuzzy relation synthesis. Using the entropy weight method, we obtained the weight set W of 18 indicator factors. $W = \{w_1, w_2, \cdots, w_m\}$ Then, by correlating the weight index set with the index fuzzy matrix, we comprehensively evaluated the evaluation indicator, and the evaluation vector B is calculated by the formula (5):

$$B = W \cdot R \qquad (5)$$

3.2.5 Determination of the evaluation score. In order to avoid the problem that the membership degree value is similar in the principle of maximum membership degree and it is difficult to accurately judge the evaluation level, we adopted the weighted average judgment model, took the median of $\{v_1, v_2, v_3, v_4, v_5\}$ and assigned scores from high to low. $V = \{95, 85, 75, 65, 30\}$ The evaluation score D of rural drinking water operation and management can be calculated by the formula (6):

$$D = V \cdot B^{-1} \qquad (6)$$

4 Case application

4.1 Overview of the case The case county is located in the hilly area in the central part of Zhejiang Province. In the county, there are abundant water resources. Rural drinking water projects have problems of small scale, scattered distribution, lack of construction funds and maintenance funds, poor management after construction. From 2017, the county actively carried out the assessment of rural drinking water qualification, promoting construction and reform through evaluation. After years of development, the situation has been greatly improved. The case took a rural drinking water project as the research object. The project belonged to a township water plant, had a daily water supply of 5 000 t, benefited 19 165 people, had 10 water plant managers, 8 with training certificates, 3 with vocational qualification certificates, and the plant had obtained the license for drawing water and hygiene license.

4.2 Determination of indicator weights When determining the weight by the entropy weight method, we selected the scoring data of 10 representative projects in the county in 2020 as samples. The scoring data adopted the method of subjectively determining the weight and taking the mean of expert scores as the final score. The results are indicated in Table 2.

Table 2 Indicator scores of 10 representative projects in a county of Zhejiang Province in 2020

Indicator	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8	Project 9	Project 10
u11	100	100	100	100	100	100	98	100	100	98
u12	100	98	100	100	100	100	97	100	102	95
u13	100	90	89	92	100	99	100	99	100	96
u14	100	100	98	100	104	100	100	100	100	100
u15	100	100	92	100	100	100	95	95	100	98
u21	92	90	95	95	96	96	96	95	99	99
u22	90	90	90	92	90	86	90	90	90	90
u23	90	88	86	90	90	90	90	90	90	89
u24	100	100	100	100	100	100	100	102	100	99
u25	90	90	85	90	90	90	92	90	90	83
u26	90	92	90	90	98	90	93	90	89	95
u27	100	90	85	100	100	92	100	100	100	78
u31	74	76	65	78	80	78	77	75	77	78
u32	86	88	86	88	87	85	86	88	82	78
u33	78	77	69	77	80	78	78	79	73	68
u34	7	10	8	15	18	20	22	11	9	5
u35	9	8	7	5	8	8	3	8	8	5
u36	6	7	6	7	8	6	12	17	21	10

According to the scoring results, we finally obtained the weight vector of 18 indicators using the entropy weight method. The result is as follows: W = (0.056, 0.038, 0.058, 0.051, 0.04, 0.042, 0.029, 0.031, 0.051, 0.037, 0.116, 0.039, 0.029, 0.033, 0.051, 0.077, 0.04, 0.182).

4.3 Calculation of evaluation scores We invited 10 experts and technicians to score, including 2 water conservancy experts, 2 engineering project managers, 3 engineering management personnel, and 3 experts engaged in rural drinking water evaluation. Then, we evaluated each individual indicator of the indicator set against the evaluation scoring standard. According to the membership degree calculation formula, we obtained the evaluation membership degree R of each indicator. From the formula (5), we obtained the matrix B. From the formula (6), we obtained the final score D of this project, the result is:

$$R=\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0.9 & 0.1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0.9 & 0.1 & 0 & 0 & 0 \\ 0.9 & 0.3 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0.8 & 0.2 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0.8 & 0.2 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0.2 & 0.2 & 0.2 & 0.4 & 0 \\ 0.6 & 0.1 & 0.3 & 0 & 0 \\ 0.1 & 0.1 & 0.2 & 0.6 & 0 \end{bmatrix},$$

$$D = V \cdot B^{-1} = [95, 85, 75, 65, 30] \cdot \begin{bmatrix} 0.61 \\ 0.15 \\ 0.09 \\ 0.14 \\ 0 \end{bmatrix} = 87.4$$

5 Conclusions

In view of the problems of the current rural drinking water project evaluation system, we put forward the actual evaluation indicators for Zhejiang Province. Using the entropy weight method, we assigned the indicator weight, which overcomes the subjectivity of the indicator weight assignment and improves the accuracy. Besides, we introduced fuzzy comprehensive evaluation method and followed the principle of fuzzy relation synthesis to make fuzzy comprehensive evaluation, so as to make the evaluation more objective. Using this evaluation model, we evaluated a township water plant in a county in Zhejiang Province, the final score was 87.5, which is good and above, and is close to the evaluation score of the project in 2020. This verified the accuracy and feasibility of the model, and is expected to provide a certain reference for the evaluation of rural drinking water projects in Zhejiang Province.

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