University Ranking Model Based on AHP and entropy weight method

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ABSTRACT

University ranking has a positive impact on making rational use of educational resources, and promoting deep-seated development of higher education and colleges and universities. This paper establishes two models to rank universities in the Yangtze River Delta: Model A uses AHP to analyze 8 main evaluation indicators; model B adopts the entropy weight method with reference to the data of the evaluation authority. In the results of the models, the ranking of top 20 universities in the Yangtze River Delta region is basically same. Comparing the two models, model B refers to the rankings of authoritative institutions, has obvious advantages over model A in terms of solution scale and model complexity, so the calculation results of model B are finally adopted. The models can not only rank the comprehensive strength of colleges and universities, but also be used to optimize the college applications and make better choices for the healthy progress of higher education.

Keywords: AHP, entropy weight method, university ranking, mathematical model

1. INTRODUCTION

The education level of the Yangtze River Delta has always been widely concerned. This area has advantages in talent attraction and development potential because of economic advantages and superior geographical conditions [1]. However, the advantage of scientific research and innovation has declined in recent years [2]. Therefore, evaluating university is of great significance for the youth to choose right universities and the government to adopt right policies. The globalization of higher education has increased the demand for university ranking and stimulated the development of ranking systems. The determination of index attribute weight in university ranking can fall into three categories: subjective weighting method, objective weighting method and combination weighting method.

Subjective weighting methods include Delphi method and AHP, etc. In the Asian evaluation of QS rankings, the information system factors were found after literature review, then utilize the Delphi method to eliminate the factors through the consensus of seven experts [3]. The Delphi method is widely representative, but the results are easily affected by the subjective consciousness and thinking limitations of experts, and the process is cumbersome. The Outline of National Middle and Long-term Education Reform and Development Plan (from 2010 to 2020) constructs a university evaluation index system based on "scientific research, talent training, university reputation and school resources", applies AHP to evaluate universities. AHP decomposes the elements into several levels, builds an index system based on classification, and uses qualitative and quantitative analysis methods to make decisions. It owns the advantages of practicality and strong systematization. Some scholars also improve the classical AHP, R Aliyev et al. [4] introduced the advanced tool FAHP to compare the performance of universities in the UK, providing greater flexibility for decision makers. Due to repeated consultation, the workload is relatively large; using any subjective analysis method, the result will be inevitably disturbed by subjectivity.

In order to weaken the influence of subjectivity, the objective weighting methods have been proposed. The determination of indicator weight mainly comes from the data displayed on the official website. Objective weighting methods mainly include: principal component analysis, factor analysis and entropy method, etc. Principal component analysis can fully reflect the information by dimension reduction. Docampo used this way to re-examine the Shanghai ranking and investigate its reliability and dimension [5]. Factor analysis is the extension of principal component analysis. V Kavitska and others carried out factor analysis on the world university ranking, studied the standardized ranking index values, and proposed a multi-factor model of ranking [6]. The entropy weight method was introduced by Shannon into the information theory, it is simple and practical to convey the importance of indicators, also can reach the standard of

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information and quality about the decision-making project [7,8]. Y Shi and others conducted a study on the influencing factors of university core competitiveness based on the entropy weight grey correlation model [9]. This method can clearly distinguish the degree of effect of each evaluation index, to better achieve the weighting of the contribution degree of the evaluation. Zhang and others [10] proposed a weighting method combined subjective AHP with objective entropy, designed an evaluation system to reflect the quality of graduate education.

The models analyze various indicators of 35 "double first-class" construction universities and 41 "double high plan" schools in the Yangtze River Delta, and makes statistical analysis on the existing university rankings in 2022 by using the characteristics of homogenization and normalization of entropy weight method, finally screen out the university rankings in this region.

2. METHODOLOGY

This paper will establish a mathematical model for evaluating the comprehensive education level according to the key indicators of the major universities, analyze them by the AHP and the entropy weight method, and calculate scores to reflect the education level, it will rank the 38 universities, the ranking of universities and the top 20 strongest universities list are obtained.

2.1 A model and parameters

2.1.1 A model evaluation index construction

The evaluation index system of model A is as follows:

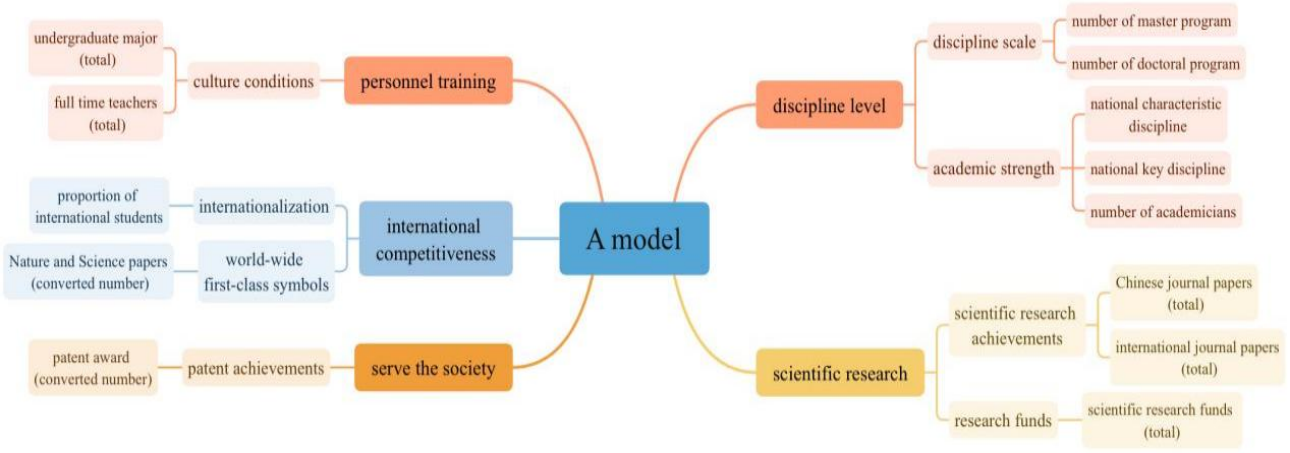

Figure 1. A model index influencing factors.

2.1.2 Determination of index weight of model A

Because indicators have different contributions to the evaluation, in order to evaluate more scientifically, model A selects a multi-level evaluation model, which needs a process from qualitative analysis to quantitative analysis. AHP is used for evaluation and scoring, which focuses on the selection and quantification of evaluation factors and the determination of weight. According to the principle of cascade calculation, the score function A_i of the i^{th} university is constructed as:

$$A_i = \sum_{j=1}^{5} A_{ij} \cdot a_j \tag{1}$$

Where a_j represents the weight of the j^{th} module, score function A_{ij} of the j^{th} module of the i^{th} university is constructed as:

$$A_{ij} = \sum_{m=1}^{x} A_{ijn} \cdot a_{jn} \tag{2}$$

Where a_{jn} represents the weight of the n^{th} item under module j, the n^{th} item score function A_{ijn} of the j^{th} module of the i^{th}

school is constructed as:

$$A_{ijn} = \sum_{m=1}^{x} A_{ijnm} \cdot a_{ijnm} \tag{3}$$

Where a_{jnm} represents the weight of the m^{th} influencing factor under the n^{th} item of module j, function A_{ijnm} of m^{th} influencing factor of the nth item of the j^{th} module of the i^{th} school is constructed as:

$$A_{ijnm} = \frac{S_{ijnm}}{\sum_{k=1}^{39} Sijnk} \tag{4}$$

With reference to ranking calculation methods, the weights a_{jnm} are weighted according to the relative importance of evaluation indicators by using AHP, the results are as follows:

Table 1. Weight of five levels and eight indicators of model A.

Modular (a_j)	Refinement index (a_{jn})	Influence factor	Score (a_{jnm})
Discipline level (0.5)	Discipline scale (0.6)	Number of master program	0.5
		Number of doctoral program	0.5
	Academic strength (0.4)	National characteristic discipline	0.4
		National key discipline	0.4
		Number of Academicians	0.2
personnel training (0.05)	Culture conditions (1.0)	Undergraduate major (total)	0.5
		Full time teachers (total)	0.5
scientific research (0.3)	research funds (0.5)	Scientific research funds (total)	1.0
	Scientific research achievements (0.5)	International Journal Papers (total)	0.5
		Chinese Journal Papers (total)	0.5
Serve the society (0.05)	Patent achievements (1.0)	Patent Award (Converted number)	1.0
International Competitiveness (0.1)	Internationalization (0.5)	Proportion of international students	0.4
	world-wide first-class symbols (0.5)	Nature and Science papers (Converted number)	0.6

Among the five first-class indicators, discipline leve and scientific research are the main indicators, accounting for 0.8 of all indicators. In the discipline level, mainly based on discipline scale, up to 0.6, and the master's degree and doctor's degree are mostly considered. A total of 13 influencing factors are set under the eight secondary indicators, with the highest proportion of scores for scientific research funds and patent awards being 14.29% and 14.29% respectively, and the lowest number of influencing factors for the number of academicians being 2.86%.

2.2 B model and parameters

2.2.1 B model related data collection

Model B refers to the ranking data of universities in the Yangtze River Delta region provided by four world authoritative third-party platforms for model construction, namely Alumni Association ranking, Shanghai ranking, US News ranking and Wu Shulian. The Alumni Association ranking uses 12 indicators such as ideological and political education, 5 indicators such as professional conditions for the Shanghai ranking, 5 indicators such as peer evaluation for US News ranking, Wu Shulian evaluated by 12 disciplines including comprehensive strength. Different institutions select different evaluation indicators, analysis methods and evaluation standards are also different. However, it is undeniable that Shanghai Jiao Tong University, Zhejiang University, Nanjing University, Fudan University and other universities are first-class universities in the Yangtze River Delta, which have a deep attraction to the majority of students. Shanghai Jiao Tong University ranks first in the comprehensive education level of universities in the Yangtze River Delta, followed by Zhejiang University, Nanjing University and Fudan University. The specific ranking is shown in the following figure:

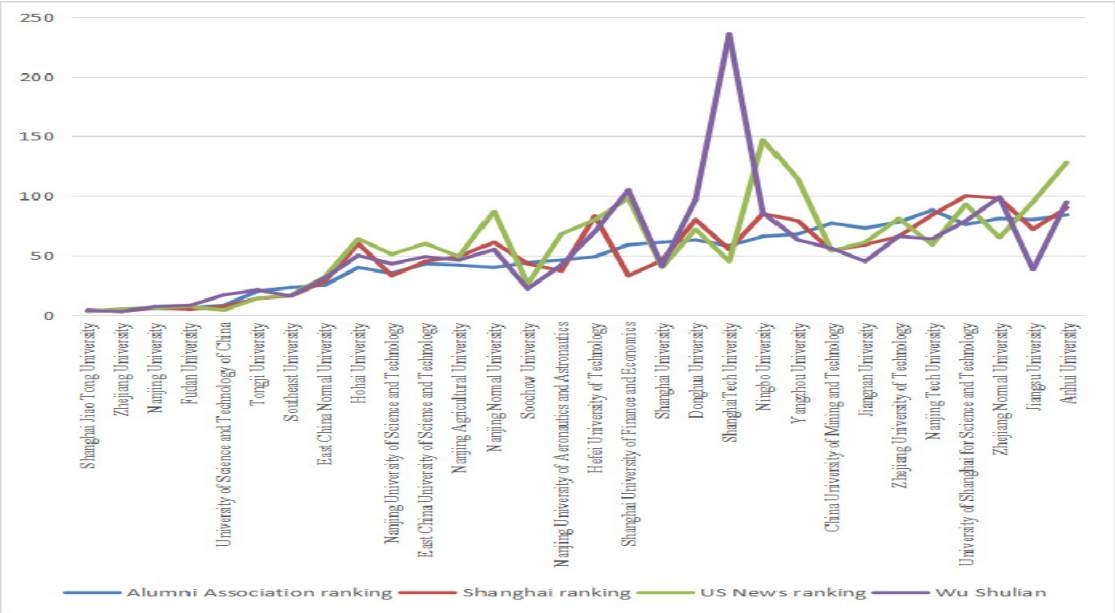

Figure 2 Ranking of universities in the Yangtze River Delta by four authoritative institutions

B model analyzes the indicators of the above four authoritative institutions, and the results obtained by normalizing each indicator with the entropy weight method can better illustrate the advantages of this model, considering not only the indicators of the authoritative institutions but also the characteristics and advantages of various professional disciplines in universities.

2.2.2 B model establishment

Model B belongs to a single-layer ranking model, after the weight is determined, the ranking can be directly obtained by calculating the weight of the ranking system, the focus is on the selection of different ranking systems and the determination of the weight. The weight of the j^{th} ranking system is represented by q_j, the i^{th} university ranking function B_i is constructed as:

$$B_i = \sum_{j=1}^{4} B_{ij} \cdot q_j \tag{5}$$

Determination method of weight q_j by entropy weight method:

2.2.2.1 Data standardization

Seven indicators are selected $X_1, X_2, X_3, X_4, X_5, X_6, X_7$, among which $X_i=(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$, if the normalized value of each indicator data is $Y_1, Y_2, Y_3, Y_4, Y_5, Y_6, Y_7$, then:

$$Y_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(Xi)} \tag{6}$$

2.2.2.2 Calculate the information entropy of each index

According to the definition of information entropy in information theory, the information entropy of a group of data:

$$E_j = -\frac{1}{\ln n} \sum_{i=1}^{n} P_{ij} \ln P_{ij} \tag{7}$$

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \tag{8}$$

If P_{ij}=0, define:

$$\lim_{P_{ij}\to 0} P_{ij}\ln P_{ij}=0 \tag{9}$$

2.2.2.3 Determine the weight of each indicator

According to the calculation formula of information entropy, the information entropy of each index is calculated as E_1, E_2, E_3, E_4. The weight of each indicator can be calculated by information entropy.

$$W_{\mathrm{i}}=\frac{1-E_{\mathrm{i}}}{k-\sum E_i}(i=1,2,3,4) \tag{10}$$

When W_i=q_i, the calculated weight is shown in Table 2:

Table 2. Weight calculation of entropy weight method of four authoritative institutions.

Entropy weight method			
Ranking system	Information entropy E	Information utility value d	Weight W_i
Wu Shulian	0.797	0.203	0.204
Alumni Association ranking	0.758	0.242	0.243
US News ranking	0.714	0.286	0.287
Shanghai ranking	0.735	0.265	0.266

3. RESULTS AND DISCUSSION

Model A uses AHP to calculate and analyze, the total score ranking is shown in model A in Table 3; using entropy weight method to determine the weight, the ranking system can be obtained by combining formula (5) - (10), the detailed ranking is shown in model B in Table 3:

Table 3. University ranking scores of model A and model B.

Model A			Model B		
ranking	University name	score	ranking	University name	Bi value
1	Zhejiang University	0.0744	1	Shanghai Jiao Tong University	3.47
2	Shanghai Jiao Tong University	0.0547	2	Zhejiang University	3.81
3	Fudan University	0.0466	3	Nanjing University	6.20
4	Nanjing University	0.0412	4	Fudan University	6.43
5	Southeast University	0.0354	5	University of Science and Technology of China	8.42
6	Tongji University	0.0342	6	Tongji University	16.88
7	University of Science and Technology of China	0.0316	7	Southeast University	17.98
8	East China Normal University	0.0283	8	East China Normal University	29.03
9	Soochow University	0.0247	9	Soochow University	34.08
10	Nanjing Normal University	0.0246	10	Nanjing University of Science and Technology	40.69

By scoring the indicators of universities selected in the Yangtze River Delta region and comparing the results of model A, it is found that Zhejiang University has significant advantages in comprehensive strength: Zhejiang University recommendation index is 0.0744, Shanghai Jiao Tong University is 0.0547, and Fudan University is 0.0466. From the results of model B, it can be seen that Shanghai Jiao Tong University ranks first in the comprehensive education level of the Yangtze River Delta region with a value of 3.47, surpassing the results of Zhejiang University, the first in model A, by a slight margin of 0.34. Shanghai Jiao Tong University, Zhejiang University, Fudan University and Nanjing University are still rated as the first echelon in terms of the comprehensive education level of universities in the Yangtze River Delta with B_i value of less than 10.

According to the above table, the results obtained by the two models are basically the same, the results of the top 7 universities are the same, and the comparison of the ranking results of the top 20 universities is only slightly different, which shows that the difference between the two models is small.

4. CONCLUSION

This paper uses AHP to analyze the evaluation indexes of universities by establishing model A; model B uses entropy weight method to work with the data of the evaluation authority, the results are as follows:

(1) Model A uses AHP to evaluate and score according to each influencing factor. The data requirements and model complexity of model A are higher than that of model B. The total weighted score has strong credibility for evaluating the comprehensive strength of a university;

(2) In model B, after using entropy weight method to determine the weight, the university ranking can be directly obtained. Therefore, the author believes that the establishment and solution results of model B are better than model A, its accuracy and feasibility are higher;

(3) There is little difference between the ranking results of models A and B, and the top 20 universities with the strongest strength in the Yangtze River Delta can be basically determined.

This paper uses two methods: analytic hierarchy process (AHP) and entropy weight method to establish model A and model B containing a variety of variables, which can be used to analyze the comprehensive strength ranking of universities in the Yangtze River Delta, both with high accuracy and effectiveness. They have a profound impact on filling out college applications reasonably, improving the quality of talent training, promoting the reform and development of universities, and maintaining the steady development of higher education in the Yangtze River. Since the influence of university ranking is multi-faceted and multi-level, the research will be promoted in the direction of establishing more complete and standardized evaluation indicators, more reliable data sources and more scientific methods for determining attribute weights.

REFERENCES

[1] Xu H, Jiao M. City size, industrial structure and urbanization quality—A case study of the Yangtze River Delta urban agglomeration in China[J]. Land Use Policy, 2021, 111.

[2] Luo D A, Liang L, Wang Z, et al. Exploration of coupling effects in the Economy–Society–Environment system in urban areas: Case study of the Yangtze River Delta Urban Agglomeration[J]. Ecological Indicators, 2021,128:107858.

[3] Dachyar M, Dewi F. Improving University Competitiveness by Management Information System[J]. Advanced Science Letters, 2015.

[4] Aliyev R, Temizkan H, Aliyev R. Fuzzy Analytic Hierarchy Process-Based Multi-Criteria Decision Making for Universities Ranking[J]. Symmetry, 2020, 12(8):1351.

[5] Docampo D. On using the Shanghai ranking to assess the research performance of university systems[J]. Scientometrics, 2011, 86(1):p.1.

[6] Kavitska V, Liubchenko V. Building of multi-factor model of world university ranking systems[J]. 2016.

[7] Kumar R, Singh S, Bilga P S, et al. Revealing the Benefits of Entropy Weights Method for Multi-Objective Optimization in Machining Operations: A Critical Review[J]. Journal of Materials Research and Technology, 2021, 10(9).

[8] Zou J, Li P. Modelling of litchi shelf life based on the entropy weight method[J]. Food Packaging and Shelf Life, 2020, 25:100509.

[9] Shi Y, Yang X. Influencing Factors of University Core Competence: An Empirical Study Based on the Entropy Weight Gray Relation Model[J]. Discrete Dynamics in Nature and Society, 2021.

[10] Zhang Z, Wang M. Research on Graduate Education Quality Evaluation Based on Combination Empowerment and Comprehensive Fuzzy Model[J]. IOP Conference Series Materials Science and Engineering, 2020, 768:052003.