Research on Evaluation of Higher Education System Based on AHP Model and TOPSIS Method

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Abstract: The progress of education is the fundamental driving force of national development. The healthy development of the higher education system is critical for a country, but the evaluation criteria of the higher education system are different in different countries. Without a rational measurement standard, it is difficult to objectively evaluate a nation's higher education system, which will bring difficulties and obstacles to mutual exchange and encouragement between higher education institutions. We will contract a suite of complete evaluation models to reduce this obstacle. In order to establish the evaluation system thoroughly, objectively, and comprehensively, we will establish the AHP higher education system health evaluation model and TOPSIS higher education system sustainability evaluation model. We use 6 representative countries and 15 important indexes to analyze and measure with the help of historical data and time forecast. Finally, we choose the American higher education system, which performs well under each evaluation system, and the Chinese higher education system, which should be improved in many aspects to make an emphatical analysis.

1. Introduction

In the past few decades, some countries have developed rapidly while others have stagnated. [1] One of the reasons for this phenomenon could be education. Education is the key to a country's development, and having a healthy and sustainable higher education system is of great value to a country. [2] Every country in the world has its higher education system, which trains its citizens for social and economic development. Each system of higher education has its shortcomings and advantages. [3] Given the current pandemic situation, countries worldwide need to assess the health and sustainability of their higher education systems and make timely changes to achieve a healthier and more sustainable system. [4]

2. Higher Education Evaluation Model Based on AHP and TOPSIS

Many indicators need to measure a healthy and perfect higher education system. Using the literature analysis method, we divide the higher education evaluation system from two dimensions horizontally and vertically and establish mathematical models to form a complete set of the modeling system. This paper gives a brief overview of the two aspects of the evaluation system:

On the one hand, it is a horizontal measurement of the state of the higher education system in the same period, including the following eight indicators: the number of higher education institutions, the number of students in higher education, the coverage rate of advantaged subjects in colleges and universitie. On the other hand, it is vertical measurement of the development potential and the sustainability of the higher education system in the time dimension. [5] There are seven indicators, including the average years of higher education, etc., as shown in Figure 1.

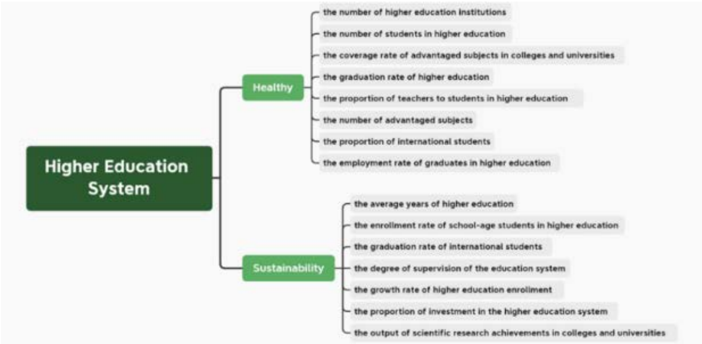

Figure 1. Higher Education System

Analytic hierarchy process (AHP) refers to taking a complex multi-objective decision-making problem as a system, decomposing a general objective into multiple objectives or criteria, and then decomposing it into several levels of multiple indicators. [6] Using the qualitative index fuzzy quantization method, we can calculate the single ranking and the general ranking of the levels, which can be used to solve objectives and schemes. The characteristics of the analytic hierarchy process above are exactly in line with the characteristics of the research model. Therefore, we construct an analytic hierarchy model to reasonably measure and evaluate the health condition of the higher education system. [7] According to this model, we can choose the country with the best higher education system and apply it to different countries, and the improvement plans can be put forward for the selected countries according to the comparison. [8]

First, we divide the model into the following three levels:

1) We regard the health of the education system as the highest level, that is, the target level, and use M to represent the highest level;

2) We choose the following eight indicators as the middle level, namely the decision-making level: the number of higher education institutions, the number of students in higher education, the coverage rate of advantaged subjects in colleges and universities, the graduation rate of higher education, the proportion of teachers to students in higher education, the number of advantaged subjects, the proportion of international students, and the employment rate of graduates in higher education; the eight indexes are denoted by "C1", "C2", "C3"..."C8" respectively;

3) The bottom layer is also called the measure layer, so we take each country we want to evaluate as the bottom layer to select the best higher education system. The countries applied in the model are denoted by "P1", "P2", "P3"..."Pn" sequentially.

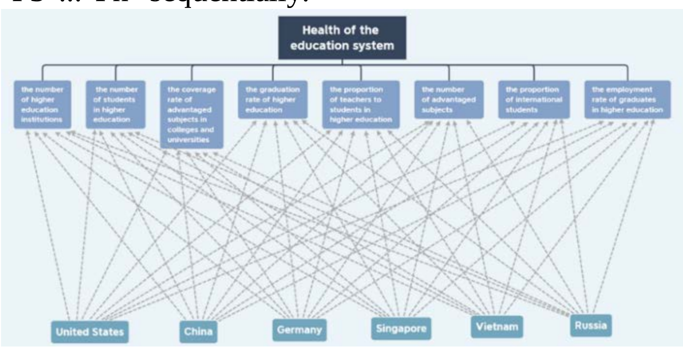

Figure 2. The Analytic Hierarchy Model of Education System

Second, construct the judgment matrix and calculate the weight coefficient.

Because of the above decision-making level indicators, we grade the indicators from top to bottom and establish a judgment matrix. The weight standard is based on T. L. Saaty's suggestion, using the numbers 1-9 and their reciprocal scale. We compared the eight indexes of the criterion layer based on the above scale and then constructed a judgment matrix A based on the results.

$$A = \begin{pmatrix} 1.00 & 2.00 & 3.00 & 3.00 & 3.00 & 2.00 & 0.50 & 1.00 \\ 0.50 & 1.00 & 1.00 & 1.00 & 0.33 & 0.33 & 0.50 & 1.00 \\ 0.33 & 1.00 & 1.00 & 1.00 & 1.00 & 2.00 & 3.00 & 3.00 \\ 0.33 & 1.00 & 0.25 & 1.00 & 0.33 & 0.50 & 1.00 & 1.00 \\ 1.00 & 3.00 & 0.50 & 2.00 & 1.00 & 1.00 & 2.00 & 2.00 \\ 1.00 & 3.00 & 0.50 & 2.00 & 1.00 & 1.00 & 2.00 & 2.00 \\ 2.00 & 2.00 & 0.33 & 1.00 & 1.00 & 0.50 & 1.00 & 1.00 \\ 1.00 & 1.00 & 0.33 & 1.00 & 0.50 & 0.50 & 1.00 & 1.00 \end{pmatrix} \tag{1}$$

Calculate weight coefficient. According to all of the eigenvalues of the indicators in the criterion layer, λmax =8.9219, and the weighting vector

$$\omega = (0.1851, 0.0729, 0.1813, 0.0637, 0.1479, 0.1479, 0.1192, 0.0820)^T \tag{2}$$

Third, the Consistency test for single hierarchical sorting. Calculate the consistency index CI according to the formula

$$CI = \frac{\lambda_{max} - n}{n-1} = 0.1317 \tag{3}$$

Calculate the consistency ratio CR when CR < 0.10. The consistency of the judgment matrix is acceptable. Otherwise, the judgment matrix should be modified appropriately. According to the calculation result:

$$CR = \frac{CR}{RI} = 0.0934 < 0.1 \tag{4}$$

It is considered to pass the consistency test.

Fourth is the Consistency test of the hierarchical total ranking. We have obtained the weight vector of the criterion layer for all the elements in the target layer. However, the ultimate goal is to get the sorting weight of each element (especially each scheme in the scheme layer for the target) to make scheme selection. The weights of the total ranking need to be combined from top to bottom under the single criteria. Therefore, to assess each country's health status, we can select data from some countries and use these countries as the lowest level of the program. These countries construct judgment matrices for the 8 indicators in the upper level of the criterion. After all the judgment matrices have passed the consistency test, the total ranking weight is calculated according to the weight of the criterion layer and the weight of the scheme layer, and this weighted ranking is the ranking of the health status of the education system of the selected countries.

In order to rank the similarity between the selected representative limited objects and the idealized target and evaluate the relative advantages and disadvantages of the limited objects according to the ranking results, we use the TOPSIS [9] comprehensive evaluation method to build the data model based on the above seven measurable and quantifiable indicators. [10] The construction process is as follows:

1) Indicator attribute assimilation processing.

According to the obtained index data set, the original data matrix is

$$\begin{pmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{pmatrix} \tag{5}$$

X_{ij} is the initial value of the i-th indicator of the j-th country

At present, there are 6 evaluation objects and 7 evaluation indicators. We transform the low excellent and neutral indicators into the high excellent indicators x_ij^', adjusting and transforming the data appropriately.

$$X'_{ij} = \begin{cases} X_{ij} \\ \frac{1}{X_{ij}} \\ 1 - \frac{|X_{ij} - X_{best}|}{max\{|X_{ij} - X_{best}|\}} \end{cases} \tag{6}$$

X_{best} is the optimal value of the i-th index, X'_{ij} is the value of the i-th indicator of the j-th country after normalization.

2) Data normalization.

Standardize the forward matrix to eliminate the dimensional influence

$$Z_{ij} = \frac{X'_{ij} - min\{X'_{i1} \cdots X'_{in}\}}{max\{X'_{i1} \cdots X'_{in}\} - min\{X'_{i1} \cdots X'_{in}\}} \tag{7}$$

Get the standardized matrix

$$Z = \begin{pmatrix} Z_{11} & \cdots & Z_{1m} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nm} \end{pmatrix} \tag{8}$$

Z_{ij} is the value of the i-th indicator of the j-th country after standardization

3) Determine the best plan and the worst plan.

The optimal scheme Z^+ consists of the maximum value in each column of Z.

$$Z^+ = (maxZ_{i1}, maxZ_{i2}, \cdots, maxZ_{in}) \tag{9}$$

The worst scheme Z^- consists of the maximum value in each column of Z.

$$Z^- = (minZ_{i1}, minZ_{i2}, \cdots, minZ_{in}) \tag{10}$$

4) Calculate the distance between each evaluation object and Z^+, and the distance is D_i^+. Calculate the distance between each evaluation object and Z^-, and the distance is D_i^-.

$$D_i^+ = \sqrt{\sum_{i=1}^{m} \left(Z^+ - Z_{ij}\right)^2} \tag{11}$$

$$D_i^- = \sqrt{\sum_{i=1}^{m} \left(Z^- - Z_{ij}\right)^2} \tag{12}$$

5) Calculate the approaching degree C_i between each evaluation object and the optimal scheme

$$C_i = \frac{D_i^-}{D_i^- + D_i^+}, \; 0 \le C_i \le 1 \tag{13}$$

$C_i \to 1$, the better the evaluation object is

6) According to the size order of C_i, the evaluation results are obtained

3. Model Solving

Based on the evaluation index system of the education system constructed above, we take China, the United States, Germany, Russia, Singapore, and Vietnam as the bottom layer of the analytic hierarchy model into the previous analytic hierarchy model. Sort by the criteria weight of the previous calculation, the total sorting is performed with the rear calculated solution layer weight. It can be seen that the total ranking of weight from high to low is the United States, Singapore, Russia, China, Vietnam, and Germany.

To measure sustainability, we first determine the preliminary indicators according to the literature analysis method. There are 18 indicators, including the average years of higher education (doctoral stage / postgraduate stage, undergraduate stage), the enrollment rate of school-age students in higher education, the graduation rate of international students, number of regulatory systems / laws of the education system, the growth rate of higher education enrollment, proportion of national/local government investment in the higher education system, Output of scientific research papers or patents in Colleges and Universities and so on.

We carried out Bartlett's test. The approximate chi-square value was 78.577, the significance level was 0.000 < 0.05, and the KMO value reached 0.755 > 0.5, which indicated that the sampling result was suitable for the factor analysis. Then we used the principal component analysis method to carry out the factor analysis.

Table.1. KMO and Bartlett test

KMO and Bartlett test	
Measure sampling adequacy	.755
Approximately chi-square	78.577
df	15
Significance	.000

The factor analysis results showed that the cumulative contribution rate of the first seven factors reached 99.831%, we selected the first seven factors. After inspection, we find no point where the load is less than 0.4 or greater than 0.4, so we do not think that further correction is necessary. Therefore, we decide to use the following seven indicators to evaluate the sustainability of the higher education system.

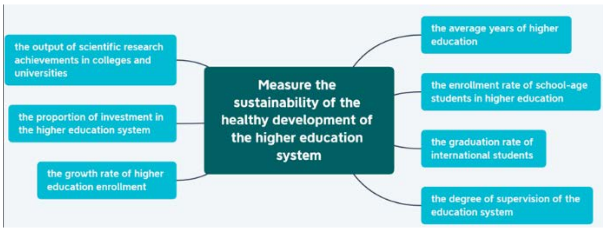

Figure 3. Policy Implementation Schedule

At present, there are 6 evaluation objects and 7 evaluation indicators, and we transform the excellent low indicators and neutral indicators into the excellent high indicators x'_{ij}, and we adjust and transform the data appropriately.

The forward matrix

$$X = 1.0e + 03 \ * \begin{pmatrix} 0.0136 & 6.1669 & 0.0512 & 0.0090 & 0.0093 & 0.0034 & 0.0090 \\ 0.0058 & 2.9128 & 0.0905 & 0.0020 & 0.0003 & 0.0031 & 0.0020 \\ 0.0113 & 1.8224 & 0.0801 & 0.0070 & 0.0009 & 0.0070 & 0.0060 \\ 0.0120 & 4.8775 & 0.0815 & 0.0050 & 0.0008 & 0.0014 & 0.0050 \\ 0.0133 & 3.6111 & 0.0923 & 0.0080 & 0.0029 & 0.0030 & 0.0070 \\ 0.0071 & 3.0614 & 0.0955 & 0.0060 & 0.0091 & 0.0034 & 0.0070 \end{pmatrix} \quad (14)$$

Data Normalization. standardization matrix

$$Z = \begin{pmatrix} 0.5077 & 0.6293 & 0.2513 & 0.5592 & 0.6944 & 0.3532 & 0.5762 \\ 0.2165 & 0.2972 & 0.4442 & 0.1243 & 0.0246 & 0.3180 & 0.1280 \\ 0.4218 & 0.1860 & 0.3930 & 0.4350 & 0.0700 & 0.7282 & 0.3841 \\ 0.4480 & 0.4977 & 0.4002 & 0.3107 & 0.0573 & 0.1502 & 0.3201 \\ 0.4965 & 0.3685 & 0.4530 & 0.4971 & 0.2151 & 0.3107 & 0.4481 \\ 0.2650 & 0.3124 & 0.4687 & 0.3728 & 0.6803 & 0.3532 & 0.4481 \end{pmatrix} \quad (15)$$

The final score is stand

$$\omega = (0.2532, 0.0720, 0.1708, 0.1221, 0.1741, 0.2079)^T \quad (16)$$

According to this result, the sustainability indicators of the American higher education system are the best among the six countries. According to sustainability indicators, the order of other countries is China, Germany, Singapore, Russia, and Vietnam.

Based on the analysis results of the above data, we consider China is a country with room for improvement in its higher education system for the following reasons:

We applied the model to the following six countries: the United States, China, Singapore, Russia, China, and Vietnam. Our model calculations found that the American education system has the highest weight in health and sustainability, which means that the American education system is the best among the six countries, so we choose the United States as a reference for improving the country. We found that in the healthy model through our observation of the results. China ranks second in the weight ranking of the three developing countries we selected and ranks fourth in the total ranking of the six countries, all in the middle reaches. China is second only to the United States in higher education schools. However, the coverage rate of advantageous subjects in higher education institutions is relatively low, and the coverage rate of advantageous subjects in higher education institutions is the highest in our health model. The second high can be improved in this regard.

In the measurement of sustainability, China's indicators are second only to the United States; however, the average length of education in China's higher education is far from that of the United States, and there is still much room for improvement. In the end, we believe that China's education system is relatively healthy, with good sustainability, and China has the most extensive population base of higher education students, so there is good room for improvement. Good performance.

4. Conclusion

Given the current pandemic situation, countries worldwide need to assess the health and sustainability of their higher education systems and make timely changes to achieve a healthier and more sustainable system. We developed a suite of models that can measure and assess the health and sustainability of each country's higher education system and give relevant, effective suggestions based on these models. Based on the evaluation of health status by AHP and sustainability by TOPSIS, we find that the fundamental factors affecting the innovation ability of universities are not technical factors, but institutional factors in three aspects: the function orientation of universities in the national innovation system, the degree of autonomy of universities and the institutional arrangement of encouraging competition; the institutional mechanism of combining teaching and scientific research; the ideological basis, the relationship between university and enterprise, the distribution of interests and the relevant legal protection of the transformation of university knowledge innovation achievements. Compared with universities in other developed countries, American universities have greater autonomy and sense of competition, clearer benefit distribution, and relevant legal protection for innovation transformation. Therefore, American universities are far ahead of the most innovative universities in the world. Chinese higher education institutions should learn from American higher education institutions and strengthen the establishment of the innovation system.

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