

Design of evaluation system for higher vocational institutions based on AHP hierarchical analysis

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Abstract. The development of higher vocational education is inseparable from a country's economic and social development and industrial structure development. Strengthening scientific evaluation of the development status of higher vocational education is an important prerequisite and foundation for scientifically promoting the development of higher vocational education. Educational evaluation is an effective scientific method for discovering the shortcomings of institutions' development and promoting their improvement. Based on this, it is important to construct a systematic, rich, measurable, forward-looking and robust as an evaluation index system. This paper uses a combination of subjective expert scoring and objective AHP hierarchical analysis to construct an evaluation system for higher vocational institutions, and comprehensively analyses the relative strength indicators and relative weakness indicators of each vocational institution, with a view to helping relevant institutions understand their overall development situation more comprehensively and objectively, and promoting the sustainable development of higher vocational education.

Keywords: Institutional evaluation; AHP; Vocational education.

1. Introduction

As human socio-economic development enters a new stage, the refinement of social division of labour and the promotion of industrial collaboration models are increasingly appearing in different fields. Vocational education is a bridge between the training of talents and the demand for social skills, and assumes a more important task in promoting industrial upgrading and economic restructuring. "How to develop vocational education well" is inevitably dependent on educational evaluation as an important tool for conveying quality information and assessing development. Research on education evaluation has been increasing by scholars and experts in related fields. The focus of research is mainly on universities and the evaluation of their professional, research, teaching and management aspects. In the area of institutional evaluation, OCTAVIO proposes a visual data extraction method to analysis the developmental changes of institutions[1], and Samuel Gratzl proposes a method of comparing multi-attribute rankings to compare the rankings of universities in different years[2]. This paper uses AHP hierarchical analysis to discover and study the comprehensive strength of the collected higher vocational institutions, and further improve the evaluation system through significance and consistency tests, with a view to providing a scientific basis for the planning and construction of higher vocational institutions in the future.

2. The theory of evaluation system of higher education institutions

The evaluation system of higher education institutions established in this paper is analyzed by AHP (Analytic Hierarchy Process), which is a method combining subjective judgment and scientific calculation proposed by Professor Thomas L. Saaty of the University of Pittsburgh in the early 1970's[3]. AHP embodies the idea of decomposing and synthesizing, Representation of different relationships by stratifying and categorizing the problems analyzed and step-by-step[4]. The application of hierarchical analysis is divided into three main steps: the first step is to construct the index system; the second step is to calculate the index weights; and the third step is to calculate the data of each institution according to the weights, resulting in an evaluation score table[5].

2.1 Constructing a hierarchical evaluation model

According to the development characteristics of higher vocational institutions, reference to the research results of relevant aspects. According to the principles of scientificity, systematicity, comparability, and operability[6], the evaluation factors were selected. The scale of school operation B1, major and curriculum construction B2, faculty strength B3, talent cultivation B4, social service B5 and scientific research strength B6 are initially determined as the guideline layers of the evaluation system. To ensure the independence and objectivity of the evaluation factors, relevant experts were invited to score the 30 evaluation indicators in Table 1. The scoring is based on the importance scale 1-9 recommended by Saaty, as shown in table 2.

Table 1 Importance Scale

Score	Description
1	Both indicators are equally important
3	x indicator 3 times more important than y indicator (marginally important)
5	x indicator 5 times more important than y indicator (clearly important)
7	x indicator 7 times more important than y for (strongly important)
9	X indicator 9 times more important than y-indicator (extremely important)
2,4,6,8 decimal	Importance indices between the above descriptions x indicator is less important than y indicator

The experts judge the importance of all the indicators collected and give them a corresponding score. Of these, the very important ones are left in the indicator system with a greater weight and the less important ones are given a smaller weight. The final results are calculated according to the different scores.

Since the sample size is less than 30, the test is carried out using the t-distribution commonly used for small samples. First, because the overall variance is unknown, the entire data obeys a distribution with degrees of freedom of n-1 and the test statistic is

$$t = \frac{\text{mean}(x) - \mu_0}{s / \sqrt{n}} \tag{1}$$

In equation (1), the overall mean was replaced using the sample variance s^2 . Results showing significance levels much less than 0.05, it proves that parameters are statistically insignificant[7].all indicators in Table 2 are retained for the next step of the calculation.

2.2 Determination of weights and consistency tests for first-level indicators

In this paper, a hierarchical single ranking method is used to calculate the importance of all the first level indicators in the criterion level for the target. There are two ways to achieve this, and this paper uses the square root method for calculation. In the judgment matrix A constructed in the previous step, the Mth power of the product of each row is calculated to obtain an M-dimensional vector W_i

$$\overline{W}_i = \sqrt[m]{\prod_{j=1}^m a_{ij}} \tag{2}$$

In Equation (2), a_{ij} denotes the vectors in the judgement matrix A and m is the total number

Table 2 Hierarchical evaluation model

Objective level	Criteria level	Sub-criteria level	Program level	
Evaluation system For higher vocational institutions	college Scale	New Student Arrival Rate	Data associated with 52 higher vocational institutions	
		Number of full-time students (including undergraduates)		
		The Average value of financial allocation per student		
	Programs and Courses	The Average value of teaching and research equipment per student (RMB)		
		National-level Excellence Courses		
		National-level Practical Training Bases		
	Teacher Capability	Teacher Capability		Number of specialties
				National-level Professional Teaching Resources Library for Vocational Education
				Number of teaching staff
				Number of full-time teachers
				Number of senior staff
				Number of associate professors
Associate or above				
Percentage of senior title				
Percentage of graduate degree teachers				
Number of doctoral teachers				
Talent Cultivation	Talent Cultivation	The Proportion of doctoral teachers		
		Number of National Master Teachers/Talent Program of the Ministry of Organization		
		Number of national-level teaching achievement awards		
Social Services	Social Services	Number of national-level teaching teams		
		Initial Employment Matching Rate		
		The Average value of monthly income from initial employment		
Research Strength	Research Strength	Employer satisfaction		
		Social training services (person-days)		
		Training volume of foreign personnel (abroad)		
		Technology service receipts (RMB million)		
		Amount of technology transactions (RMB million)		
		Number of scientific research projects at national and ministerial levels		
		Number of scientific research platforms at or above prefectural and municipal levels		
		First-class awards at national level		

of row vectors. The ratio of each vector to the sum of all vectors is then calculated using equation (3), which is the weight of each indicator W_i

$$W_i = \frac{\bar{W}_i}{\sum_{i=1}^n \bar{W}_i} \quad (3)$$

To ensure that the data is reasonable, a consistency test needs to be performed on each matrix. Use equation (4) to find the maximum characteristic roots of the judgment matrix and the corresponding eigenvectors[8].

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{(AW)_i}{W_i} \quad (4)$$

In Equation (4), λ_{max} is the largest characteristic root in the judgment matrix, and w is the weight value of the index after standardization[9]. Then the Consistency index is calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

In Equation (5), n denotes the total number of indicators. The consistency ratio CR is then derived to determine whether there is a logical problem with the constructed matrix.

$$CR = \frac{CI}{RI} \quad (6)$$

Equation (6), the random consistency index (Random Index, RI) by looking up the table 3, we use Saaty simulated 50,000 times to obtain a table of random consistency values[10].

Table 3 Mean random consistency index

Order	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4

The judgment matrix of the first-order indicators in this paper is six, and the CR value calculated by bringing in the RI value is 0.093, which is less than 0.1. The results show that the degree of consistency of the judgment matrix A is considered to be within the tolerable range, and the weight vector calculation can be carried out using the eigenvectors of A. The final calculation results are shown in Table (2.3).

2.3 Weight determination and consistency test of secondary indicators

The weight determination method of the secondary indicators is the same as that of the primary indicators, using the hierarchical single ranking method to obtain the weights of each secondary indicator for the corresponding primary indicators respectively. The two-factor judgment matrix of the second-level indicators under each first-level indicator is constructed, and the CR value of the matrix is calculated to see if it meets the consistency requirements. In this paper, six CR values were obtained for the second-level indicators under the six first-level indicators, which were 0.0083, 0.0042, 0.0358, 0.0858, 0.0452 and 0.0653 respectively, all of which were less than 0.1 and met the consistency requirement. Finally, according to the weight relationship between the primary indicators and the total target, the weights of the secondary indicators were calculated relative to the total target, as shown in Table (2.4)

3. Analysis of Evaluation Results

The data in this paper comes from the reports provided by institutions in the Ministry of Education's statistical annual report, and the evaluation analysis of 52 double-high institutions. The top 10 institutions with high overall evaluation scores are shown in Table 3.1.

From Table 4 we can see that the development of vocational institutions on different evaluation indicators is uneven, and each institution has its strengths and weaknesses in different aspects. Taking the second-ranked institution as an example, we can find out by comparing the relevant information on the official website of this institution. This institution is a national key vocational institution and has been selected to participate in the national "High level development Program". Under the guidance of the program, the university has achieved remarkable results in terms of professional and curriculum development and talent training, indicating that it has achieved good results in teaching and learning, and the quality of employment of its students is high. However, when compared vertically with other institutions, it can be found that its score in social services is low, indicating that this school has a low contribution to social and technical training and occupational Science Popularization, and it has not effectively driven the development of regional vocational education-related economic industries. It also proves that the integration of industry and education and school-enterprise cooperation needs to be strengthened. Other vocational institutions can also adopt this similar analysis method for interpretation and analysis.

Table 4 Factor weights of criterion layer and indicator layer

Criteria level/ Weights	Sub-criteria level	Weights	Total target weighting
college Scale/ 0.1309	New Student Arrival Rate	0.1436	0.01879724
	Number of full-time students (including undergraduates)	0.4589	0.06007001
	The Average value of financial allocation per student	0.3975	0.05203275
Programs and Course/ 0.2683	The Average value of teaching and research equipment per student (RMB)	0.3524	0.09454892
	National-level Excellence Courses	0.3521	0.09446843
	National-level Practical Training Bases	0.2135	0.05728205
	Number of specialties	0.2342	0.06283586
	National-level Professional Teaching Resources Library for Vocational Education	0.082	0.0220006
Teacher Capability/0.2577	Number of teaching staff	0.1125	0.02899125
	Number of full-time teachers	0.1257	0.03239289
	Number of senior staff	0.0622	0.01602894
	Number of associate professors	0.0511	0.01316847
	Associate or above	0.0602	0.01551354
	Percentage of senior title	0.0536	0.01381272
	Percentage of graduate degree teachers	0.0623	0.01605471
	Number of doctoral teachers	0.0651	0.01677627
	The Proportion of doctoral teachers	0.0686	0.01767822
	Number of National Master Teachers/Talent Program of the Ministry of Organization	0.1132	0.02917164
Talent Cultivation/0.1308	Number of national-level teaching achievement awards	0.1022	0.02633694
	Number of national-level teaching teams	0.1233	0.03177441
	Initial Employment Matching Rate	0.3233	0.04228764
Social Services/0.1086	The Average value of monthly income from initial employment	0.4253	0.05562924
	Employer satisfaction	0.2514	0.03288312
	Social training services (person-days)	0.2311	0.02509746
	Training volume of foreign personnel (abroad)	0.1051	0.01141386
Research Strength/0.1037	Technology service receipts (RMB million)	0.3564	0.03870504
	Amount of technology transactions (RMB million)	0.3074	0.03338364
	Number of scientific research projects at national and ministerial levels	0.5388	0.05587356
	Number of scientific research platforms at or above prefectural and municipal levels	0.358	0.0371246
	First-class awards at national level	0.1032	0.01070184

Table 5 Score and aRanking of each Vocational college

Rank	B1	B2	B3	B4	B5	B6	Score
1	0.829467	0.678584	0.608623	0.373939	0.453848	0.285442	0.5752829
2	0.377415	0.659737	0.584312	0.952648	0.008602	0.265686	0.5025287
3	0.316276	1.324412	0.013789	0.333413	0.095411	0.426404	0.4542657
4	0.630166	0.141483	0.597899	0.451599	0.846699	0.006333	0.4255478
5	0.276415	0.532531	0.634525	0.384583	0.195882	0.607607	0.4141541
6	0.187405	0.343579	0.718036	0.569949	0.166789	0.288191	0.3944140
7	0.182427	0.423676	0.748725	0.443132	0.008915	0.444984	0.3894282
8	0.275417	0.344244	0.483898	0.790677	0.218102	0.542368	0.3802196
9	0.37695	0.525249	0.180176	0.4349	0.056014	0.588216	0.2996664
10	0.480168	0.175933	0.164723	0.307537	0.800271	0.777778	0.2796412

4. Summary and outlook

In this paper, the method of AHP was used to evaluate the comprehensive development of vocational institutions. The indicators were selected using the expert scoring method to count the data involved in the relevant indicators. In order to ensure that the questionnaire has objectivity, a mean t-test was conducted on different questionnaires, and the significance level showed that the probability of falling into "I error" did not exceed the given level, and the indicators could be retained for calculation. In terms of weight determination, the square root method of the hierarchical single ranking approach was chosen to calculate the weights of the indicators in the criterion level relative to the target level separately and Weighting of indicators at sub-criterion level relative to indicators at guideline level. Then this paper calculates the weights of the second-level indicators relative to the total target according to the weights of the first-level indicators, and finally calculates the evaluation results of vocational institutions.

It should be noted that the indicators in this paper are selected with the help of experts and related scholars' scoring tables, and some more objective methods can be selected for analysis in the subsequent research. The weights of the secondary indicators in the sub-criteria level can also be calculated using the hierarchical total ranking method, which is not repeated here.

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