Research on Evaluation of Employment Quality of Higher Vocational Students Based on Multi-hierarchal Gray Systematic Evaluation Method

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Abstract
The employment quality of higher vocational students reflects the school’s operation quality. In order to overcome ambiguity and uncertainty in the evaluation of the employment quality of higher vocational students, the multi-hierarchal gray systematic evaluation method is applied for evaluation research. The evaluation indicator system for the employment quality of higher vocational students is built around the government level, the graduate level and the social level. The weight coefficients of indicators at all levels are determined using the analytic hierarchy process, and the gray evaluation matrix of indicators at all levels is obtained in combination with the gray evaluation method. The evaluation results of the employment quality of students from higher vocational colleges are obtained through fuzzy operation. This method can help higher vocational colleges understand the overall situation of the employment quality of their students as well as provide theoretical and practical references for higher vocational colleges to improve the employment quality of graduates.

Index Terms—Multi-hierarchal gray systematic evaluation method; higher vocational students; evaluation on employment quality.

1. INTRODUCTION

With the promulgation of the Implementation Scheme for National Vocational Education Reform issued by the State Council, the categorization of vocational colleges has become clearer, and the employment quality of vocational colleges has also become an important indicator for the development of vocational education. It is an issue that the vocational education personnel are constantly thinking about, on the ways to achieve high-quality employment for graduates from vocational colleges on the basis of ensuring employment. It is also an issue worthy of in-depth discussion, on the ways to evaluate the employment quality of graduates from vocational colleges more objectively.

Through literature retrieval, it is not difficult for us to find that the "employment quality of college students" has long been a hot topic in the academic circle. There are dozens to more than a hundred articles discussing this topic every year, which, from another perspective, also confirms the importance of the employment quality of college students. Judging from the evaluation of the "employment quality of college students", the amount of literature in this aspect has decreased sharply, which indicates that there are more qualitative literature but fewer articles on quantitative research on the topic of "employment quality of college students". However, quantitative research is an important method for evaluating the "employment quality of college students". The representative pieces of literature are as follows: Liang Guanghua [1] researched the optimization of
3. PROCESS OF MULTI-HIERARCHAL GRAY EVALUATION

3.1. Establish an evaluation indicator system

The evaluation indicator system is the basis for evaluating the evaluation object, and is a set of various factor indicators that affect the evaluation object. The factor indicators in the set are broken down into several levels from the top to the bottom according to different attributes. All factor indicators in the same layer effect and be subordinate to a certain factor indicator in the upper layer, and each factor indicator in the same layer dominates and is affected by the corresponding factor indicator in the next layer. The evaluation indicator system $U$ is as follows:

- Target layer: $U$
- The comprehensive indicator layer is: $\{U_1, U_2, \ldots, U_x\}$
- The project indicator layer is: $\{U_{x1}, U_{x2}, \ldots, U_{xy}\}$
- The project sub-indicator layer is: $\{U_{xy1}, U_{xy2}, \ldots, U_{xyz}\}$

Where: $U_{xy} - y$th project indicator under the $x$th comprehensive indicator, $U_{xyz} - z$th project indicator in the $y$th project indicator under the $x$th comprehensive indicator.

3.2. Determine the indicator weight with the analytic hierarchy process

(1) Construct a numerical judgment matrix

In the analytic hierarchy process, the relative importance between factors in pairs at each level is qualitative. The T.L. saaty 1-9 scale method is used to transform qualitative evaluation into quantitative evaluation, and the values are used to measure the relationship between various relative importance. This is done so as to construct a judgment matrix.

(2) Calculate the indicator weight

After determining the judgment matrix $A$, use the Matlab software to solve the maximum eigenvalue $\lambda_{max}$ and its corresponding eigenvector $V$, and normalize the eigenvector $V$ to obtain the indicator weight $W$.

(3) Check the consistency

Calculate the consistency indicator $CI = (\lambda_{max} - 1)/(n - 1)$ and the random consistency ratio $CR = CI/RI$. Among them, $RI$ is the average consistency indicator of the judgment matrix. Judge the size of $CR$. If $CR < 0.1$, the consistency is met. Otherwise, the value of the judgment matrix should be adjusted until the consistency is satisfactory.
3.3. Develop the scoring level standards of evaluation indicators

Develop the scoring level standards, and quantify the evaluation indicator $U_{ij}$. The conventional four-level comment system is adopted in this paper. Various evaluation indicators are divided into four levels, i.e., "excellent, good, average and poor", and the corresponding scores are 4, 3, 2 and 1 point respectively. The indicator level is between two adjacent levels, and the corresponding scores are 3.5, 2.5 and 1.5 points.

3.4. Organize scoring to obtain the evaluated sample matrix

Assuming that there are $k$ evaluators to score the indicator $U_{xyz}$, and the serial number of the evaluator is $s, s = 1,2, \ldots, k$, then the score given for the indicator $U_{xyz}$ by the $s$th evaluator is recorded as $u_{xyz}$, and the evaluated sample matrix $R^{(xy)}$ of the $y$th project indicator under the $x$th comprehensive indicator can be obtained;

$$R^{(xy)} = \begin{bmatrix}
    r_{xy11} & r_{xy12} & \cdots & r_{xy1k} \\
    r_{xy21} & r_{xy22} & \cdots & r_{xy2k} \\
    \vdots & \vdots & \ddots & \vdots \\
    r_{xyz1} & r_{xyz2} & \cdots & r_{xyzk}
\end{bmatrix}$$

3.5. Determine the evaluation gray class

Analyze the scoring level standard of the analysis indicator $U_{xyz}$, and determine the level of gray class. The gray number of evaluation gray class $e, e = 1,2, \ldots, g$ and the whiteningization weight function of the gray class $f_e(x)$. $f_e(x)$ can quantitatively describe the degree to which a certain evaluation object belongs to a certain gray class, i.e., the relationship of changes with the size of the evaluated indicator or sample point value.

3.6. Calculate the gray evaluation coefficient

For the evaluation indicator $U_{xyz}$, the gray evaluation coefficient belonging to the $e$th evaluation gray class is recorded as $p_{xyz}$, and

$$p_{xyz} = \sum_{s=1}^{k} f_e(r_{xyz})$$

(1)

The total gray evaluation coefficient belonging to various evaluation gray classes is recorded as $p_{xyz}$, and

$$p_{xyz} = \sum_{e=1}^{g} p_{xyz}$$

(2)

3.7. Calculate the gray evaluation weight vector and weight matrix

For the evaluation indicator $U_{xyz}$, all evaluators record the gray evaluation weight belonging to the $e$ gray class as $d_{xyze}$, and: $d_{xyze} = p_{xyz}/p_{xyz}$. The gray evaluation weight vector $d_{xyze}$ is calculated as $\sum_{s=1}^{k} f_e(r_{xyz})$ of the evaluation indicator $U_{xyz}$ for each gray class.

After integrating the gray evaluation weight vector of indicator $U_{xyz}$ to which $U_{xy}$ belongs for each evaluation gray class, the gray evaluation weight matrix $D_{xy}$ of indicator $U_{xyz}$ to which $U_{xy}$ belongs for each evaluation gray class is obtained:

$$D_{xy} = \begin{bmatrix}
    d_{xy1} & d_{xy2} & \cdots & d_{xyg} \\
    d_{xy11} & d_{xy12} & \cdots & d_{xy1g} \\
    \vdots & \vdots & \ddots & \vdots \\
    d_{xy21} & d_{xy22} & \cdots & d_{xy2g}
\end{bmatrix}$$

3.8. Perform comprehensive evaluation of $U_{xy}$

Comprehensive evaluation of $U_{xy}$ is performed through fuzzy operation, the evaluation result is recorded as $C_{xy}$, and

$$C_{xy} = W_{xy} \circ D_{xy} = [c_{xy1}, c_{xy2}, \ldots, c_{xyg}]$$

(3)

3.9. Perform comprehensive evaluation of $U_{x}$

The gray evaluation weight matrix $D_{x} : D_{x} = [c_{x1}, c_{x2}, \ldots, c_{xg}]$ of indicator $U_{xy}$, to which $U_{x}$ belongs for each evaluation gray class is obtained through the comprehensive evaluation result $C_{xy}$ of $U_{xy}$. Comprehensive evaluation of $U_{x}$ is performed through fuzzy operation, the evaluation result is recorded as $C_{x}$, and

$$C_{x} = W_{x} \circ D_{x} = [c_{x1}, c_{x2}, \ldots, c_{xg}]$$

(4)

3.10. Perform comprehensive evaluation of $U$

The gray evaluation weight matrix $D : D = [c_{1}, c_{2}, \ldots, c_{8}]$ of indicator $U_{x}$, to which $U$ belongs for each evaluation gray class is obtained through the comprehensive evaluation result $C_{x}$ of $U_{x}$. Comprehensive evaluation of $U$ is performed through fuzzy operation, the evaluation result is recorded as $C$, and

$$C = W \circ D = [c_{1}, c_{2}, \ldots, c_{g}]$$

(5)
4. PROCESS OF MULTI-HIERARCHICAL GRAY EVALUATION ON EMPLOYMENT QUALITY OF COLLEGE STUDENTS

4.1. Establish the evaluation indicator system for the employment quality of college students

After having extensively collected opinions from the Enrollment and Employment Office (Student Work Department), Youth League Committee, secondary colleges, internal students, graduates and employers, three aspects, i.e., government-level evaluation, graduate-level evaluation and social-level evaluation, are determined as the comprehensive indicator layer of the evaluation system. In actuality, the subset of each factor of the comprehensive indicator layer also includes the corresponding factor, i.e., the corresponding project indicator layer. Through informal discussion among the experts, six factors, including employment opportunities, are determined as the project indicator layer, and 17 factors, including the initial employment rate of the graduates, are determined as the project sub-indicator layer according to the statistical results. The evaluation system is as shown in Figure 1.

![Evaluation Indicator System for Employment Quality of College Students](image)

**Figure 1** Evaluation indicator system for employment quality of college students

4.2. Determine the indicator weight with the analytic hierarchy process

The literature [6] is quoted and the analytic hierarchy process adopted to determine the weight of the evaluation indicator of each layer so as to determine the weights of the comprehensive indicator layer, the project indicator layer and the project sub-indicator layer. The weight set of the comprehensive indicator layer is \( W = (0.3 \ 0.4 \ 0.3) \); the weight sets of various project indicator layer are \( W_1 = (0.5 \ 0.5) \), \( W_2 = (0.625 \ 0.375) \), \( W_3 = (0.2 \ 0.8) \); and the weight sets of various project sub-indicator layers are \( W_{11} = (0.1 \ 0.26 \ 0.64) \), \( W_{12} = (0.273 \ 0.091 \ 0.091 \ 0.273 \ 0.273) \), \( W_{21} = (0.5 \ 0.5) \), \( W_{22} = (0.1 \ 0.26 \ 0.64) \), \( W_{32} = (0.1 \ 0.26 \ 0.64) \).

4.3. Organize scoring to obtain the evaluated sample matrix

Five experts from the education system were gathered to score the project sub-indicators under the project indicator layer corresponding to the government-level evaluation indicator layer according to the scoring level standard; Five graduates were gathered to score the project sub-indicators under the working conditions and career development according to the scoring level standard; the parents and employers of the five graduates scored the project sub-indicators under the social-level evaluation respectively. The corresponding scores of excellent, good, average and poor are 4, 3, 2 and 1 point respectively. The corresponding scores between two adjacent levels are 3.5, 2.5 and 1.5 points. The evaluated sample matrix \( R^{(11)} \), \( R^{(12)} \), \( R^{(21)} \), \( R^{(22)} \), \( R^{(31)} \) and \( R^{(32)} \) of six project indicator layers are obtained:

\[
R^{(11)} = \begin{bmatrix}
3.5 & 4.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.0 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.5 \\
3.5 & 3.0 & 3.0 & 3.5 & 3.5 \\
1.5 & 2.0 & 3.0 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.0 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.0 & 3.5 \\
2.5 & 2.0 & 2.0 & 1.5 & 2.0 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.0 & 3.5
\end{bmatrix}
\]

\[
R^{(12)} = \begin{bmatrix}
3.5 & 4.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.0 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.5 \\
3.5 & 3.0 & 3.0 & 3.5 & 3.5 \\
1.5 & 2.0 & 3.0 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.0 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.5 & 3.5 \\
2.5 & 2.0 & 2.0 & 1.5 & 2.0 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.0 & 3.5
\end{bmatrix}
\]

\[
R^{(21)} = \begin{bmatrix}
3.5 & 4.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.0 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.5 \\
3.5 & 3.0 & 3.0 & 3.5 & 3.5 \\
1.5 & 2.0 & 3.0 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.0 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.5 & 3.5 \\
2.5 & 2.0 & 2.0 & 1.5 & 2.0 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.0 & 3.5
\end{bmatrix}
\]

\[
R^{(22)} = \begin{bmatrix}
3.5 & 4.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.0 \\
3.0 & 3.5 & 3.5 & 3.0 & 3.5 \\
3.5 & 3.0 & 3.0 & 3.5 & 3.5 \\
1.5 & 2.0 & 3.0 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.0 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.5 & 3.5 \\
2.5 & 2.0 & 2.0 & 1.5 & 2.0 \\
3.5 & 3.0 & 3.5 & 3.5 & 3.5 \\
3.0 & 3.5 & 3.5 & 3.5 & 3.5 \\
3.0 & 2.5 & 3.0 & 3.0 & 3.5
\end{bmatrix}
\]
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4.4 Determine the evaluation gray class

Considering 4 evaluation gray classes, the serial number of the evaluation gray class is set as e, that is to say, e=1, 2, 3, 4. They correspond to four levels, i.e., "excellent", "good", "average" and "poor" respectively. The corresponding gray number and whitenization weight function are as follows: First gray class "excellent" (e=1), gray number $\mathcal{E}_1 \in [4.0, \infty)$, the whitenization weight function is $f_1(x)$ (as shown in Figure 2 (a)); Second gray class "good" (e=2), gray number $\mathcal{E}_2 \in [0.3,0.6,0)$, the whitenization weight function is $f_2(x)$ (as shown in Figure 2 (b)); Third gray class "average" (e=3), gray number $\mathcal{E}_3 \in [0.2,0.4,0)$, the whitenization weight function is $f_3(x)$ (as shown in Figure 2 (c)); Forth gray class "poor" (e=4), gray number $\mathcal{E}_4 \in [0.1,0.2,0)$, the whitenization weight function is $f_4(x)$ (as shown in Figure 2 (d)).

\[
R^{(21)} = [4.0 \ 3.5 \ 3.5 \ 4.0 \ 4.0] \\
R^{(22)} = 
\begin{bmatrix} 
3.5 & 4.0 & 3.0 & 3.5 & 3.0 \\
3.5 & 3.0 & 3.0 & 3.0 & 2.5 \\
3.0 & 3.0 & 3.5 & 3.0 & 3.0 
\end{bmatrix}
\]

\[
f_1(x) = \begin{cases} 
\frac{1}{4} x & (xe[0,4.0)) \\
1 & (xe[4.0, \infty)) 
\end{cases}
\]

When e=2, the 2nd gray class is "good", set the gray number $\mathcal{E}_2 \in [0.3,0.6,0)$, and record the whitenization weight function of the class as $f_2(x)$,

\[
f_2(x) = \begin{cases} 
\frac{1}{3} x & (xe[0,3.0)) \\
-\frac{1}{3} x + 2 & (xe[3.0,0.6,0)) 
\end{cases}
\]

When e=3, the 3rd gray class is "average", set the gray number $\mathcal{E}_3 \in [0.2,0.4,0)$, and record the whitenization weight function of the class as $f_3(x)$,

\[
f_3(x) = \begin{cases} 
\frac{1}{2} x & (xe[0,2.0)) \\
-\frac{1}{2} x + 2 & (xe[2.0,0.4,0)) 
\end{cases}
\]

When e=4, the 4th gray class is "poor", set the gray number $\mathcal{E}_4 \in [0.1,0.2,0)$, and record the whitenization weight function of the class as $f_4(x)$,

\[
f_4(x) = \begin{cases} 
x & (xe[0,1.0)) \\
-x + 2 & (xe[1.0,2.0)) 
\end{cases}
\]

4.5 Calculate the gray evaluation coefficient

Since e=1, 2, 3, 4, the gray evaluation weight vector of the evaluation indicator $U_{xyz}$ for each gray class $d_{xyz} = (d_{x,y,z1}, d_{x,y,z2}, d_{x,y,z3}, d_{x,y,z4})$. For the evaluation indicator $U_{111}$, the gray evaluation coefficient belonging to the e th evaluation gray class is: e=1, $P_{111} = \sum_{i=1}^{d_{xyz}} f_1(r_{111i}) = f_1(3.5) + f_1(4) + f_1(3.5) + f_1(3.5) + f_1(3.5) = 0.875 + 1 + 0.875 + 0.875 + 0.875 = 4.5$. Similarly, e=2, $P_{1112} = 4$; e=3, $P_{1113} = 1$; e=4, $P_{1114} = 0$, and the total gray evaluation coefficient of the evaluation indicator $U_{111}$ belonging to each evaluation gray class is $P_{111} = \sum_{e=1}^{4} P_{111e} = 9.5$.

4.6 Calculate the gray evaluation weight vector and weight matrix

For the evaluation indicator $U_{111}$, all evaluators record the gray evaluation weight belonging to the 1 gray class as $d_{111}$, and: $d_{111} = P_{111}/P_{111} = 0.4737$. It can be concluded that the gray evaluation weight vector of each gray class to which the evaluation indicator $U_{111}$ belongs is: $d_{111} = (d_{1111}, d_{1112}, d_{1113}, d_{1114}) = (0.4737, 0.4211, 0.1053, 0)$. Similarly, the following can be obtained: $d_{112}$, $d_{113}$ and $d_{114}$. After integrating the gray evaluation weight vector of indicator $U_{112}$ for the evaluation gray class, the gray evaluation weight matrix $D_{11}$ of indicator $U_{112}$ to which $U_{111}$ belongs for each evaluation gray class is obtained.

\[
D_{11} = 
\begin{bmatrix} 
0.4737 & 0.4211 & 0.1053 & 0 \\
0.3750 & 0.4375 & 0.1875 & 0 \\
0.3750 & 0.4375 & 0.1875 & 0 
\end{bmatrix}
\]
Likewise, $D_{12}$, $D_{21}$, $D_{22}$, $D_{31}$ and $D_{32}$ can be obtained.

4.7. Perform comprehensive evaluation of $U_{xy}$

For $U_{11}$, the comprehensive evaluation result $C_{11}$ is:

$$C_{11} = W_{11}^\circ D_{11} = (0.3750, 0.4375, 0.1875, 0)$$

Similarly, $C_{12}, C_{21}, C_{22}, C_{31}$ and $C_{32}$ can be obtained.

4.8. Perform comprehensive evaluation of $U_x$

The gray evaluation weight matrix $D_1 = [C_{11}, C_{12}]^T$ of indicator $U_{11}$ to which $U_1$ belongs for each evaluation gray class is obtained through the comprehensive evaluation result $C_{11}$ of $U_{11}$. Comprehensive evaluation of $U_1$ is performed, and the evaluation result $C_1$ is recorded as:

$$C_1 = W_1^\circ D_1 = (0.3750, 0.4375, 0.273, 0.091)$$

Similarly, $C_2$ and $C_3$ can be obtained.

4.9. Perform comprehensive evaluation of $U$

The gray evaluation weight matrix $D = [C, C_1, C_2]^T$ of indicator $U_1$ to which $U$ belongs for each evaluation gray class is obtained through the comprehensive evaluation result $C_1$ of $U_1$. Comprehensive evaluation of $U$ is performed, and the comprehensive evaluation result is:

$$C = W^\circ D = (0.4, 0.4, 0.273, 0.091)$$

The evaluation result weight vector $C$ is only a description of the degree of the evaluation object’s gray class. In order to avoid information distortion, uniformization treatment should be performed, and each gray level should be assigned according to the gray level. Let the gray level vector $V = [4, 3, 2, 1]$ and obtain comprehensive evaluation $S: S = CV^\top = 3.437$. The results show that the employment quality of the students of this college is evaluated as good.

5. CONCLUSION

The analytic hierarchy process can break down the complicated target layer and determine the importance of each indicator, making the evaluation system fairer and more objective. The gray evaluation method assigns the corresponding values to the qualitative indicators according to the division level so as to improve the reliability and accuracy of the evaluation system. The combination of the two achieves objective and an accurate evaluation of the employment quality of higher vocational colleges. This method can help higher vocational colleges to understand the overall situation of the employment quality of their students through data analysis, analyze and find the weak links of the college in the early employment work in a targeted manner as well as provide the basis and reference for further formation of a large employment system that can be checked, modified and controlled.

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