

Research on Scholarship System in Universities Based on AHP-EWM Combined Empowerment Method

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Abstract. It is crucial to scientifically evaluate students' excellence and to study the motivating effect of scholarships on students. In this paper, we develop a merit-based scholarship system that focuses on students' overall ability and is tailored to individual students. Firstly, the data in the annexes are pre-processed to eliminate the unqualified data and quantify the definite category data in them, and then a three-level evaluation index system is established to determine the overall performance of students, including 4 secondary indicators and 11 tertiary indicators. The weight of each tertiary indicator to the secondary indicators is determined by the entropy weighting method, and then the weight of the secondary indicators to the primary indicators is determined by the AHP-EWM combined weighting method, and finally the TOPSIS method is used to quantify and rank the students' comprehensive performance, and the scholarship is divided into school-level first, second and third grades, and the students with the top grades are selected for the award.

Keywords: AHP-EWM; TOPSIS; scholarship; indicator system.

1. Introduction

Scholarships can stimulate students' motivation to learn and innovate, motivate them to be active in their studies and strive for breakthroughs in their innovative practices. The establishment of a scholarship system in schools is important not only for individual students, but also for school management and educational development. Therefore, when developing a scholarship system, it is necessary to consider various factors and develop a merit-based scholarship system that focuses on the overall ability of students and targets them individually [1].

In this paper, we need to develop a scholarship system that meets the different professional characteristics of the three majors and highlights the characteristics of each major, and we need to establish an incentive evaluation model to analyze the developed scholarship system and explore how the system motivates the students of different majors.

2. Establishment of scholarship system

2.1. Construction of index evaluation system

In this paper, in order to comprehensively consider the development of students' comprehensive ability, this paper establishes a three-level evaluation index system that determines students' comprehensive performance, which includes four second-level indicators (social practice performance, academic performance, grade 4 and 6 performance, and scientific research competition performance) and eleven third-level indicators. This paper determines the weight of each three-level indicator to the second-level indicators by entropy weighting method, and then determines the weight of the second-level indicators to the first-level indicators by using AHP-EWM combined assignment method to determine the weight of the third-level indicators by normalization and entropy weighting method.

2.2. Calculation of three-level index weights using entropy weighting method

(1) Calculation of the weights of the three levels of indicators

Entropy weighting method is an objective weighting method, which can avoid the influence of subjective factors on the quantification results of three-level indexes to the maximum extent. The method is based on the principle of variability degree of indicators for weight assignment.

Firstly, in this paper, the quantified three-level index data need to be normalized and normalized to ensure the non-negativity of the data.

$$C_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

Where C_{ij} is the normalized variable, and x_{\min} and x_{\max} are the maximum values of each indicator, respectively. The weight occupied by the i th tertiary indicator under the j th secondary indicator is calculated and considered as the probability p_{ij} in calculating the information.

$$p_{ij} = \frac{C_{ij}}{\sum_{i=1}^n C_{ij}} \quad (2)$$

The information entropy d_j of the j th secondary index is calculated, and the corresponding information utility value h_j is calculated. The larger the information entropy is, the less effective information is available for the secondary index, and the introduction of the information utility value h_j can positively measure the amount of information.

$$d_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln(p_{ij}) \quad (3)$$

$$h_j = 1 - d_j \quad (4)$$

The final normalization yields the entropy weight of each indicator w_j .

$$w_j = \frac{h_j}{\sum_{j=1}^n h_j} \quad (5)$$

3. Establish an improved compound weight model to calculate the secondary index weights

In this paper, AHP and EWM are combined in a dynamic way to form a composite weight that can meet the requirements [3].

Suppose an evaluation problem has an evaluation indicator, the weight of the j th indicator determined by using AHP is φ_j , and the weight of the j th indicator determined by using EWM is θ_j ; at the same time, suppose the decision is made with a risk preference of ε_j tending to use the weight determined by AHP, then the risk preference of $(1-\varepsilon_j)$ tends to use the weight determined by EWM [4].

(1) Acquisition of AHP weighting coefficients

Let the judgment matrix resulting from the comparison be $A = \{\alpha_{jk} \mid k, j = 1, 2, \dots, n\}$.

$$A = (\alpha_{jk})_{n \times n} = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2n} \\ \vdots & \vdots & & \vdots \\ \alpha_{n1} & \alpha_{n2} & \cdots & \alpha_{nn} \end{bmatrix}_{n \times n} \quad (6)$$

First normalizes the column vectors of the judgment matrix, then myopically finds the corresponding maximum eigenvalue λ_{Max} and the corresponding eigenvector F , and finally normalizes F to determine the weights of each evaluation factor, calculated as

$$\varphi'_{jk} = \frac{a_{jk}}{\sum_{k=1}^n a_{jk}} \quad (7)$$

$$\varphi_j = \frac{\sqrt[n]{\prod_{k=1}^n \varphi'_{jk}}}{\sum_{k=1}^n \sqrt[n]{\prod_{k=1}^n \varphi'_{jk}}} \tag{8}$$

The AHP weights of each evaluation factor for the three majors are as shown in Table 1:

Table 1. AHP weights of each evaluation factor for the three majors

	Engineering AHP(%)	Science AHP(%)	Arts and Sciences AHP(%)
Social Practice	4.754	4.427	5.258
Class 4 and 6	10.377	8.882	22.905
Scientific Research	22.6	26.139	9.108
Competition			
Study	62.259	60.552	62.728

To test the coordination among the indicators in the judgment matrix, a consistency test is required, which can usually be expressed as

$$C_R = \frac{\lambda_{max} - n}{(n-1)R_I} \tag{9}$$

In the above equation: n is the number of evaluation indicators; C_R is the consistency test ratio; R_I is the random consistency indicator, whose value is related to the number of comparison factors. It is usually considered that: when $C_R < 0.1$, the judgment matrix meets the consistency requirements and the weight vector $\psi = (\varphi_1, \varphi_2, \dots, \varphi_j, \dots, \varphi_n)$; when $C_R \geq 0.1$, the judgment matrix does not meet the consistency requirements and must be adjusted until it passes the consistency requirements. It can be seen that the consistency ratio C_R of each profession is less than 0.1, which meets the consistency requirement.

(2) Acquisition of EWM weight coefficients

Entropy E_j is calculated based on the decision matrix B with the following formula:

$$E_j = -K \sum_{i=1}^m \frac{x_{ij}}{e_{ij}} \ln \frac{x_{ij}}{e_{ij}} \tag{10}$$

$$e_{ij} = \sum_{i=1}^m x_{ij} \tag{11}$$

In the above equation, $i=1, 2, \dots, m; j=1, 2, \dots, n; K = 1/\ln n$, K is the constant coefficient; x_{ij} is the value of the j th evaluation index of the first scheme; E_j is the entropy value of the j th index and there is $E_j \in [0, 1]$.

f_j is the degree of consistency of the contribution of the programs under the j th evaluation index, and the formula is as follows:

$$f_j = 1 - E_j \tag{12}$$

Therefore, the standardized EWM weight coefficient for the j th evaluation indicator is

$$\theta_j = \frac{f_j}{\sum_{j=1}^n f_j} \tag{13}$$

When the value of each program under a certain evaluation indicator tends to be the same, i.e., tends to 0, it indicates that the sensitivity of each program to this evaluation indicator is not high, the contribution of this evaluation indicator to the evaluation of the program is small, and the weight coefficient of this evaluation indicator is correspondingly small; Conversely, the weight coefficient value of this evaluation indicator is large.

The analysis of EWM weight coefficients for the three specialties is as shown in Table 2:

Table 2. EWM weighting factors for the three professions

	Engineering EWM(%)	Science EWM(%)	Arts and Sciences EWM(%)
Social Practice	24.163	62.212	57.355
Class 4 and 6	5.993	6.807	9.208
Scientific Research Competition	64.248	24.342	27.984
Study	5.596	6.638	5.452

(3) Improving the calculation of compound weights

In order to organically combine the weights obtained by subjective and objective assignment methods, and considering the different dispersion of different indicator values, the fixed weight preference coefficients cannot fully reflect the information characteristics of EWM, the final indicator weights are obtained by using distance indicator ρ_j as the composite weight.

Combined with the already derived AHP weight coefficients φ_j and EWM weight coefficients θ_j , the composite weights ρ_j can be expressed as

$$\rho_j = \sqrt{(\varepsilon_j \varphi_j)^2 + [(1 - \varepsilon_j) \theta_j]^2} \tag{14}$$

To determine the value of ε_j , a planning model can be built using the least squares method.

$$\min \rho_j = \sqrt{(\varepsilon_j \varphi_j)^2 + [(1 - \varepsilon_j) \theta_j]^2} \quad 0 \leq \varepsilon \leq 1 \tag{15}$$

The dynamic weight preference coefficient ε_j is obtained by solving for

$$\varepsilon_j = \frac{\theta_j^2}{\varphi_j^2 + \theta_j^2} \tag{16}$$

The results of the composite weights of the secondary indicators for the three specialties are as shown in Table 3:

Table 3. Composite weights of secondary indicators for each profession

Compound weights	Academic Performance	Research and Competition Achievements	Grade 4 and 6 results	Social Practice Achievements
Engineering	0.992	0.1105	0.2506	0.0373
Science	0.9883	0.4636	0.3695	0.0047
Arts and Sciences	0.9924	0.0957	0.1415	0.4571

4. Development of an improved composite weight TOPSIS integrated judging model

TOPSIS is a multi-objective decision analysis method for ranking multiple evaluation options according to their relative merits [5].

(1) Initial judgment matrix

Let $U = \{U_1, U_2, \dots, U_m\}$ be the set of programs, where $U_i (0 < i \leq m)$ is the i th feasible program, and the set of evaluation indicators for each program is set to $P = \{P_1, P_2, \dots, P_n\}$, with $x_{ij} (0 < i \leq m, 0 < j \leq n)$ denoting the value of the i th evaluation indicator of the j th program, a decision matrix B can be established.

$$B = (x_{ij})_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}_{m \times n} \tag{17}$$

(2) Decision matrix standardization

In order to maintain the comparability among evaluation indicators, the indicators with larger values are usually called revenue indicators, and the indicators with smaller values are called consumption indicators. In order to compare the indicators in the decision matrix, standardization is required.

For the revenue indicators and expendable indicators, there are

$$\delta_{ij} = \frac{x_{ij}}{\max_j x_{ij}} \tag{18}$$

$$\delta_{ij} = \frac{\max_j x_{ij}}{x_{ij}} \tag{19}$$

Normalizing the evaluation metrics, there are

$$\delta'_{ij} = \frac{\delta_{ij}}{\sum_{i=1}^m \delta_{ij}} \tag{20}$$

The final normalized decision matrix obtained is

$$R = (\delta'_{ij})_{m \times n} = \begin{bmatrix} \delta'_{11} & \delta'_{12} & \dots & \delta'_{1n} \\ \delta'_{21} & \delta'_{22} & \dots & \delta'_{2n} \\ \vdots & \vdots & \dots & \vdots \\ \delta'_{m1} & \delta'_{m2} & \dots & \delta'_{mn} \end{bmatrix}_{m \times n} \tag{21}$$

(3) Posting progress analysis

In the process of decision matrix normalization, the evaluation criteria of revenue and consumption indicators have been revised to be consistent, i.e., larger values of the indicators indicate better performance. Therefore, the positive ideal solution is the solution consisting of the maximum value of each row vector in the decision matrix R, while the negative ideal solution is the solution consisting of the minimum value of each row vector in the decision matrix R. The expression is

$$\begin{cases} R^+ = \{ \max(\delta'_{ij}) \mid i \in (1, m); j \in (1, n) \} \\ R^- = \{ \min(\delta'_{ij}) \mid i \in (1, m); j \in (1, n) \} \end{cases} \tag{22}$$

In the above equation, and are the positive ideal solution and negative ideal solution, respectively.

As a result, the distances of each evaluation scheme from the positive ideal solution and the negative ideal solution are expressed as

$$\begin{aligned} d_i^+ &= \sqrt{\sum_{j=1}^n \varepsilon_j (\delta'_{ij} - \delta_j^+)^2} \\ d_i^- &= \sqrt{\sum_{j=1}^n \varepsilon_j (\delta'_{ij} - \delta_j^-)^2} \end{aligned} \tag{23}$$

In the above equations: d_i^+ and d_i^- are the distance values of the i th solution from the positive and negative ideal solutions, respectively; ε_i is the value of the composite weight obtained above; δ_j^+ and δ_j^- are the values of the indicators corresponding to R^+ and R^- , respectively.

As a result, the equation for the fit degree τ_i can be expressed as

$$\tau_i = \frac{d_i^-}{d_i^+ + d_i^-}, i \in (1, m) \tag{24}$$

Obviously, the fit of the program to be evaluated takes the value of (0, 1), and the closer it is to 1 indicates that the farther it is from the negative ideal solution, the better the program is.

In this paper, based on the ranking of the posting degree from highest to lowest, the winning students are selected according to the coverage of the award, and the award categories are: school-level first prize, school-level second prize, and school-level third prize.

5. Summary

This paper innovatively uses an improved compound weight TOPSIS composite judging model to calculate students' composite scores. This method can take into account both subjective intention and objective facts. The composite score has different weights among different colleges, which fully reflects the characteristics of each college and can better reflect the differences among different colleges.

The scholarship system given in this paper is too simple and lacks other separate awards. In order to better stimulate students' enthusiasm and innovation, further improvements can be made in the award setting in the future. This paper does not consider other student profiles, such as interpersonal relationships, financial situation and gender. These factors can also have an impact on students' learning and research.

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