Healthy and Sustainable Higher Education System Assessment Model

Muyi Lei, Pengying Wan

Beijing Jiaotong University, Beijing 100044, China

Abstract. A healthy and sustainable higher education system not only helps a person to develop rapidly, but also promotes a country to flourish. The purpose of this paper is to develop an evaluation model of a healthy and sustainable higher education system and apply it to countries such as China to evaluate the health of the higher education systems in these countries. In addition, this paper proposes policies for countries with room for improvement in their higher education systems, as represented by China, and discusses the impact of policy implementation on universities, students, and society. In this paper, eight indicators are identified to measure the health of higher education systems, and a weighted arithmetic averaging algorithm is used to develop a healthy and sustainable higher education system evaluation model in combination with the indicator weights determined using AHP. Then, by applying the established higher education system evaluation model to several countries, Japan, China and the United States, this paper identifies the country, China, where the higher education system needs to be improved. Using a single-variable control approach, a weighted arithmetic averaging algorithm, and a gray prediction model, this paper establishes the policies and implementation timeline that China should implement to improve its higher education system, as well as the impact of policy implementation on universities, students, and society.

Keywords: Higher education, gray forecast model, Multi-attribute decision-making model, AHP, WAA.

1. Introduction

According to Britannica, “higher education is any of various types of education given in postsecondary institutions of learning and usually affording, at the end of a course of study, a named degree, diploma, or certificate of higher studies.” [1]

Higher education is important both at a personal level and a country’s perspective. After obtaining the higher education, a person can learn more professional skill and in-depth knowledge to pursue a higher quality life. Theory principle is a basic of practice then educated people are more likely to make greater contribution to a country’s progress. In that way, having a healthy and sustainable higher education system is essential to make a nation more competitive around the world. However, with the development of the social needs and situation, a perfect higher education system is almost nonexistent. And it’s necessary to develop a model to make a unified assessment to check the current issues and make adjustment.

First, a specific definition of a health and sustainable higher education system is needed to make. A health higher education system mainly needs national attention, sufficient educational resources, educational fairness and some achievements. In this essay, a country’s higher education system is divided into health group by calculating whether its educational standard is higher than the world average. Moreover, a sustainable higher education system means it can keep health and even show a trend of progress.

2. Model Establishment and Application

First, all data are assumed to be authentic and reliable. Table 1 shows the list of parameters and symbols.

Then, the essence of multi-attribute decision-making model is to use the existing decision information to sort or select a group of alternatives in a certain way. Its implementation needs two parts: first, obtaining decision information and aggregating decision information in a certain way.

Second, sorting and selecting the best schemes. Among them, decision information generally includes two aspects, namely attribute weight and attribute value. [3]

Table 1. List of Parameters and Notations

Parameter	***Description***
u_1	Research funds (10^8 \$) involved the degree of the national attention directly.
u_2	Number of significant academic achievement by data of Nobel Prize winners from 1901 to 2020
u_3	Student-faculty ratio, which is on behalf of the level of education quality
u_4	Number of world-class universities, mainly from USN EWS, QS, and AR WU websites [2]
u_5	Average annual income of graduation (\$), which quantifies quality of higher education, social integration and career support services among graduates from PhD, Master, Bachelor, Associate and below
u_6	Enrollment rate, from world bank, indicating the relative scale of education and educational opportunities
u_7	Tuition (10^4 \$), a basic cost for higher education
u_8	Number of higher education schools (per 10,000 square kilometer). It's in direct proportion to the education cost and national attention.
u_9	Final score for specimen countries
$x_{average}$	World average score
x_i	The final score for the countries to be evaluated
α_i	The ratio of newest growth rate α ($\alpha = \frac{current\ ratio}{last\ year's\ ratio} - 1$) i is synchronize with the number of u
β_i	The ratio of newest growth rate β ($\beta = \frac{next\ year's\ ratio}{current\ ratio} - 1$)

First, collect the raw data of eight indicators for countries. Then, for the index of u_4, the ranking reference index and weight of the three rankings of QS, US news, and AR WU are checked. It shows that in the QS World University Ranking Reference Index, the weight of peer evaluation indicators in the academic field accounts for 40%. Correspondingly, in the USN EWS World University Ranking Reference Index, the weight of peer evaluation indicators in the academic field accounts for 25% and in the AR WU World University Ranking Reference Index, the weight of peer evaluation indicators in the academic field accounts for 10%. Therefore, the new weights of QS, US news, and AR WU based on the value of universities are obtained, which are 0.167, 0.083 and 0.033. According to the three comprehensive weights and the collected data of these three rankings, a final data of the indicator of u_4 can be gotten.

Due to the inconsistent dimension of the eight indicators, the attribute value is needed to normalize to pursue the objectivity of the attribute value. Attribute types generally include benefit type, cost type, fixed type, deviation type, etc. For the benefit attribute, the larger the attribute value is, the better the attribute, while for cost attribute, the smaller the attribute value is, the better the attribute. As for the indicators of this model, the number of higher education schools, the number of significant academic achievement, the enrollment rate, research funds, average annual income of graduation, and the number of world-class universities are all benefit attributes, while the student-faculty ratio and tuition are all cost attributes. In order to normalize the attribute value, for the benefit attribute, this paper lets $r_{iu} = \frac{a_{iu}}{max_{a_{iu}}}$, and for the cost attribute this paper lets $r_{iu} = \frac{min_{a_{iu}}}{a_{iu}}$, where a_{iu}represents the unnormalized original data, r_{iu}represents the normalized processed data, i represents different country and u ($u \in N,\ u \in [1,8]$)represents different indicators.

Then, AHP is used to determine the attribute weight. The Analysis hierarchy process decomposes the problem into different components according to the nature of the problem and the overall goal to be achieved. Moreover, according to the interrelationship between the factors and the affiliation relationship, the factors are gathered and combined at different levels to form a multi-level analysis structure model. Therefore, ultimately the problem is attributed to the determination of the relatively important weight of the lowest level relative to the highest level or the scheduling of the relative order of superiority and inferiority. [4]

In the process of building the model, the scale table of paired comparison matrix is used to establish the paired comparison matrix so as to determine the attribute weight. Using expert scoring, the paired comparison matrix is established. Through calculation, CI=0.1170 and CR=0.0830, which means that the consistency of the paired comparison matrix is acceptable.

Table 2. Weights of eight indicators

Indicators	*Weight*
$\boldsymbol{u_1}$	0.2932
$\boldsymbol{u_2}$	0.2162
$\boldsymbol{u_3}$	0.1605
$\boldsymbol{u_4}$	0.1297
$\boldsymbol{u_5}$	0.0874
$\boldsymbol{u_6}$	0.0525
$\boldsymbol{u_7}$	0.0439
$\boldsymbol{u_8}$	0.0167

This article uses WAA operator to gather information. WAA operator supposes function $WAA: R^n -> R,(a_1, a_2, L, a_n)$ is a set of given data, if $WAA_w(a_1, a_2, L, a_n) = \sum_{j=1}^{n} w_j a_j$, where $w = (w_1, w_2, L, w_n)^T$ is the weight vector of the data set (a_1, a_2, L, a_n), $w_j \in [0,1], 1 \le j \le n, \sum_{j=1}^{n} w_j, R$ is the set of real numbers, then WAA is the weighted arithmetic averaging operator. By using weighted arithmetic averaging operator, x_i and $x_{average}$ can be calculated successfully and table 3 shows the healthy system judgment standard.

Table 3. Healthy system judgment standard

EXPRESSION	*RESULT*
$\boldsymbol{x_i<x_{average}}$	The higher education system is unhealthy, it still has room for improvement
$\boldsymbol{x_i>x_{average}}$	The higher education system is healthy

Then, this model is applied to three countries: Japan, the United States, and China. Based on the eight indicators that affect the health of the higher education system and the available world average data, the following data is organized.

Table 4. Normalized data of specimen countries and the world average

	China	**Japan**	**USA**	**World Average**
$\mathbf{u_1}$	0.175343583	0.010453767	1	0.059153916
$\mathbf{u_2}$	0.028132992	0.076726343	1	0.007750529
$\mathbf{u_3}$	0.618904519	0.783265998	1	0.695480349
$\mathbf{u_4}$	0.265269384	0.131541726	1	0.01849351
$\mathbf{u_5}$	0.019230769	0.222058457	1	0.019874759
$\mathbf{u_6}$	0.585233072	0.911477747	1	0.44060338
$\mathbf{u_7}$	0.506903675	0.620918029	0.449755665	1
$\mathbf{u_8}$	0.039235807	1	0.038447846	0.335731017

Through the above steps, the attribute value and attribute weight have been successfully established. Next, WAA operator is used for information aggregation and judgment.

Table 5. Model Final Score

	China	Japan	USA	World Average
Final Score	0.21755	0.33356	0.95989	0.22023

Finally, the following results can be gotten. First, because the scores of Japan and the United States are higher than the world average, the higher education systems in Japan and the United States are relatively healthy. Second, because China's score is lower than the world average, China's higher education system still has room for improvement.

3. Improvement Vision

Based on the results of the study, the vision of this paper is to achieve improvements in China's higher education system.

First, compare the 8 indicators of China with of health level. It shows that there are four indicators deviating from healthy level which finally make China's score lower than health standards: u_5, u_3, u_7, and u_8. In consideration of the weight calculated before, the improvements measures tend to pay more attention to u_5 and u_3. So, the primary goal is to increase u_1 and u_3 to the basic health level.

On the one hand, if the realization of the primary goal enables the final score China's higher education meet the health standards, this paper assumes it has improved to the health level. Then, turn to the secondary goal: increase u_5 to currently the highest industry average annual salary among new graduate and u_3 to currently the highest ration around the world with the ratio of newest growth rate α, to keep the sustainable. On the other hand, if the realization of the primary goal still cannot meet the health standards, the secondary goal is adopted to realize the requirement in health.

From the above analysis, it can be found that China has shortcomings in u_5 and u_3. In order to explore the best solution to improve China's higher education system, the method of controlling variables is used to analyze u_5 and u_3 separately to determine the best solution that is easiest to implement.

In view of the shortcomings of China's higher education system in u_5, in order to improve China's higher education system, first raise China's u_5 to the world average level. The obtained $x_i = 0.21774$and $x_{average} = 0.22023$. In order to find out how much the increase of u_5 will $x_i$be exactly equal to $x_{average}$, a line chart about the final score and the average annual salaries is drawn.

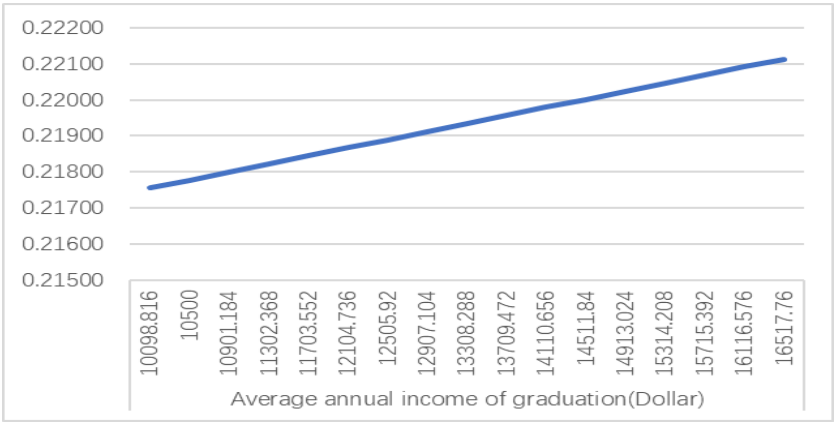

Figure 1. x_i changes with u_5 line chart

Then the dichotomy method continues to be used to determine the data: When u_5=14904, $x_i$will be exactly equal to $x_{average}$. Therefore, the first option is increasing u_5 to 14904, at this time x_i=$x_{average}$.

In view of the shortcomings of China's u_3, this paper still first reduces China's u_3 to the world average level. The $x_i = 0.24949$ and $x_{average} = 0.22023$ obtained at this time. It shows that after

decreasing u_3 to the average level, x_i will more than $x_{average}$. Therefore, the second option is established, which is reducing u_3 to the world average level, which is 17.28301887, at this time $x_i > x_{average}$.

In order to find out an option that can make China's higher education system easier to reach a healthy level, this paper still explores how much the decrease of u_3 will let x_i be exactly equal to $x_{average}$. A line chart about the final score and the student-faculty ratio is also drawn.

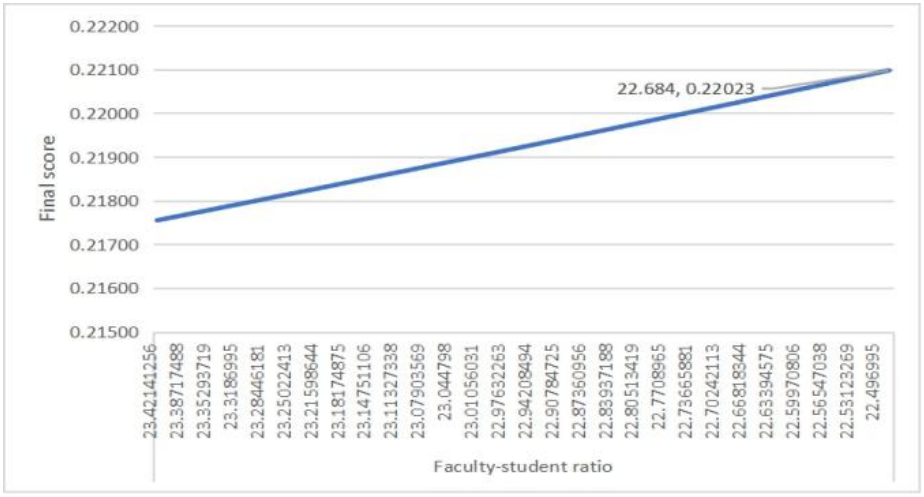

Figure 2. x_i changes with u_3 line chart

Then the dichotomy method continues to be used to determine the data: when u_3=22.684, x_i will be exactly equal to $x_{average}$. Therefore, the third option is established: reduce u_3 to 22.684, at this time $x_i = x_{average}$.

Gray forecast model is an effective tool to deal with small sample prediction problems. GM (1.1) model is used in this paper. In order to determine whether the selected model is reasonable, posteriori error test is used for checking the model.

This paper applies the average annual income of graduation for the past five years to the program, then the posterior difference ratio is 0.21781, which means that the system has fair prediction accuracy. Moreover, the two predicted values are 10954.7576 and 12149.7178.

Then this paper applies the student-faculty ratio for the past five years to the program. The posterior difference ratio is 0.49544, which means that the system has qualified prediction accuracy. Moreover, the two predicted values are 23.4749 and 23.6646.

Finally, the improved options are compared and the best measure is selected.

Table 6. different optional measures

Option	Specific Measures	Result	Change
1	Increase u_5 to 14904	$x_i = x_{average}$	u_5 should increase 47.58%;
2	Reduce u_3 to 17.28%	$x_i > x_{average}$	u_3 should decrease 26.22%
3	Reduce u_3 to 22.68%	$x_i = x_{average}$.	u_3 should decrease 3.16%

First, there are three optional measures which can enable Chinese higher education system to a health level. Obviously, option 1 and 3 is easier to meet. Then, the degree of difficulty to adjust u_5 with u_3 is compared. Since $\alpha_5 = 17.65\%$, $\alpha_3 = 2.17\%$, $\beta_5 = 9.69\%$ and $\beta_3 = 0.52\%$, so, if choose option 1, it needs at least 4-5 years to reach the average level. On the contrary, though the scale of change of choosing option 3 intuitively seems easier, there is a growth tendency of u_3's change, which is better to be declining to reach the average level.

In conclusion, this paper thinks China can improve its u_5 to 14904, and keep its u_3.

Table 7. Improved standards of China

	China
$\mathbf{u_1}$	277.937114
$\mathbf{u_2}$	11
$\mathbf{u_3}$	19.42141256
$\mathbf{u_4}$	4.126
$\mathbf{u_5}$	14904
$\mathbf{u_6}$	51.6
$\mathbf{u_7}$	9120855.662
$\mathbf{u_8}$	3.649552831

Next, a number of policies are proposed to help China achieve a healthy and sustainable higher education system.

First, using Macro-control policy to raise starting salaries for graduates is vital. The first policy is that faculty and schools improve the percent for the specialty to reduce the unemployment rate. According to the wage premium effect, for each random graduate, the average wage premium effect was 3.5%, higher than the professional mismatching group (1.2%), lower than the professional matching group (8.6%), which shows well-matched job is in favor of raising staring wages. [5] However, government should pay more attention and impose the rate on educational government budget. It is supposed that Chinese higher education system can reach the health level no more than 4 years. So, the growth rate of $\boldsymbol{u_5}\geq$ 10.22%. And since current major-job match is 41.92% so every year the growth rate of major-job match is supposed to 136.45%.

Then, higher student-faculty ratio maintains lower efficiency of education, which makes a waste of resources occupation. First is the reformed policy to unify title systems of higher school teachers and set up senior titles. In reality, the personnel structure of the teaching staff is unreasonable for low percentage of senior titles but high in intermediate grade. [6] Meanwhile, raising the welfare benefits of faculty, especially for the teaching. What' s more, for schools, they should limit the total number of faculty and enlarge the main task to teach. Based on Behavioral Utility Theory and Teacher Incentive Chess Style by Southwest Jiao Tong University, 54.3% survey participants consider "lack of enthusiasm for teaching" in their colleges and universities. [8] Therefore, schools should focus on training of teaching and managing faculty to make sure the lower faculty- student ratio.

Furthermore, the policy on tuition control is also useful for improving the Chinese higher education system. Since tuition change shows the growing tendency. From the perspective of feasibility, the purpose of the policy is to control the increase less than 5.4%. First, Chinese colleges and universities should actively carry out diverse system of fee reduction. Chinese colleges should gradually increase the funding of college scholarships and grants, and improve the funding and exemption mechanism for college tuition. Moreover, the government should also assist Chinese universities to widely absorb social fund donations and improve the diversified university donation mechanism.

Table 8. Results in timeline

Timeline	**Result**
The 1st year	$\boldsymbol{u_5}$= 11130.91, $\boldsymbol{u_3}$= 19.42%, $\boldsymbol{u_7}$= 12477.57, $\boldsymbol{u_8}$=3.75
The 2nd year	$\boldsymbol{u_5}$= 12268.49, $\boldsymbol{u_3}$= 19.42%, $\boldsymbol{u_7}$= 13151.36, $\boldsymbol{u_8}$=3.85
The 3rd year	$\boldsymbol{u_5}$= 13522.33, $\boldsymbol{u_3}$= 19.42%, $\boldsymbol{u_7}$= 13861.53, $\boldsymbol{u_8}$=3.96
The 4th year	$\boldsymbol{u_5}$= 14904.32, $\boldsymbol{u_3}$= 19.42%, $\boldsymbol{u_7}$= 14610.06, $\boldsymbol{u_8}$=4.06

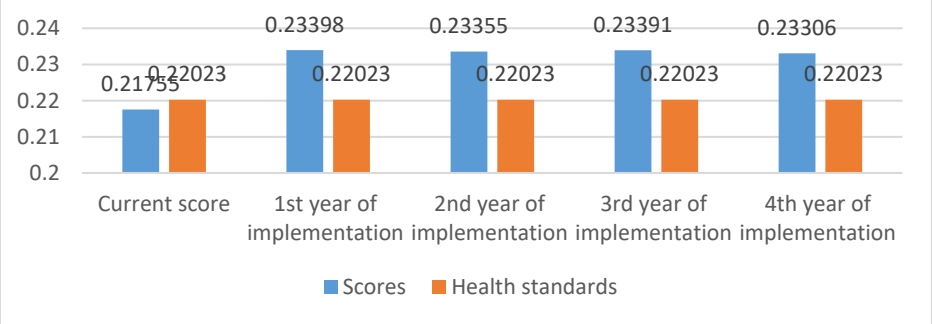

Figure 3. The final score after implementation

Moreover, the government should also increase the number of universities. The government can promote the investment of social and private funds in education, and approve private independent education, under the condition that the amount of capital investment is strictly reviewed and the conditions are satisfied, to increase 96 higher education sectors per year to ensure the growth rate of u_8 can reach 2.73%.

In general, there is a curve of fluctuation. However, according to the definition of the sustainable, in the 3rd year, this paper decides that it can reach the sustainable level. When these policies are implemented, schools, students and the society will all be affected.

First, schools will have more autonomy. Nowadays, schools are restricted by the system subject construction, professional setting, and training programs, and it is difficult to match the demand for talents with the labor market. Some positions can't be satisfied with graduates who has well-matched majors, but there are still other jobs with too heavy competitiveness. In that case, some graduates may ignore the requirements for job search that match their majors, in order to find jobs in a timely manner, which results in a mismatch between majors and jobs. [9] Because colleges and universities have greater advantages than the educational department in terms of information collection, process and response. Therefore, in order to align college majors with labor market job demands and ensure the efficiency of graduate work matching, schools will have full autonomy in managing schools. At present, six universities in China have the right to set up majors independently, and twenty-two universities have the right to enroll students independently. [10] In the future, more universities will have these rights. At the same time, while colleges and universities have these rights, they will also be required to strengthen their own self-discipline to ensure the fair implementation of rights.

Then, these policies can help graduates to quickly recognize the value to find the direction in life. According to the survey, more than 85% of graduates want to work in cities and coastal areas for work locations, and for jobs, more than 20% of graduates choose to work in party and government agencies. However, the demand for talents in state agencies is much less then supply. Among the 1.98 million jobs provided by 89 cities, the job demand in state agencies only accounts for 0.8% according to the training and employment department of the Ministry of Labor and Social Security. In other words, many graduates do not seem to realize this difference, or won't revise their ideals. By enhancing the job matching level of graduates, graduates can quickly set their mindset and quickly find their own life direction. [11]

Finally, these policies can speed up rural economic development. According to a survey on the employment intentions of college graduates across the country, only 22.6% of college graduates are willing to work in rural areas. Many graduates are unwilling to work in rural areas, western regions, or informal sectors, due to the poor conditions and low salaries. By correcting the working mentality of graduates and enabling graduates to reasonably understand their own value, the degree of job matching of graduates can be improved, and more graduates can enter rural work.

4. Conclusion

In summary, this paper develops a model for evaluating healthy and sustainable higher education systems through a combination of AHP and weighted arithmetic averaging operations using eight

established indicators, and proposes policies for improving education systems in countries where higher education needs to be improved through a combination of weighted arithmetic averaging operations and gray prediction models. This paper establishes an evaluation model of a healthy and sustainable higher education system which can help people to evaluate the excellence of higher education systems in various countries in the world and contribute value to people to propose specific improvement policies.

References

[1] Britannica, The Editors of Encyclopaedia. "Higher education." Encyclopedia Britannica, 3 Mar. 2016, https://www.britannica.com/topic/higher-education. Accessed 6 February 2021.

[2] Bryce, Loo. "Education in the United States of America." WENR, 16 Apr. 2019, wenr.wes.org/2018/06/education-in-the-united-states-of-america. Accessed 6 Feb. 2021.

[3] Feng Shilan, et al. "the Quality of Higher Education in China and the Starting Salary of College Graduates -- a Quantitative Study Based on the National Survey of Employment Status of College Graduates." World Economic Bulletin .03(2019):73-84. Doi. Accessed 8 Feb. 2021.

[4] Guo, Jinyu, Zhang Zhongbin, and Sun Qingyun. "Research and Application of Analytic" Accessed 7 February 2021.

[5] Lai, Desheng. "How to understand the current difficulties in obtaining employment for college graduates." Science and Education World, pp. 54-56. Accessed 7 February. 2021.

[6] Liu, Yang. "Research on University Major and Job Matching: Empirical Analysis Based on Employment Survey of University Graduates." TSIN GHUA J OURNAL OF EDUCA TION, Dec. 2010, pp. 82-88. Accessed 6 Feb. 2021.

[7] Luo, Lin. "International Comparison of Faculty-student ratio in Chinese Universities." Journal of Hubei Institute for Nationalities (Social Sciences Edition).04(1993):85-89 doi : 10.13501/j.cnki.42-1328/ c.1993.04.021... Accessed 6 Feb. 2021.

[8] Wei, Shixiao, and Zhou Xianzhong. "Multi-attribute Decision Making Theory and Its Application in C3I System." National Defense Industry Press, 1998. Accessed 7 February.

[9] Yang Suhong. "Can Professional Matching bring Wage Premium -- Based on Endogenous Processing Effect Estimation of Employment Choice of College Graduates in Jiangsu Province." Peking University Education Review 16.04(2018):79-104 doi. Accessed 6 Feb. 2021.

[10] Zhang, Wei Min. "Research on the Number of Enrollment Expansion in Universities and Education Quality." Journal of Chongqing University of Posts and Telecommunications, Nov. 2007, pp. 123-126. Accessed 6 February. 2021.