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Construction and Application of a Comprehensive Evaluation Index for Personnel Abilities and Quality Based on the Fuzzy Analytic Hierarchy Process: A Case Study of Students at a Specific University

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Abstract: The evaluation of personnel's ability and quality is an important link in promotion, ranking, annual assessment, etc. The introduction of the fuzzy analytic hierarchy process can deal with aspects that are difficult to cover using traditional quantitative methods, such as ideological and political quality, psychological quality, teamwork, etc. Taking student evaluation as an example, this paper combines the fuzzy analytic hierarchy process with factor analysis to process course scores to ensure the objectivity and scientificity of evaluation results while maintaining flexibility and comprehensiveness, and providing a reference for scientific evaluation in various scenarios.

Keywords: Fuzzy analytic hierarchy process; Factor analysis; Comprehensive quality assessment

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1. Introduction

In the current context, various industries generally need to conduct comprehensive evaluations of personnel's ability and quality, but traditional methods have limitations: first, they only add up scores, ignoring differences in evaluation content, leading to the phenomenon of "only focusing on scores"; second, indicators that are difficult to quantify are easily affected by subjectivity; third, ranking by total scores provides limited information. Using the fuzzy analytic hierarchy process to determine the weight of each indicator and convert the fuzzy judgment matrix into specific weight values can reduce subjective deviation [1], scientifically integrate qualitative and quantitative information, and provide reliable weight support for evaluation.

2. Establishing a comprehensive evaluation index for assessing students' abilities and qualities: A case study at a university

The Overall Plan for Deepening the Reform of Educational Evaluation in the New Era proposes to "build a scientific and comprehensive student evaluation system" [2]. The talent cultivation in schools should enhance adaptability to the comprehensive quality needs of employers [3]. A comprehensive consideration is given to constructing a comprehensive evaluation index system for students' ability and quality, as shown in **Table 1**. The main principles considered are as follows: first, the index setting focuses on comprehensiveness; second, the quantification method reduces the impact of subjective judgment; third, the index setting has good operability.

Table 1. Comprehensive evaluation index system for students' ability and quality

Goal layer	Criterion layer	Alternatives layer
Comprehensive evaluation of students' abilities and qualities	Course assessment and grade determination (A1)	Assessment and evaluation of professional courses (A11)
		Evaluation and assessment of basic courses (A12)
	Sports and Arts Course Assessment and Performance Evaluation (A2)	Physical Education Course Assessment Evaluation (A21)
		Literary and Artistic Activity Assessment Evaluation (A22)
	Ideological and Political Quality Evaluation (A3)	Political Theory Assessment (A31)
		Ideological and Political Appraisal (A32)
	Other Achievement Evaluation (A4)	Rewards and Punishments (A41)
		Discipline Competition Awards, Academic Achievements (A42)
		Social Practice (A43)

2.1. Introduction to the Fuzzy Analytic Hierarchy Process

Fuzzy Analytic Hierarchy Process (FAHP) is a multi-factor decision analysis method based on the Analytic Hierarchy Process. The fuzzy logarithmic least squares method, fuzzy geometric mean method, etc., are widely used [4]. The concept of the fuzzy judgment matrix is introduced, and the influence of subjective factors is reduced through the fuzzy consistency matrix [5]. It combines qualitative and quantitative analysis to obtain more scientific and objective results [6].

2.2. Construction of a comprehensive evaluation model based on fuzzy analytic hierarchy process (FAHP)

2.2.1. Steps for calculating weights of each criterion using FAHP

(1) Establish a fuzzy complementary judgment matrix

Quantitative expression is conducted in the form of "the relative importance of two factors with respect to their upper-level index (criterion)." If the 0.1–0.9 scaling method shown in **Table 2** is used for quantitative scaling, a fuzzy complementary judgment matrix $R = (r_{ij})_{n\times n}$ (i, j = 1, 2, ..., n) can be obtained. Here, rii = 0.5 indicates that factor ri is equally important compared to itself; if rij $\in$ [0.1, 0.5), it means factor rj is more important than factor ri; if rij $\in$ (0.5, 0.9], it means factor ri is more important than factor rj.

Table 2. 0.1–0.9 Scaling method and its meanings

Scaling	Definition	Explanation
0.5	Equally important	The two factors are equally important when compared
0.6	Slightly important	When comparing the two factors, the row factor is slightly more important than the column factor
0.7	Obviously important	When comparing the two factors, the row factor is obviously more important than the column factor
0.8	Much more important	When comparing the two factors, the row factor is much more important than the column factor
0.9	Extremely important	When comparing the two factors, the row factor is extremely more important than the column factor
0.1, 0.2, 0.3, 0.4	Inverse comparison	If the judgment obtained from comparing factor ri with factor rj is rij = 0.6, then rji = 0.5 - (0.6 - 0.5) = 0.4

(2) Weight calculation

If $R = (r_{ij})_{n\times n}$ is a fuzzy complementary judgment matrix, and $w = (w_1, w_2 \ldots, w_n)$ is the weight vector of R, then the weight of the fuzzy complementary judgment matrix is solved by using the general formula proposed in Document [7], whose expression is as follows:

$$W_i = \frac{\sum_{i,j=1}^{n} r_{ij} + \frac{n}{2} - 1}{n(n-1)} \quad \text{(I)}$$

In the formula, w_i is the weight of factor r_i

(3) Consistency check

To determine whether the weight values calculated according to formula (I) are reasonable, it is necessary to conduct a consistency check on the comparative judgment process. Based on the definitions of the compatibility index I(A, W*) of the judgment matrix and the characteristic matrix W* in reference [8], the compatibility index between the judgment matrix and its characteristic matrix is calculated, and their expressions are as follows:

$$I(A, W*) = \frac{1}{n^2}\sum_{i,j=1}^{n} |a_{ij} + b_{ji} - 1| \quad \text{(II)}$$

$$W_{ij} = \frac{w_i}{w_i + w_j} \quad \text{(III)}$$

$$A = (a_{ij})_{n*n},\ W* = (b_{ij})_{n*n} \quad \text{(IV)}$$

Among them, both A and W* are fuzzy complementary judgment matrices. If the consistency index value I(A, W*) is less than a specific threshold α (usually α = 0.1), the judgment matrix can be regarded as a satisfactorily consistent matrix. The smaller the value of α, the higher the requirement of the decision-maker for the consistency of the fuzzy judgment matrix.

2.2.2. Data calculation

Score the criterion layer and indicator layer. After obtaining the fuzzy complementary judgment matrix, the relevant results calculated are as follows:

(1) Calculation of the judgment matrix for the criterion layer

Judgment matrix

$$A = \begin{bmatrix} 0.5 & 0.7 & 0.6 & 0.7 \\ 0.3 & 0.5 & 0.6 & 0.6 \\ 0.4 & 0.4 & 0.5 & 0.6 \\ 0.3 & 0.4 & 0.4 & 0.5 \end{bmatrix}$$

Feature matrix

$$W *= \begin{bmatrix} 0.5 & 0.5385 & 0.5469 & 0.5738 \\ 0.4615 & 0.5 & 0.5084 & 0.5357 \\ 0.4531 & 0.4916 & 0.5 & 0.5273 \\ 0.4262 & 0.4643 & 0.4727 & 0.5 \end{bmatrix}$$

Table 3. Calculation results of the criterion layer

Evaluation index	Relative weight	I(A,W*)
A_1	0.29167	0.0712 < 0.1 Passed the verification
A_2	0.25	
A_3	0.24167	
A_4	0.21667	

(2) Calculation of the judgment matrix for the indicator layer

Here, take A1 as an example:

Judgment matrix

$$\mathrm{A1} = \begin{bmatrix} 0.5 & 0.6 \\ 0.4 & 0.5 \end{bmatrix}$$

Feature matrix

$$\mathrm{W1} *= \begin{bmatrix} 0.5 & 0.45 \\ 0.45 & 0.5 \end{bmatrix}$$

Table 4. Calculation results of the indicator layer corresponding to A

Evaluation index	Relative weight	I(A,W*)
A11	0.55	0.025 < 0.1 Passed the verification
A12	0.45	

For the convenience of subsequent calculations, we will uniformly retain four decimal places. Similarly, by calculating the judgment matrices of A2, A3, and A4 (**Table 5**).

Table 5. Index weight table

Target layer	Criterion layer	Weight	Indicator layer	Relative weight	Integrated weight
Comprehensive Evaluation of Students' Abilities and Qualities A	Course Assessment Grade Evaluation (A1)	0.2917	Professional Course Assessment (A11)	0.55	0.1604
			Basic Course Assessment (A12)	0.45	0.1313
	Sports and Arts Subject Assessment Grade Evaluation (A2)	0.25	Physical Education Course Assessment (A21)	0.55	0.1375
			Art and Cultural Activity Assessment (A22)	0.45	0.1125
	Ideological and Political Quality Evaluation (A3)	0.2417	Political Theory Assessment (A31)	0.40	0.0967
			Ideological and Political Appraisal (A32)	0.60	0.1450
	Other Achievements Evaluation (A4)	0.2167	Rewards and Punishments (A41)	0.3333	0.0722
			Awards in Disciplinary Competitions and Academic Achievements (A42)	0.3833	0.0831
			Social Practice (A43)	0.2833	0.0614

3. Model application

3.1. Original data processing

3.1.1. Factor analysis of course assessment results

Factor analysis is a dimensionality reduction method in multivariate statistical analysis, used to analyze the role of factors [9]. After processing the data with SPSS software, the author can obtain the comprehensive rankings of each student in basic courses and specialized courses, respectively.

Table 6. Original course assessment results of 50 students

Student number	A1	A2	A3	B1	B2	B3	Total score
1	80	78	74	79	81	80	472
2	87	84	77	80	86	85	499
…	…	…	…	…	…	…	…
50	75	80	71	70	78	80	454

Factor analysis was conducted on the basic courses A1, A2, A3 and specialized courses B1, B2, B3 in the original score (**Table 6**). The comprehensive score **Table 7** can be obtained, and here the top five in the comprehensive ranking are shown as examples. Similarly, the comprehensive score tables for specialized courses B1, B2, and B3 can be obtained through calculation.

Table 7. Comprehensive score ranking table of students' basic courses

Rank	Row index	Composite score	A1	A2	A3
1	19	1.880428277834128	88	89	90
2	43	1.880428277834128	88	89	90
3	35	1.8110146240801182	90	89	86
…	…	…	…	…	…
50	22	-2.409010725	69	66	68

3.1.2. Standardized processing of assessment results for literary and sports subjects

Literary and sports activities are conducive to enhancing students' enthusiasm and initiative in participating in social activities [10]. Their assessments are mostly non-numeric scores and need to be converted into percentage scores. For example, taking participation in activities two times as the benchmark,60 points are recorded; if participating less than two times,50 points are recorded; each additional participation adds 10 points, with a full score of 100 points [11].

Z-score standardization can be used for further analysis, converting the data into a normal distribution with a mean of 0 and a standard deviation of 1. Its formula is:

$$z = \frac{x - \mu}{\sigma} \qquad \text{(V)}$$

Where Z is the standard score, x is the raw score, μ is the average score, and σ is the standard deviation. A Z-score greater than 0 indicates a level above the average, while a Z-score less than 0 indicates a level below the average. Then, rank the standardized data.

3.1.3. Processing of ideological and political quality indicators

Political theory assessments are mostly given as specific scores, while ideological and political appraisals are usually based on a set of comments such as “Excellent, Good, Average, Pass.” These need to be quantified. For example, the level with the largest number of students receiving that comment can be set as 70 points, with each higher level adding 10 points and each lower-level subtracting 10 points, and then sorted after such quantification [12].

3.1.4. Processing of other achievement evaluation indicators

Since other achievements are “icing on the cake” bonus items and the calculated integrated weight is low, it is considered appropriate to conduct sub-item ranking after calculating the corresponding bonus points and then perform a weighted calculation based on the ranking.

3.2. Weighted calculation and ranking

The weights of each evaluation indicator are determined using the Fuzzy Analytic Hierarchy Process, and the scores of students in each indicator are weighted and calculated [13]. The operation has a high degree of standardization and proceduralization, which can reduce the time cost and resource consumption of the evaluation work [14]. This paper uses the total number of students minus the student’s ranking in that item as the basic score, which is then multiplied by the integrated weight of the corresponding indicator layer to get the weighted score of that item.

Suppose a student’s comprehensive ranking in a certain indicator is x_1, the integrated weight of that item is a, and the weighted score is y.

Given that there are 50 students in this cohort, then

$$y = a(50 - x_1) \qquad \text{(VI)}$$

Take the assessment of student No. 1’s course performance as an example for demonstration

(1) Calculation of weighted scores for professional courses

Table 8. Ranking table of comprehensive scores for professional courses of student No. 1

Ranking	Row index	Comprehensive score	B1	B2	B3
33	1	-0.023946149	79	81	80

According to the formula:

$$y = a(50 - x_1)$$

The integrated weight here is a=0.1604, and the ranking $x_1 = 33$

Then:

$$y = 0.1604\times(50 - 33) = 2.7268$$

For the convenience of subsequent calculations, the result is uniformly retained to two decimal places. Therefore, the weighted score of professional courses for Student No. 1 is 2.73. In case of a tied ranking, the two students can be calculated with the same score, which will not affect the overall ranking.

(2) Calculation of weighted scores for basic courses

Table 9. Ranking table of comprehensive scores for the basic courses of student No.1

Ranking	Row index	Comprehensive score	A1	A2	A3
35	1	-0.393626815	80	78	74

Similarly, the weighted score of basic courses for Student No.1 is calculated to be 1.97.

(3) Calculation of course assessment score

Course assessment score = weighted score of professional courses + weighted score of basic courses

Taking Student No. 1 as an example, his course assessment score is 4.7. In accordance with this calculation method, the weighted scores of each item in the indicator layer are calculated and summed up, and then the students' comprehensive quality evaluation rankings can be obtained by sorting. Taking students numbered 1 to 5 as examples.

Table 10. Score rankings of indicators for students No. 1–5

Serial Number	Professional Course Assessment	Basic Course Assessment	Physical Education Course Assessment	Literary and Art Activity Assessment	Political Theory Assessment	Ideological and Political Appraisal	Rewards and Punishments	Disciplinary Competition	Social Practice
1	33	35	25	22	31	20	25	37	30
2	15	9	15	28	12	10	14	14	16
3	13	33	17	20	30	27	30	38	30
4	17	34	10	12	35	21	37	17	30
5	21	27	27	18	33	33	40	39	30

Since there are no bonus points awarded to individuals ranked below 30th in bonus categories such as disciplinary competitions and academic achievements, all such individuals are uniformly recorded as having a rank of 30th. **Table 11** presents the results obtained by calculating the weighted scores.

Table 11. Ranking of 5 students by scores of various indicators

Serial Number	Profession-al Course Assessment	Basic Course Assessment	Physical Education Course Assessment	Literary and Art Activity Assess-ment	Political Theory Assess-ment	Ideolog-ical and Political Appraisal	Rewards and Pun-ishments	Discipline Competi-tion	Social Practice	Com-pre-hensive Quality Score	Compre-hensive Quality Ranking
1	2.73	1.97	3.44	3.15	1.84	4.35	1.81	1.08	1.23	21.6	4
2	5.61	5.38	4.81	2.48	3.67	5.8	2.6	2.99	2.09	35.43	1
3	5.93	2.23	4.54	3.38	1.93	3.34	1.44	1	1.23	25.02	3
4	5.29	2.1	5.5	4.28	1.45	4.2	0.94	2.74	1.23	27.73	2
5	4.65	3.02	3.16	3.6	1.64	2.47	0.72	0.91	1.23	21.4	5

Ranked by the weighted score of comprehensive quality, the order of the 5 students in the example is as follows: Student 2 > Student 4 > Student 3 > Student 1 > Student 5.

4. Application value and practical significance

The Fuzzy Analytic Hierarchy Process (FAHP) is an effective method for determining the weights of various indicators and calculating personnel performance scores, thereby addressing the challenges of multi-factor decision-making in human resource management [15]. By utilizing FAHP, subjectivity is minimized, which enhances the accuracy of evaluation results. This approach offers more targeted decision support for decision-makers, while the process data and final outcomes provide comprehensive support for data analysis.

Although the application of FAHP is relatively more complex compared with simple scoring methods, it minimizes human subjective judgment. Its implementation is highly standardized and procedural, which enhances the efficiency of the evaluation process, ensures consistency in evaluation standards, and ultimately reduces both time and resource expenditures associated with the evaluation work.

5. Conclusion

The Fuzzy Analytic Hierarchy Process (FAHP) effectively addresses the limitations of traditional evaluation methods by scientifically determining indicator weights, converting fuzzy judgments into precise values, and integrating qualitative and quantitative analyses. This approach enhances the objectivity and comprehensiveness of personnel ability assessments.

The comprehensive evaluation index system, developed using FAHP and factor analysis, demonstrates strong operability and practical value. This is evidenced by its successful application in student assessment, which incorporates multidimensional indicators and standardized processing of both quantitative and qualitative data.

The FAHP-based evaluation model provides a reliable and extensible framework for assessing scientific personnel across various fields. It reduces subjective bias, enhances decision-making support, and offers a structured approach adaptable to contexts such as enterprise performance reviews and industry-specific talent evaluations.

Disclosure statement

The authors declare no conflict of interest.

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