

# Research on the Application of AHP-Based Models to Higher Education Systems —Internationalization Perspective as an Example

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## ABSTRACT

In this paper, we will start from constructing a healthy and sustainable higher education system by using the Analytic Hierarchy Process (AHP) to evaluate four guideline layers and fifteen measure layers, calculate the corresponding weights of each indicator and pass the consistency test. Then our model will be applied to three countries, China, Germany and Canada. And then each indicator will be scored high, medium and low by questionnaire and expert evaluation, and the combination of AHP and fuzzy comprehensive evaluation method (FCE) will be used to quantify the comprehensive scores of higher education systems in these three countries.

**Keywords:** *higher education system, Analytic Hierarchy Process, fuzzy comprehensive evaluation method*

## 1. INTRODUCTION

In order to indicate the healthy, sustainable higher education system, the following background is worth mentioning.

A system of higher education is an important element in a nation's efforts to further educate its citizens beyond required primary and secondary education, and therefore has value both as an industry itself and as a source of trained and educated citizens for the nation's economy. Under the background of vigorous development of higher education, how to build a perfect evaluation system of higher education is one of the important tasks to be considered by a country. The further development of education makes the enrollment scale of higher education expand rapidly, and the quality of education largely reflects the quality of talent cultivation in colleges and universities, and a perfect evaluation system of higher education can promote the healthy and sustainable development of higher education. It can be seen that the construction of higher education evaluation system is in line with the development direction of higher education, which can not only highlight the importance of colleges and universities to the level of education under the background of new curriculum reform, but also drive the monitoring of teaching quality through quality evaluation, guide colleges and universities to carry out education reform based on education practice, so as to promote

teaching reform in all aspects and highlight the nature and function of educating people in colleges and universities.

## 2. HIGHER EDUCATION SYSTEM OVERVIEW

Burton Clark examined higher education systems in an international comparative way. His conclusion is that everywhere, higher education works in two basic longitudinal and cross-cutting patterns by discipline and institution [1]. A diverse higher education system usually requires the evaluation of different types of institutions (disciplines) by multiple parallel value criteria, forming a game of reputation between similar institutions (disciplines) and the "beauty of each" between different types of institutions (disciplines), in order to maintain the "harmony but different" quality of the whole higher education system [2]. The reform of education systems in Asia has been significantly influenced by the new management-oriented theories and neoliberalism in the West. European and American academia are considered more "advanced" than domestic academia, but higher education institutions must critically reflect on the extent to which Western education systems can truly integrate with non-Western education systems [3]. Specifically, Germany has been somewhat of a pioneer in government support for institutional excellence in higher education through highly targeted policy initiatives [4]. Canada has a "high participation system of higher education"

(HPSHE), and as early as the 1960s, increasing student enrollment became a major and fairly consistent policy, providing Canada with the foundation for Canada to become one of the most highly educated countries in the world [5]. Higher education in Canada is highly decentralized, and indeed it is often argued that Canadian higher education is best understood as the sum of 13 quite distinct provincial and territorial systems (Jones, 1997) [6]. In the same way, our country is at a disadvantage in internationalization with countries that have well-established assessment mechanisms (such as the United States, Canada, Germany, etc., which are also the main target countries for internationalization of higher education in China) [7].

In China, theoretical studies and researches on the performance of universities have been conducted since the 1980s, and the economist Professor Li Yining used specific indicators such as developmental ability index, skill standard score index and graduate development potential as indicators for measuring university education [8]. Gong Jingyu (2020) selected some key indicators data from the Ministry of Education in 2019 for comparative analysis and used the balanced scorecard to construct a comprehensive budget performance evaluation system for colleges and universities [9]. Chao Liu (2020) established a set of university government procurement performance evaluation system based on network hierarchical analysis and applied the system to evaluate the government procurement work of X universities [10]. Based on the functions of colleges and universities, Xia Dan (2019) screened evaluation indexes from the dimensions of talent cultivation, teaching and education reform, financial management, resource allocation and social service, and constructed a multi-level and three-dimensional evaluation model of college

budget performance based on AHP [11]. In determining the indicators, we designed them according to the principles of orientation, wholeness, objectivity, measurability and simplicity [12]. No matter how different the evaluation indicators are among different countries or different nationalities, the fundamental purpose of all evaluation indicators is to regulate and lead, improve and promote the development of internationalization affairs of higher education [13].

### 3. HIGHER EDUCATION SYSTEM CONSTRUCTION

#### 3.1. Index construction

Higher education system is an important factor for the further development of a country. To assess the health of any nation's system of higher education, we should consider social benefit, teaching and scientific research indicators, talent cultivation indicators, capital efficiency indicators etc to achieve the purpose of comprehensive evaluation. In this paper, we choose the index which is easy to measure and evaluate. In addition, considering the interrelation between the indicators, the hierarchical structure of indicators of higher education system can put the original multi-objective into practice the problem is transformed into a new multi-objective problem with hierarchical index.

Through in-depth analysis of practical problems, the relevant factors are stratified from top to bottom (goal criterion or index scheme or object). The upper layer is affected by the lower layer, while the factors in the layer are basically relatively independent. As shown in the figure1 below.

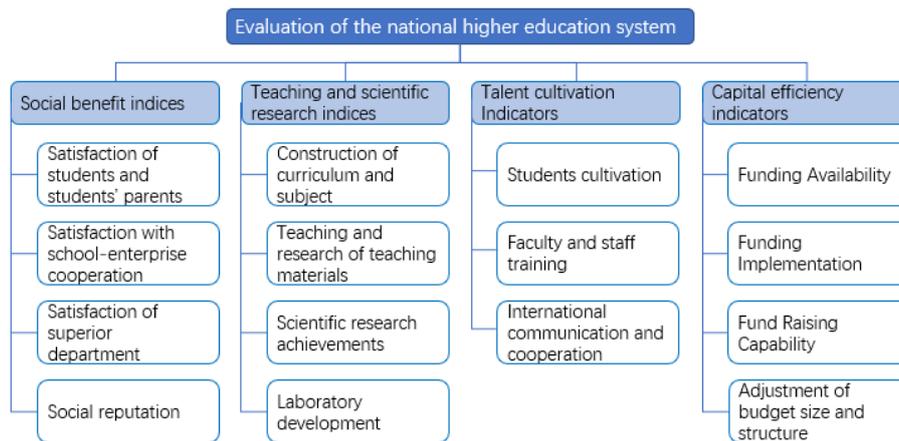


Figure 1 Index hierarchy construction chart

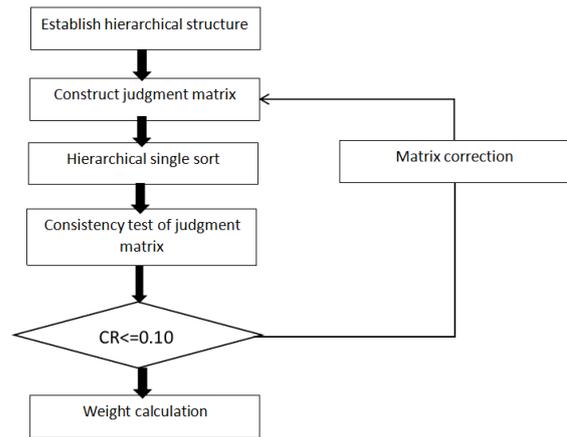
As shown in the figure, a multi-level ordered hierarchical structure model is formed, which is generally divided into Target layer (O), Guideline layer (C) and Measure Layer (P). Then, according to the judgment of objective facts, through the established method of

quantitative analysis, the relative importance of each element at each level is determined, and the judgment matrix is formed in quantitative form. The weight of the relative importance of each element in each level matrix is calculated, and the comprehensive ranking is carried

out accordingly, so as to establish the importance order of each element at the hierarchical level, the best choice is made in different schemes. Due to the characteristics and applicability of analytic hierarchy process (AHP), the national higher education system, which is characterized by strong systematic integrity and difficult to directly quantify the objectives, is very suitable to use AHP to quantify the indicators. According to the importance of the indicators to the objectives, the index system is designed. The target layer is divided into four dimensions: social benefit, teaching and scientific research indicators, talent cultivation indicators, capital efficiency indicators; each criterion layer index is divided into several specific scheme layer indexes, and the criterion layer is divided into 15 specific indexes.

**3.2. Determination of Index weights**

The evaluation can be carried out according to the steps shown in Figure 2



**Figure 2** Step chart of AHP evaluation

The judgment matrix is constructed. Judgment matrix is the key point in the whole model. Through the establishment of the judgment matrix of pairwise comparison, the element pairs of this level are achieved a comparison of the relative importance of a hierarchy of elements. As shown in the table below.

**Table 1.** Judgment matrix of total index level

Evaluation of the national higher education system (O)	Social benefit indices C <sub>1</sub>	Teaching and scientific research indicators C <sub>2</sub>	Talent Cultivation indicators C <sub>3</sub>	Capital efficiency indicators C <sub>4</sub>	Normalized weight ω
Social benefit indices C <sub>1</sub>	1	3	3	7	0.5045
Teaching and scientific research indicators C <sub>2</sub>	1/3	1	1/4	5	0.1551
Talent Cultivation indicators C <sub>3</sub>	1/3	4	1	3	0.2825
Capital efficiency indicators C <sub>4</sub>	1/7	1/5	1/3	1	0.0579

We can compute:  $\lambda_{max} = 4.2064$ ,  $CI = 0.0688$

Because of  $CI = \frac{\lambda - n}{n - 1}$  (1)

Therefore,  $CI = 0.0688$

**Table 2.** Random consistency index RI

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Because of  $CR = \frac{CI}{RI}$  (2)

Consistent ratio  $CR=0.0764<0.1$

Therefore, it passed the consistency test. The weight can be used as C1, C2, C3, C4 weight.

Similarly, the judgment matrix of the measure layer to the guideline layer is as follows:

**Table 3.** Social benefit Judgment matrix

Social benefit C1	Satisfaction of students and students' parents	Satisfaction with school-enterprise cooperation	Satisfaction of superior department	Social reputation	Normalized weight $\omega$
Satisfaction of students and students' parents	1	5	6	2	0.4049
Satisfaction with school-enterprise cooperation	1/5	1	2	1/2	0.0821
Satisfaction of superior department	1/6	1/2	1	1/3	0.0590
Social reputation	1/2	2	3	1	0.2047

We can compute:  $\lambda_{max} = 4.055$ ,  $CI = 0.0182$ ,  $CR = 0.020 < 0.1$ . Therefore, it passed the consistency test.

**Table 4.** Teaching and scientific research Judgment matrix

Teaching and scientific research C2	Construction of curriculum and subject	Teaching and research of teaching materials	Scientific research achievements	Laboratory development	Normalized weight $\omega$
Construction of curriculum and subject	1	5	3	2	0.4647
Teaching and research of teaching materials	1/5	1	1/4	1/5	0.0634
Scientific research achievements	1/3	4	1	1/2	0.1791
Laboratory development	1/2	5	2	1	0.2929

We can compute:  $CI = 0.0327$  , Therefore, it passed the consistency test.  
 $CR = 0.0367 < 0.1$

**Table 5.** Talent Cultivation Judgment matrix

Talent Cultivation C3	Students cultivation	Faculty and staff training	International communication and cooperation	Normalized weight $\omega$
Students cultivation	1	2	5	0.5695
Faculty and staff training	1/2	1	4	0.3331
International communication and cooperation	1/5	1/4	1	0.0974

We can compute:  $CI = 0.0123$  , Therefore, it passed the consistency test.  
 $CR = 0.0236 < 0.1$

**Table 6.** Capital efficiency Judgment matrix

Capital efficiency C4	Funding Availability	Funding Implementation	Fund Raising Capability	Adjustment of budget size and structure	Normalized weight $\omega$
Funding Availability	1	2	2	3	0.3448
Funding Implementation	1	1	2	4	0.3705
Fund Raising Capability	1/2	1/2	1	2	0.1852
Adjustment of budget size and structure	1/3	1/4	1/2	1	0.0995

We can compute:  $CR = 0.0038 < 0.1$  Therefore, it passed the consistency test.

Finally, the relative importance weight of each level is integrated to get all the indicators. The importance weight relative to the target is shown in table 7

**Table 7.** Evaluation of the national higher education system Weight distribution table

Target layer	Guideline layer	weight	Measure Layer	weight	Comprehensive weight
Evaluation of the national higher education system	Social benefit indices	0.5045	Satisfaction of students and students' parents	0.4049	0.20463646
			Satisfaction with school-enterprise cooperation	0.0821	0.04149334
			Satisfaction of superior department	0.0590	0.0298186
			Social reputation	0.2047	0.10345538
	Teaching and scientific	0.1551	Construction of curriculum and subject	0.4647	0.07207497
			Teaching and research of teaching materials	0.0634	0.00983334

	research indicators		Scientific research achievements	0.1791	0.02777841
			Laboratory development	0.2929	0.04542879
	Talent Cultivation indicators	0.2825	Students cultivation	0.5695	0.16088375
			Faculty and staff training	0.3331	0.09410075
			International communication and cooperation	0.0974	0.0275155
	Capital efficiency indicators	0.0579	Funding Availability	0.3448	0.01996392
			Funding Implementation	0.3705	0.02145195
			Fund Raising Capability	0.1852	0.01072308
			Adjustment of budget size and structure	0.0995	0.00576105

It can be seen from the results in Table 7 that the most important index for the evaluation of higher education system is social benefits, followed by talent cultivation, teaching and scientific research, and the capital efficiency comes last in turn. From the analysis of the interaction of the four indicators, the four indicators complement each other and work together in the higher education system. The high efficiency of teaching and scientific research indicators leads to the optimization of professional courses, the improvement of teaching quality and the inheritance of excellent culture, so as to enhance the satisfaction of students / parents and improve the social reputation, The satisfaction of students / parents will make the management of colleges and universities produce greater social benefits, improve the popularity of colleges and universities, and strive for more financial funds. The acquisition of funds can create more discipline peaks, drive the construction of characteristic specialties and the optimization of first-class teachers, cultivate top-notch innovative talents, improve the level of scientific research, promote the transformation of achievements, and realize the sustainable development of colleges and universities.

From the weight distribution of specific indicators, the biggest weight in the social benefit indicators is the satisfaction of students / parents. High public satisfaction means high social recognition. Colleges and universities should further strengthen the dominant position of students and the leading role of teachers, and improve public satisfaction on the premise of ensuring the quality of teaching. In the teaching and research indicators, in order to better achieve the purpose of running a university, it is most important to set up a reasonable specialty / curriculum, which means that universities need to constantly reform the curriculum and specialty to provide

guarantee for the quality of teaching. In talent cultivation, colleges and universities need to actively pay attention to the cultivation of students. The most important index of capital efficiency in Colleges and universities is the Funding Availability. Whether the funds can be fully and timely in place is related to the strategic progress of the development and construction of colleges and universities. Colleges and universities should keep the balance of financial revenue and expenditure, and the proportion of expenditure should be reasonable.

#### 4. APPLICATION FOR HIGHER EDUCATION SYSTEM

##### 4.1. Establish evaluation factor set

We select 3 countries to apply our model. We determine to combine Analytic Hierarchy Process (AHP) and fuzzy comprehensive evaluation method (FCE) to choose a country whose system of higher education has room for improvement.

Firstly, we should establish evaluation factor set:

$$V = \{\text{high, medium, low}\}$$

Through questionnaire survey and expert evaluation, we evaluate the four criteria and fifteen measures at high, medium and low levels. Among them, we have collected 278 valid questionnaires which are filled in by the requesting institutions to German and Canadian students and Chinese college students.

##### 4.2. Establishing fuzzy relation matrix

Using questionnaire investigation and expert evaluation from China, German and Canada, we can establish fuzzy relation matrix.

Guideline layer	Measure Layer	China			German			Canada		
		high	medium	low	high	medium	low	high	medium	low
Social benefit indices	Satisfaction of students and students' parents	0.32	0.44	0.24	0.48	0.39	0.13	0.43	0.32	0.25
	Satisfaction with school-enterprise cooperation	0.27	0.52	0.21	0.53	0.38	0.09	0.55	0.34	0.11
	Satisfaction of superior department	0.43	0.31	0.26	0.31	0.52	0.17	0.52	0.32	0.16
	Social reputation	0.22	0.30	0.48	0.41	0.45	0.14	0.49	0.30	0.21
Teaching and scientific research indicators	Construction of curriculum and subject	0.25	0.41	0.34	0.4	0.32	0.28	0.48	0.42	0.10
	Teaching and research of teaching materials	0.48	0.32	0.20	0.39	0.51	0.1	0.33	0.45	0.22
	Scientific research achievements	0.32	0.33	0.35	0.34	0.45	0.21	0.39	0.40	0.21
	Laboratory development	0.41	0.31	0.28	0.43	0.37	0.2	0.33	0.46	0.21
Talent Cultivation indicators	Students cultivation	0.50	0.28	0.22	0.47	0.35	0.18	0.32	0.47	0.21
	Faculty and staff training	0.42	0.24	0.34	0.32	0.57	0.11	0.38	0.39	0.23
	International communication and cooperation	0.31	0.47	0.22	0.49	0.38	0.13	0.40	0.46	0.14
Capital efficiency indicators	Funding Availability	0.49	0.26	0.25	0.33	0.51	0.16	0.33	0.46	0.21
	Funding Implementation	0.34	0.41	0.25	0.39	0.46	0.15	0.30	0.43	0.27
	Fund Raising Capability	0.55	0.27	0.18	0.37	0.46	0.17	0.28	0.40	0.32
	Adjustment of budget size and structure	0.32	0.40	0.28	0.28	0.53	0.19	0.31	0.43	0.26

Figure 3 The statistics of questionnaire investigation and expert evaluation from China German and Canada

4.3. Fuzzy comprehensive evaluation result

Now we have known the comprehensive weight of these measure layer using AHP. So now we can measure the national higher education system of these 3 counties.

Measure Layer	China			German			Canada		
	high(80)	medium(50)	low(20)	high(80)	medium(50)	low(20)	high(80)	medium(50)	low(20)
Satisfaction of students and students' parents	0.07	0.09	0.05	0.10	0.08	0.03	0.09	0.07	0.05
Satisfaction with school-enterprise cooperation	0.01	0.02	0.01	0.02	0.02	0.00	0.02	0.01	0.00
Satisfaction of superior department	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.00
Social reputation	0.02	0.03	0.05	0.04	0.05	0.01	0.05	0.03	0.02
Construction of curriculum and subject	0.02	0.03	0.02	0.03	0.02	0.02	0.03	0.03	0.01
Teaching and research of teaching materials	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Scientific research achievements	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Laboratory development	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01
Students cultivation	0.08	0.05	0.04	0.08	0.06	0.03	0.05	0.08	0.03
Faculty and staff training	0.04	0.02	0.03	0.03	0.05	0.01	0.04	0.04	0.02
International communication and cooperation	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00
Funding Availability	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00
Funding Implementation	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
Fund Raising Capability	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjustment of budget size and structure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
comprehensive feudatory degree	0.32	0.31	0.25	0.37	0.36	0.14	0.36	0.34	0.18
comprehensive score	45.68			50.80			49.01		

Figure 4 The comprehensive score of the national higher education system from China German and Canada

It can be seen from the above table, we can see China whose system of higher education has room for improvement. Compared to the other two countries, China has the lowest score.

5. CONCLUSION

In the whole system, four objectives are interlinked and promote each other. The improvement of management efficiency will improve the satisfaction of students and parents and achieve good social effect. The improvement of social benefit will help the higher education system to absorb more capital, and then strengthen the management level. Then it will make the management system optimized, improve the efficiency of resource allocation. This process is cyclical. Ultimately, the goal of higher education will be achieved, and the healthy and sustainable development of higher education will be realized.

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