Research and Practical Application of Higher Education Health Index Model Based on AHP and EWM Methods

Long Cheng(✉) and Yuxuan Liu

Heilongjiang University of Science and Technology, Harbin 150022, Heilongjiang, China
781224827@qq.com

Abstract. The sustainable development of higher education is crucial for building a healthy and sustainable society. In this paper, to evaluate the health of higher education in a country, we developed a Higher Education Health Index (HEHI) model that comprises 16 indicators across five aspects. We used principal component analysis to select relevant indicators and applied Analytic Hierarchy Process (AHP) and Entropy Weight Method (EWM) to calculate the weights of the model's indicators. We also conducted cluster analysis using the K-means algorithm. We applied the HEHI model to evaluate India's Higher Education Health Level (HEHL) and proposed a vision for India's higher education system. The gray prediction model was used to forecast HEHI, propose policies, and assess their effectiveness. We predict that India will achieve its proposed vision before 2032. Our research provides valuable solutions for improving the country's higher education level and building a sustainable higher education system.

Keywords: AHP · EWM · HEHI · K-means · gray Prediction

1 Introduction

In the 21st century today, the level of higher education has been an important basis for whether a country is strong. Education is a century-old project of a country, and a country's strong education is a strong comprehensive national strength. In order to make the country full of talents and various undertakings prosperous, we must build a good education. However, in the context of the global pandemic, many problems have emerged in the higher education system, so it is necessary to reflect on our higher education system, find advantages and disadvantages, and update policies to improve it in order to establish a healthier and more sustainable higher education system.

Education indicators and index systems have become a crucial topic in education research worldwide since the late 1980s. Many countries and organizations have proposed various evaluation systems to reflect the state of education inputs, process, and products. However, there is no specific system for higher education, which is essential for achieving Sustainable Development Goal. Therefore, it is necessary to develop a model to measure and evaluate the health of higher education and provide rational policy recommendations for decision-makers.

D. Kumar et al. (Eds.): IEIT 2023, AHSSEH 10, pp. 925–932, 2023.
https://doi.org/10.2991/978-94-6463-230-9_112

As of 2022, while many indicators have been proposed to assess education, there is still no index system specifically built for the health of higher education. UNESCO emphasizes the need for a healthy and sustainable higher education system, with equal access to quality education for all. Therefore, it is crucial to establish a model to evaluate and improve the health of the higher education system, providing decision-makers with rational policy recommendations.

To address the issues caused by the above background factors, we have collected raw data from 20 countries over the past 10 years, and processed outliers and missing values to ensure the accuracy and validity of the data and screening effective indicators using principal component analysis [5]. Using analytic hierarchy process and entropy weight method to calculate the weight of indicators, a health index model of higher education system was established. In addition, we use the K-means method [6, 7] to classify the health level of national higher education into three categories: poor, average, and excellent. The model was validated by applying it to India and proposing a policy implementation plan. We discussed the impact of policy implementation, recognized the difficulties of change, and introduced the transition phase in detail, providing Chinese solutions to address India's specific challenges.

2 HEHI Model Construction

2.1 Indicator Selection

Our team has established a three-level evaluation index system to assess the health of the higher education system, using 16 primary indicators from five aspects. We utilized the entropy weight method (EWM) [3, 4] and analytic hierarchy process (AHP) [1, 2] to combine these indicators and employed an improved k-means algorithm to divide the higher education system's health status into five categories. Our definition of a healthy higher education system includes fair competition opportunities for students, high-quality education, advanced scientific research results, and sustainable development. To establish our indicators, we collected data from the ranking standards of QS and THE, which mainly refer to various aspects of the education system.

In combination with the above evaluation criteria and our definition of the health of the higher education system, our team will evaluate the health of a country's higher education system from **5 dimensions** and refine **16 indicators**, as shown in Fig. 1.

2.2 Data Collection and Filling

Through visiting relevant international websites, the team collected most of the data on 16 indicators in different countries, of which the data on education investment, education quality, and education atmosphere mainly came from the World Bank. International exchange and academic achievement data mainly come from ARWU and Clarity Analytics, as shown in Table 1.

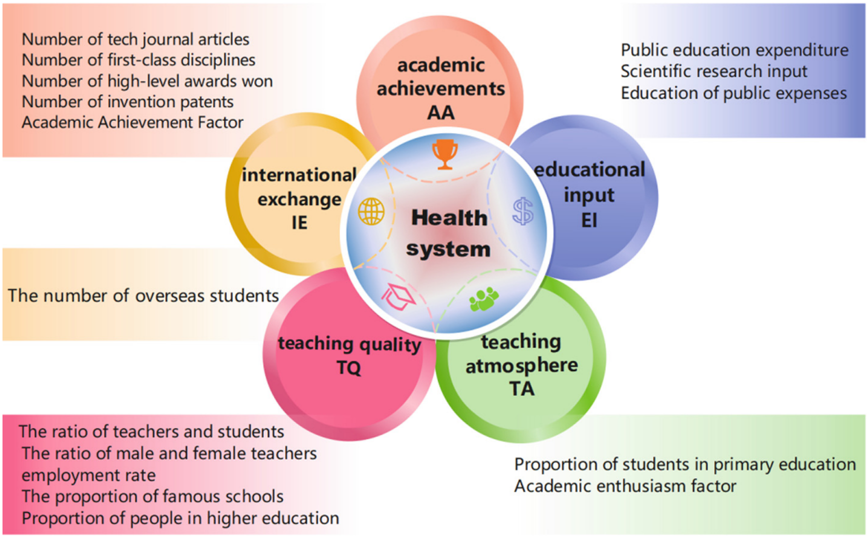

Fig. 1. Three-level indicator system diagram

Table 1. Data and Database Websites

Database Name	Database Websites
World Bank	https://data.worldbank.org.cn/
ARWU	http://www.shanghairanking.com/
Clarity Analytics	https://clarivate.com/highly-cited-researchers/

2.3 Data Normalization

Because the 16 primary indicators have different dimensions, they cannot be compared. For normalized data, all data are converted from 0 to 1.

For the 16 indicators, our team divided them into benefit indicators, cost indicators, and intermediate indicators. The larger the benefit index data, the better the HEHI. On the contrary, the smaller the data, the greater the HEHI. The closer the intermediate index is to a special value, the better the HEHI is.

We use the following three methods to standardize data:

For benefit indicators:

$$z_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}}, \ \mathrm{i} = 1, \cdots, \mathrm{n}; \mathrm{j} = 1, \cdots, \mathrm{m} \tag{1}$$

z_{ij} is the normalized value of x_{ij}, x_{ij} is the value corresponding to the jth index of the ith object, $x_j^{\max}$ is the maximum value of x_j, and $x_j^{\min}$ is the minimum value of x_j.

In the model, the number of excellent disciplines, public education investment, and the proportion of famous schools belong to this category of indicators.

For cost indicators:

$$z_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}},\ \ \mathrm{i} = 1, \cdots, \mathrm{n}; \mathrm{j} = 1, \cdots, \mathrm{m} \tag{2}$$

In the model, the proportion of teachers and students belongs to this type of indicator.

For intermediate indicators:

$$\mathrm{M} = \max\left\{\left|\mathrm{x_{ij}} - \mathrm{x_{best}}\right|\right\},\quad \mathrm{z_{ij}} = 1 - \frac{\left|\mathrm{x_{ij}} - \mathrm{x_{best}}\right|}{\mathrm{M}} \tag{3}$$

z_{ij} is the normalized value of x_{ij}, x_{ij} is the value corresponding to the jth index of the ith object, x_{best} represents the best value of the jth index.

2.4 Weighted Model Based on Entropy Weight Method (EWM)

Due to the judgment matrix in AHP, the weight obtained has a certain subjectivity. In order to make up for this shortcoming, we use the entropy weight method to calculate the weight of each primary indicator more objectively based on the collected and improved data. Since the indicator data has been normalized in the data processing section, we will omit the first step and directly carry out subsequent operations on the processed indicator data. From the data, we can get an initialization matrix, as shown below:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{4}$$

Step 1: Calculate the probability matrix P to ensure that each column is 1 and the sum of probabilities corresponding to all objects under each column of indicators is 1.

The calculation formula for each element P in P_{ij} is:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x}(j = 1, 2, \ldots, m) \tag{5}$$

Step 2: e_j represents the information entropy of each indicator and d_j represents the information utility value. The calculation formula is as follows:

$$\begin{aligned} e_j &= \frac{1}{\ln n}\sum_{i=1}^{n} P_{ij}\ln\left(P_{ij}\right)(j = 1, 2, \ldots, m) \\ d_j &= 1 - e_j \end{aligned} \tag{6}$$

Step 3: normalize the information utility value and get the weight W_j of each index. The calculation formula is as follows:

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{7}$$

3 Results and Discussion

3.1 Metric of HEHI

In this part, we use the improved K-means algorithm to formulate appropriate standards. As shown in Fig. 2, the classification criteria of the five combined indicators are different. Taking the teaching atmosphere as an example, when the score of teaching atmosphere is lower than 35.81, it means normal level. The score of teaching atmosphere is between 35.81 and 78.04, indicating good. It is considered excellent when the IE is greater than 78.04. In order to better display the evaluation criteria of the health index of the higher education system, we also use the radar chart, as shown in Figs. 2 and 3.

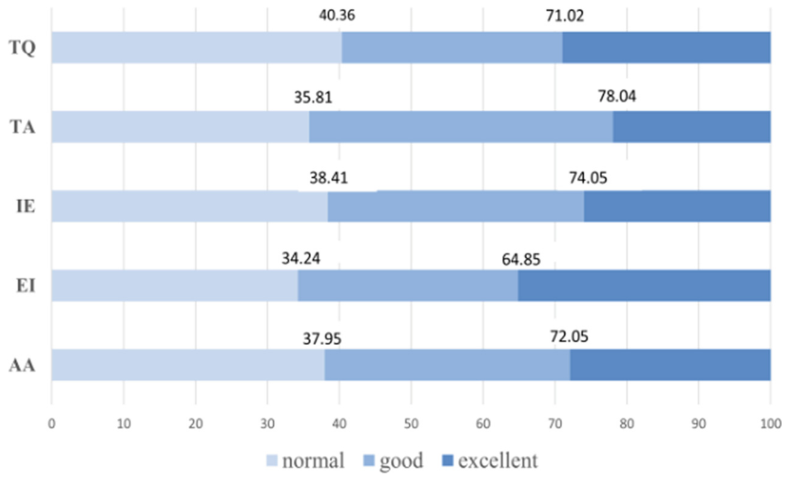

Fig. 2. Evaluation criteria of main indicators

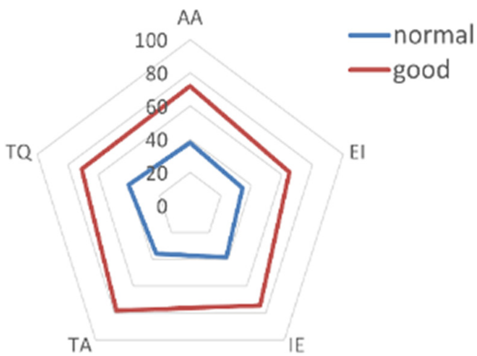

Fig. 3. Radar chart

3.2 Application of HEHI Model

My team applied the HEHI model, and its measurement established in the above part to five countries to evaluate the health and sustainable development level of their higher education system. The five countries selected are France, Germany, Japan, India and Russia. Apply the model to these countries to obtain the scores of each country in five two-dimensional indicators and their total scores, as shown in Table 2.

In order to more intuitively reflect India's performance in all aspects and the gap with other countries, our team visualized the data, as shown in Figs. 4 and 5.

According to the results of applying the model to the selected five countries, we can see that India performs well in terms of education investment, around the passing line in the other four areas, and even below the passing line in terms of international exchanges. There is a certain gap between India and the other four countries, so India's higher education system has a large room for improvement. Our team will select India as the specific analysis country and put forward relevant policies, Promote the development of its higher education system.

Table 2. Score of 5 countries

Country	AA	EI	IE	TA	TQ	HEHI
Germany	54.69	65.9	60.53	81.03	69.05	70.55
France	49.96	64.51	69.01	62.2	69.96	65.86
Japan	55.4	53.3	61.79	70.38	67.15	64.86
Russia	47.4	39.81	62.07	79.95	72.76	64.64
India	38.42	66.16	29.42	42.84	36.27	45.29

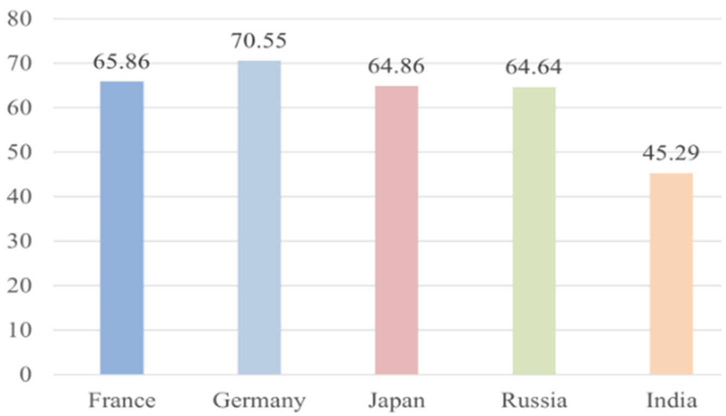

Fig. 4. HEHI scores of 5 countries

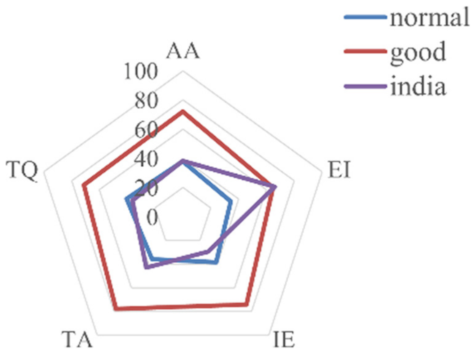

Fig. 5. India's performance

4 Conclusion

In conclusion, we first established a HEHI evaluation system based on EWM combined with AHP to evaluate the health status of the state-level higher education system. Then, we applied the K-means algorithm to determine the normal, poor, excellent range. The results of the tests conducted in 10 countries show that our model is accurate. Next, to analyze HEHI in India, we analyzed the correlation, combined with the PCA approach, presenting an achievable and reasonable vision for India. Then, the rationality of this vision is verified through the modified HEHI model. Then, we use GM (1,1) [8, 9] to predict the data, and we can draw conclusions from the results of India has s potential in terms of government investment. The effectiveness of our targeted policy is compared and evaluated with the proposed vision. Finally, we discuss its actual impact on different populations. It provides reasonable suggestions to the decision makers.

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