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A Model for Evaluating and Optimizing Higher

Summary

With the development of society, higher education system plays an important role in economics, politics and academic research field. there are specific issues for system of different countries and regions, with urgency to be solved, especially during this coronavirus pandemic period. Therefore, evaluation and policy design to higher education system is necessary.

In this paper, a higher education system evaluation model for assessing health and sustainability is proposed based on multi-criteria decision analysis (MCDA), genetic algorithm (GA), and state space model (SSM).

To build evaluation structure, this model firstly transforms two objectives (health and sustainability) into four specific criteria (academic level, Contribution of Economics, Politics and Equality (CEPE), service level and property of system). Next, the four criteria are divided into some specific indicators. To reduce redundancy, correlation analysis is used to eliminate unnecessary factors. It should be noticed that the indicators of academic level are MIMO (multiple input and multiple output) system. Thus, data envelopment analysis (DEA) is extra used to analyze academic level. As for the three other criteria, different methods from MCDA (critic method, coefficient of variation, entropy method and TOPSIS) are used to determine the weight and score according to their specific features. With evaluation structure, the United States, Japan, India and China are chosen to make assessments. From the results, Indias higher education system still has plenty improvement room. Therefore, India is selected and a vision for its system with targets of health and sustainability is proposed.

In terms of national higher education system itself, it is featured by nonlinearity, adaptability and complexity. In addition, limits like resources should not be ignored. Therefore, GA is used to obtain the optimal vision, with the constraints of resources (funding and human) and objectives of health and sustainability measurement. Optimized indicators are then assessed with evaluation structure and compared with initial status. As a result, health and sustainability measurement have 2.3% and 18.5% increase respectively.

GA can find the optimal vision of current higher education system. However, it is also important to design the policy intensity and its timetable. To obtain time-variable policy intensity, optimal indicators obtained from GA form a set of state vectors to operate a model called SSM, which is characterized by the state vector and state transition matrix. By setting different intensity of policy, timetable of policy intensity is acquired with the constraint of systems stability, and it can be proved by simulation or validating Lyapunov stability criterion. Further, difficulty in reality is quantified with controllability of system and it can be determined by controllability matrix. Finally, the effectiveness of your policy is important. Effectiveness analysis of system is divided into four sections. ARIMA, sensitivity analysis, coupling analysis and DEA method are used in error test, rationality analysis, harmony analysis and efficiency analysis. Finally, effect of policy to reality is analyzed.

Keywords: keyword1; keyword2

Contents

1 Introduction

1.1 Background

Nowadays, the comprehensive national strength is composed of a country's economy, culture, science and technology, education, talents, enterprises and other fields. The innovation of science and technology, the accumulation of high-quality human resources and the improvement of national overall quality all depend on a country's higher education level. However, the problems and advantages of higher education vary from country to country. Therefore, it is necessary to develop a health and sustainable evaluation model for higher education system to deal with the problems existing in higher education system and make it develop in the long run.

1.2 Our Work

To construct the higher education evaluation system, this paper starts from defining the criteria by which higher education is judged. Then, the weight of each index is calculated by CRITIC, coefficient of variation and entropy weight method in consideration of the different characteristics of the indicators respectively. All of the criteria are scored by TOPSIS. Countries with strong representativeness were selected as the targets of evaluation, which are compared with both the UN level and comprehensive score synchronously. India's higher education system was chosen as a target for improvement because of its low comprehensive scores. GA algorithm is used to optimize the target, and funding and resource are used as constraints when the resource is fixed. After that, the state space equation is used to get the policy implementation process and the intensity schedule. Finally, sensitivity analysis, coupling analysis and controllability analysis are used to test the effectiveness of the proposed policy. And the impact on the real world is analyzed and discussed.

2 Assumption

1. The weight of evaluation indicators remains unchanged in a short period of time.
2. The statistics data are true and reliable.
3. The predicted results are acceptable within a certain error range.
4. The objective can meet the optimization requirements provided.
5. The relative error of the variables studied is small enough that the random error can be ignored.
6. The only limiting factors for optimization are human and financial resources.

3 Tertiary Education Assessment System

Higher education system health is the ability of an organization or system to effectively execute around a shared vision and renew itself through innovation and creative thinking. Since the purpose of higher education itself is to promote the progress of productive forces, the contribution

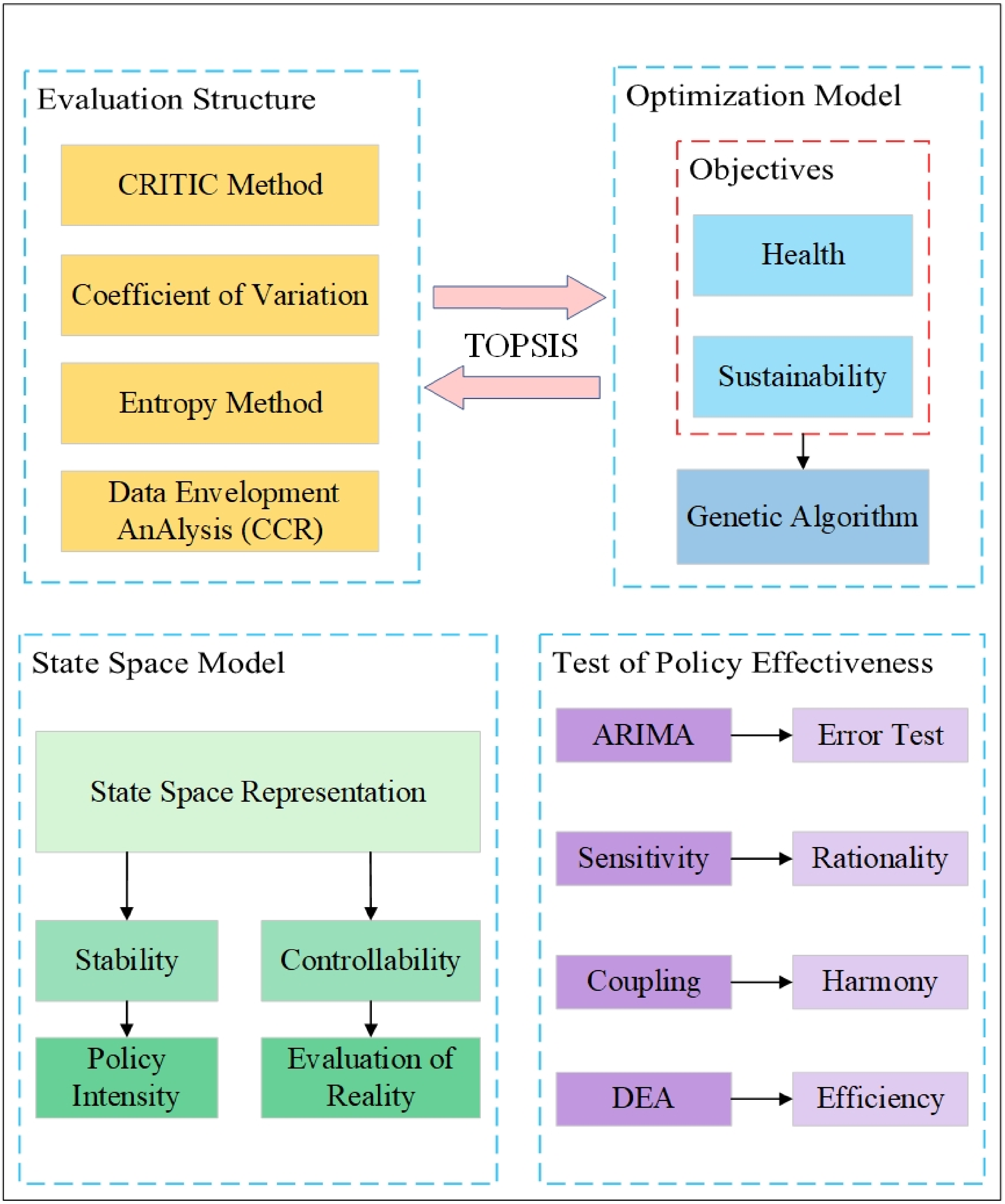

Figure 1: The framework of the proposed model.

of academic level and higher education to politics, economy and culture and the maintenance of equal citizenship relationship.

Sustainable higher education system can be defined as local, national and international institutions of higher education network and its system, these institutions by addressing social, economic, cultural, political, and stable, the problem such as research and extension, to maintain the core function of higher education, as well as the influence of higher education system environmental objectives and constraints.

3.1 Selection of Indicators

To have a healthy, sustainable higher education system, there is a valid demand among higher education institutions and their stakeholders for an evidence-based, data-driven analysis of higher education and its performance.

UNESCO gives six specific recommendations to policy makers: 1) to guarantee that those who need help the most are getting it; 2) to guarantee equity and affordability in regulatory frameworks; 3) to establish national agencies to ensure equal opportunities; 4) to use different admissions criteria to respond to different individuals needs; 5) to establish an agency to coordinate different forms of student aid, such as loans and grants; and 6) to limit student loan repayments to under 15 percent of their annual income. According to these six standards, indicators are mapping into 4 parts which are Academic Level, Property of Higher Educational System, Service Level and Contribution of economy, Politics and Equality. As is shown in Fig. 2.

Since the criteria has four parts, each of which can be divided into several smaller indicators, Contribution of economy, Politics and Equality, for example, can be divided into Collaborations among Universities and Companies, Gender, Race, Private Institution Percentage, Government intervention and Financial Support. This may lead to multi-collinearity. Therefore, correlation expression analysis is used to reduce the dimension of the indicators in the four parts, and independent and equally distributed variables are screened out to establish a higher education evaluation system. The correlation analysis results are shown in the Fig. 3.

It can be found from Figure 3 that Government Expenditure on Education, Citations of Papers, Number of patents, Global Ranking and Average Annual Fees have low correlation. Therefore, these five indicators are selected as the scoring criteria for academic level. Similarly, according to Fig. 3 B, C and D, Quality of Education, Graduation Rate, Proportion of International Students, Reputation of Employees and Ability of Online Education are selected as the scoring criteria of Service Level. Collaborations among Universities and Companies, Gender, Race and Proportion of Private University as a Contribution to Economic, Politics and Equality Stability and Poll Satisfaction are the scoring criteria of Property of Higher Educational System.

3.2 Higher Education System Assessment Model

3.2.1 CEPE weight analysis

CRITIC method is based on the comparative strength of the evaluation indicators and the conflict between the indicators to measure the objective weight of the indicators.

The reasons for choosing CRITIC algorithm are as following:

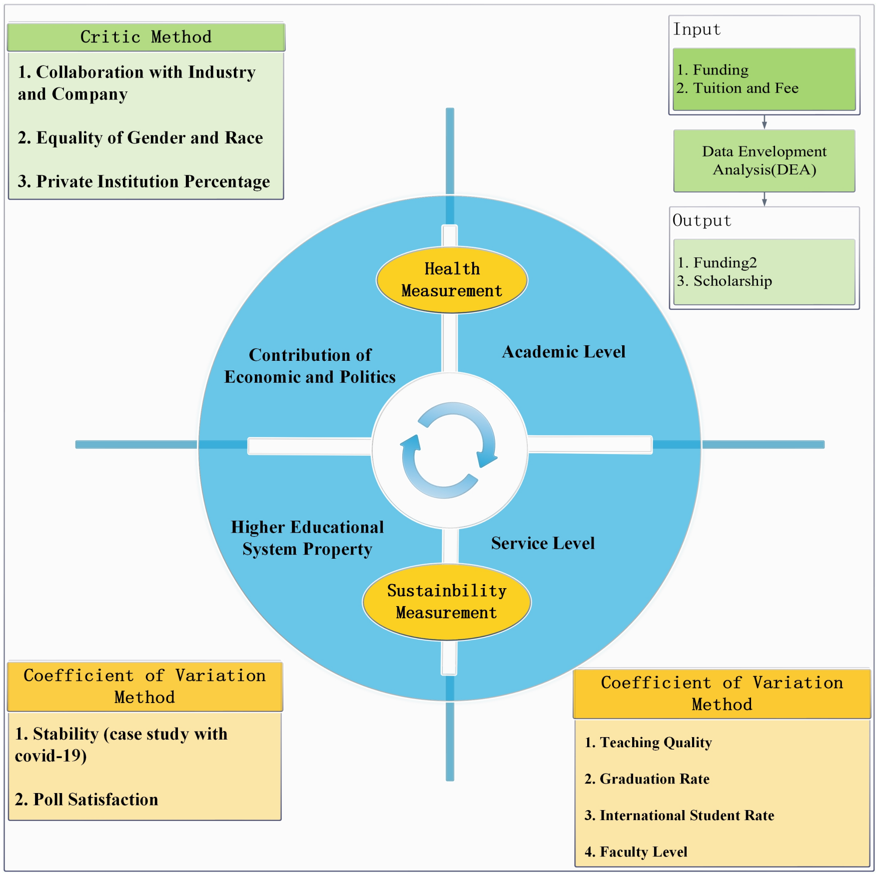

Figure 2: The framework of indicators.

- Factors such as gender, race and interaction with other industries to evaluate the degree of CEPE have multi-collinearity and random fluctuations.
- Criterion is positively correlated with CEPE, and CRITIC weights take into account data fluctuations and correlations between indicators, so this method is more effective than other independent weight analysis methods.

CRITIC weights are calculated from the conflict between the contrast strength and the indicators, and the steps are as follows:

1. Contrast intensity calculation. Contrastive intensity refers to the value difference between various evaluation schemes of the same index, which is expressed in the form of standard deviation:

$$\begin{cases} \bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij} \\ S_j = \sqrt{\frac{\sum_{i=1}^{n}(x_{ij}-\bar{x}_j)}{n-1}} \end{cases} \quad (1)$$

Where, X_{ij} represents the value of the jth evaluation index in the ith sample. S_j is the standard deviation of the jth index

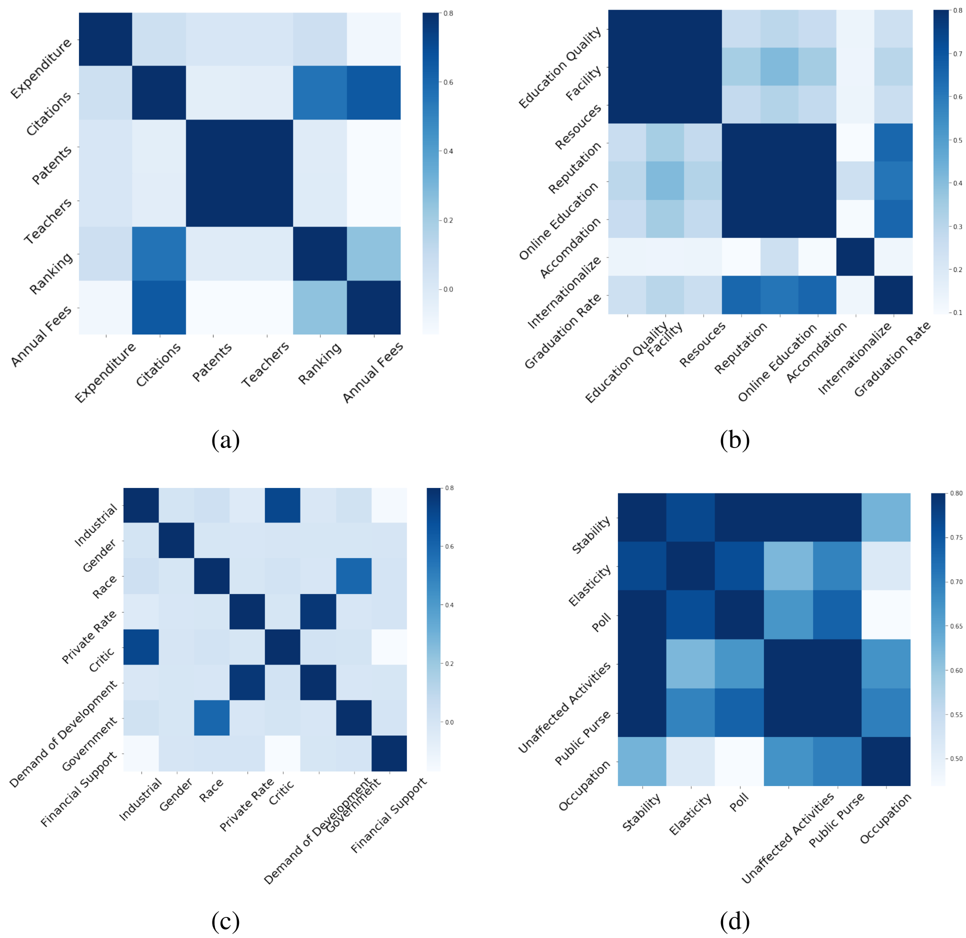

Figure 3: Correlation analysis of 4 criterion.

2. Information content and objective weight calculation

$$C_j = S_j \sum_{i=1}^{p} (1 - r_{ij}) = S_j \times R_j \tag{2}$$

$$W_j = \frac{C_j}{\sum_{j=1}^{p} C_j} \tag{3}$$

The larger C_j is, the greater the role of the jth evaluation index in the whole evaluation index system, and more weight should be assigned to it. Where W_j is the calculated objective weight.

3.2.2 Analysis of stability and service level based on coefficient of variation method

Coefficient of variation method is a method to calculate the change degree of each indicator of the system according to the statistical method, which is an objective weighting method.

The reasons for choosing Coefficient of variation are as following:

- It is impossible to evaluate the stability of the education system by using the situation of the pandemic during the epidemic, while the poll results at this time become the key to reflect the stability of the education system.
- The graduation rate and faculty strength of different countries are basically the same due to the essence of global economic integration, while the proportion of overseas students and teaching quality assessment of different countries vary greatly due to the reasons of economic level, life and educational environment.

The steps of using the coefficient of variation method to calculate the weight are as follows:

$$\begin{aligned} v_j &= \frac{S_j}{\bar{x}_j} \\ w_j &= \frac{v_j}{\sum_{j=1}^{p} v_j} \end{aligned} \tag{4}$$

Where V_j is the coefficient of variation of the evaluation index of j, and W_j is the weight of the evaluation index of j.

3.2.3 Academic level based on DEA-CCR

DEA-CCR is a nonparametric method used to analyze the efficiency evaluation of an individual or unit. The basic principle is to determine the relatively effective production frontiers by means of linear programming and statistical data, and to judge the relative effectiveness by comparing the degree of deviation of decision making units from the frontiers. In the higher education system, the output and input of academic level are positively correlated to a certain extent. DEA can comprehensively consider the input-output ratio and calculate the teaching level or expenditure efficiency evaluation index according to the output results.

Vectors X_j and Y_j represent input and output vectors of decision unit j respectively, and v and u represent input and output weight vectors respectively.

3.2.4 Education system score by entropy weight based TOPSIS

Entropy weight method refers to that the smaller the variation degree of the index, the less the existing information reflected, and the lower the corresponding weight. Due to the large number of data and too many evaluation indicators in this paper, the subjective method (AHP) cannot be used for calculation here. The possibility of mutual influence of indicators in the Besides category is low, so the method with strong correlation (coefficient of variation method, CRITIC weight method) cannot be used for calculation here. To sum up, in order to avoid the mutual interference of evaluation indexes, the entropy weight method is superior to other methods.

The steps of the entropy weight method are as follows:

- Calculation of the proportion of the ith enterprise:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, \quad i = 1, \cdots, n, j = 1, \cdots, m \tag{5}$$

- Calculate the entropy of the jth characteristic factor:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln \left(p_{ij}\right), j = 1, \cdots, m \tag{6}$$

- Calculate the redundancy of information entropy and the weight of each feature factor:

$$\begin{aligned} d_j &= 1 - e_j, j = 1, \cdots, m \\ w_j &= \frac{d_j}{\sum_{j=1}^{m} d_j}, j = 1, \cdots, m \end{aligned} \tag{7}$$

- Standardize each element of the matrix:

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{8}$$

- Calculate score normalization. Define the $i(i = 1, 2, ...M)$ Distance between evaluation objects and the maximum and minimum value:

$$D^{+}{}_{i} = \sqrt{\sum_{j=1}^{n} \left(Z_j^{+} - z_{ij}\right)^2} \tag{9}$$

$$D_i^{-} = \sqrt{\sum_{j=1}^{n} \left(Z_j^{-} - z_{ij}\right)^2} \tag{10}$$

caculate the $i(i = 1, 2, ..., m)$ Un-normalized scores of evaluation objects:

$$S_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \tag{11}$$

3.3 Selection of Country

This paper selects four countries for analysis: China, the United States, Japan and India. The sample of countries is based on a 1:1 ratio between developed and developing countries.

As the United States has the strongest higher education system in the world, it represents the level of a series of European educational powers, so it has guiding significance for the evaluation of a healthy and sustainable higher education system. Japan is a representative island education country, and its results are representative of the higher education level of Southeast Asian island countries. As a country with a relatively backward education system, India has a large population and complex national conditions. It has a large room for improvement in academic and service level, educational fairness and stability, and economic and political contribution. Therefore, it represents the higher education level of a series of countries with weak comprehensive national strength in Africa and other countries. Compared with the above three countries, China is a country with rapid development of higher education in recent decades. It is different from the old strong educational countries like the United States and weak educational countries like India, and it represents a new type of country with rapid development in the era of economic globalization and integration.

To sum up, the four countries selected in this paper represent the higher education levels of different types of countries in the world.

3.4 Comprehensive Evaluation of Higher Education System

The weights of the major indicators calculated by CRITIC weights and coefficient of variation are shown in Fig. 4 and the input-output efficiency of academic level evaluated by DEA-CCR is shown in Fig. 5.

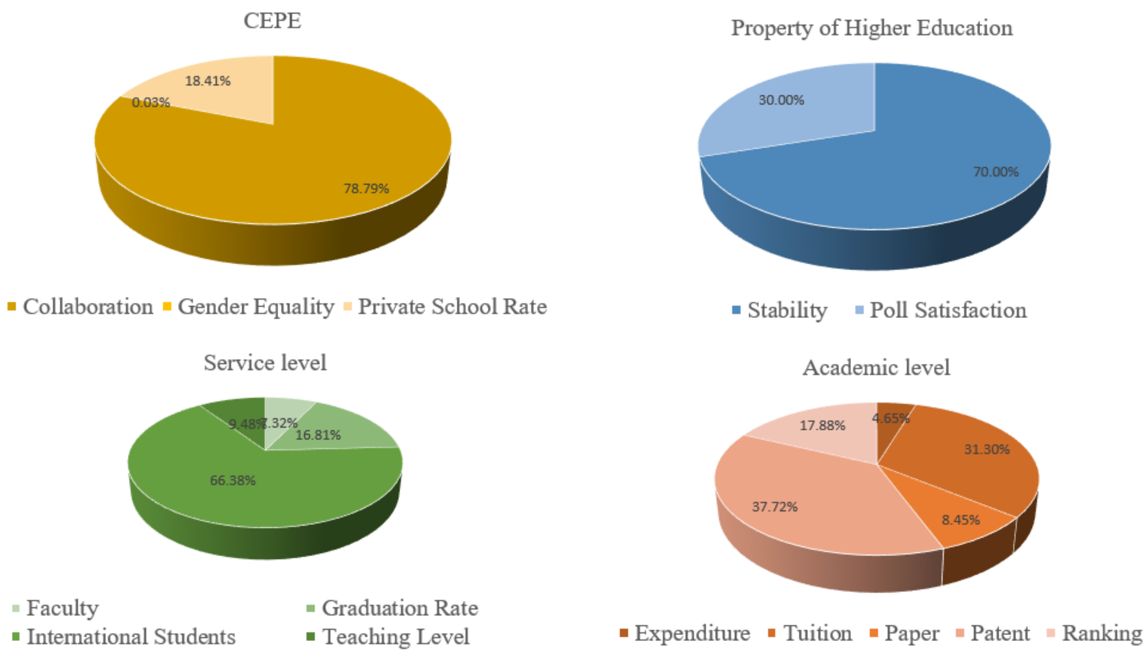

Figure 4: Evaluation indicators' weight

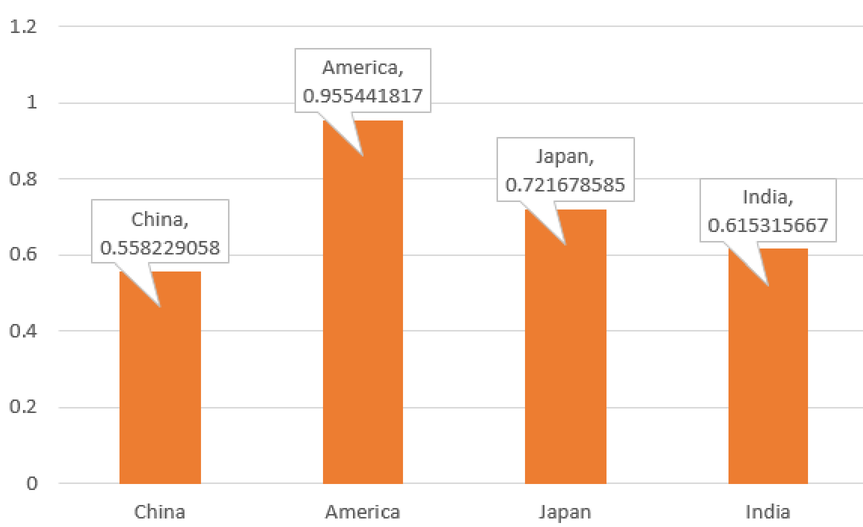

Figure 5: Academic efficient based on DEA-CCR

In order to better reflect the trend and development direction of some countries with unbalanced development, this paper adds the indicators of the level and sustainability of health indicators of higher education recommended by the United Nations to calculate. At the same time, the scores of academic level, CEPE, Property of Higher education system and service level are calculated according to CRITIC weight, coefficient of variation method and DEA-CCR model. All of these scores are shown in Table. 1.

Table 1: Score of academic level, CEPE, Property of Higher education system and service level in 2019.

	Academic level	CEPE	Service level	Property
China	0.5582291	3.793086	6.748203	0.61528
America	0.9554418	4.623582	8.986802	0.52778
Japan	0.7216786	3.857473	8.142128	0.67301
India	0.6153157	3.367839	5.898203	0.28793
World Average	0.6	3.5	6	0.4

According to the above four scores, we can get the score of health and sustainable development of higher education by the TOPSIS model, which is shown in Table. 2. India is selected as the country that needs to be improved for the following reasons:

Table 2: Score of Health, Sustainability and Comprehensive Score.

	Health	Sustainability	Comprehensive Score
China	0.4285916	2.09022	0.547204
America	0.5901778	2.665807	0.726282
Japan	0.4737998	2.493959	0.735644
India	0.4100237	1.726	0.064825
World Average	0.416392	1.799057	0.227952

1. As shown in Table. 1, there is a large gap between India's small indicators and the status recommended by the United Nations.
2. As shown in Fig. 6, the growth rate of India's various indicators calculated from 2015 to 2019 is slow, and its health, sustainability and overall scores are much lower than those calculated from the indicators recommended by the United Nations for that year.
3. As shown in Table. 2, all the indicators of India are lower than those recommended by the United Nations, so there is much room for improvement.
4. Combined with the actual situation of India's higher education system, it is true that India's higher education level is weaker than that of several other countries.

4 Optimization of Higher Education System Vision

To consummate vision of India, not only qualitative description, but also quantitative description is necessary. To get vision, genetic algorithm(GA) is used with indicator structure. Our analysis is as follows:

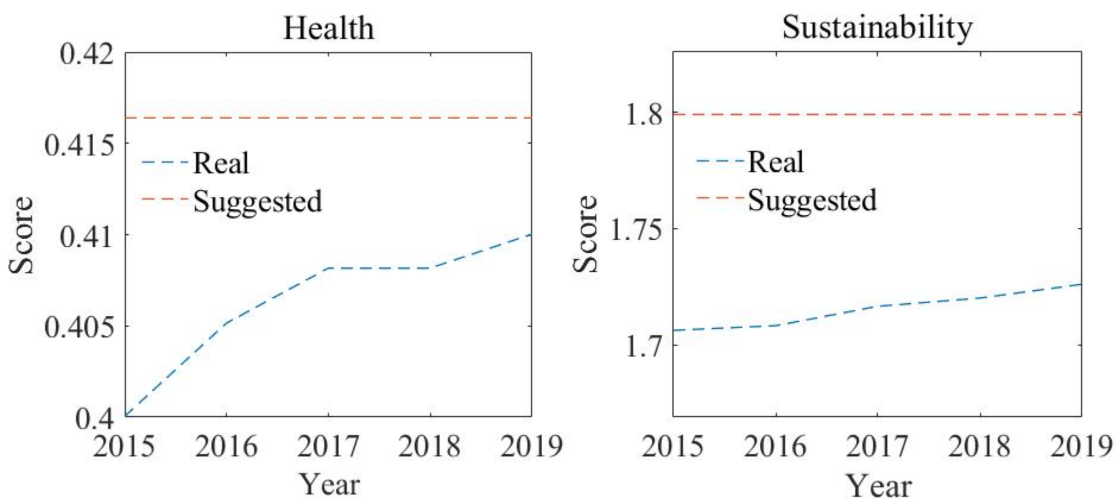

Figure 6: Health and sustainability situation of India.

- Evaluation of higher education system has been quantified with indicator structure.
- Vision of higher education system can be determined with two objectives (health and sustainability). Measurement of health and sustainability is connected with evaluation structure
- GA is often used to solve complex system.
- Issues in reality like limited resource can be described with constraints in GA. This ensures the authenticity of model.
- After GA optimization, system can be further assessed by the indicators.

In conclusion, GA is used there to get optimal vision.

4.1 Preliminary for Genetic Algorithm

The GA is used in our model to analyze the dynamic change and final state of higher education systems. The higher education system has the characteristics of academic level, service level and economic & political contribution, and its own system property. In addition, a large number of sampled data in the model can fully reflect the characteristics of policy evolution with its influence. Therefore, the GA is applied here to simulate the higher education changes and its final status.

Before applying GA, some necessary variables to construct biological evolutionary system is given in Table. 3 below:

The GA in a complex system to solve global optimization problems can be defined as:

$$\begin{cases} \text{Minimize} & f(\boldsymbol{X}) \\ \text{Subject to} & \boldsymbol{X} \in \Omega \end{cases}$$

where f is a function to evaluate the results of biological evaluation, $X = \{x_1, x_2, \cdots, x_m\}^T$ is target variables set in $\mathbb{R}^N$, Ω represents feasible solutions set.

Table 3: Variable description of genetic algorithm.

Name	Value	Meaning
Population size	10000	The amount of the initial population
Generation	150	The maximum evolution generation
Crossover probability	0.8	The chance for genes to crossover
Mutation probability	0.1	The chance for genes to mutate

Generally, X is represented as

$$\boldsymbol{X} = \begin{bmatrix} c_{11}c_{12}\dots c_{1n} \\ c_{21}c_{22}\dots c_{2n} \\ \dots \\ c_{m1}c_{m2}\dots c_{mn} \end{bmatrix}$$

where $c_{11}, \cdots, c_{mn}$ are called genes; $c_{ij}(i(j) = 1, 2, \cdots, m(n))$ is genetic position and c_{ik}, c_{kj} is called equi-locus between variable x_i and x_j. In the GA, the population space is denoted as $\vec{X} = X_1, X_2, \dots, X_N$, where N is the population size.

4.2 Procedure Description

We adopt the meta-rule that select the superior and eliminate the inferior. This rule guarantees the convergence of the algorithm. The following part is the procedure of GA and the flow chart of GA is shown in Fig.7.

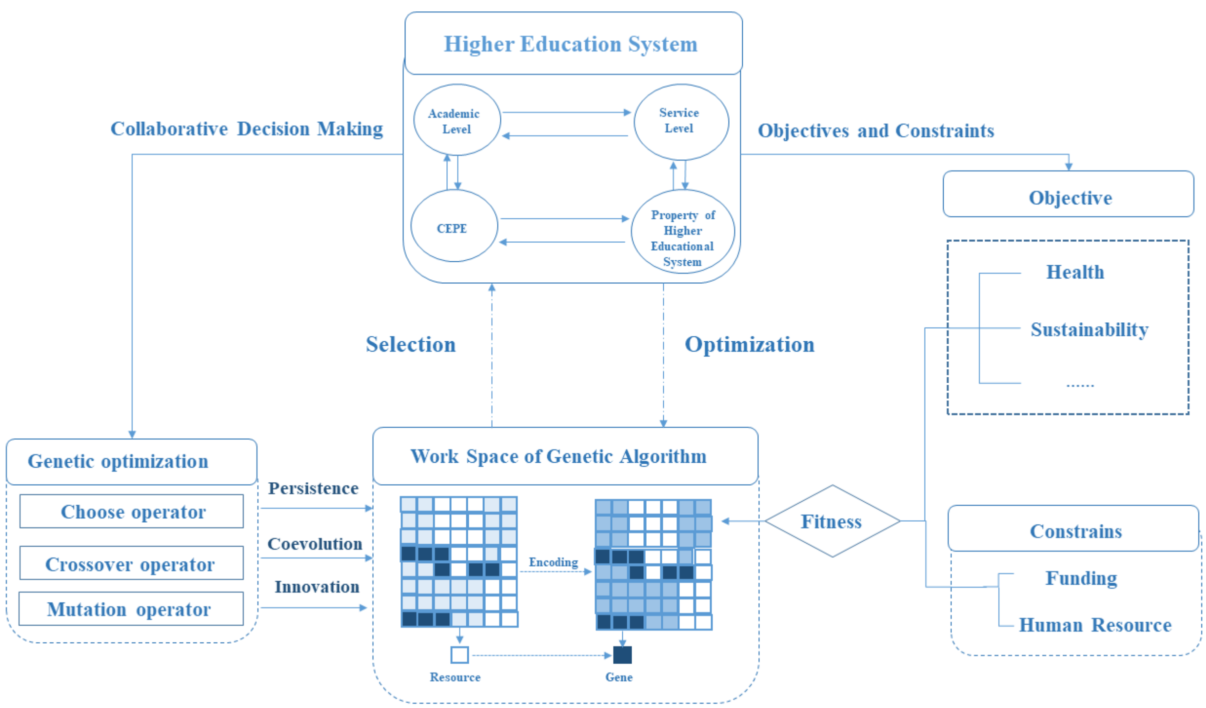

Figure 7: Model framework of genetic algorithm.

4.3 Basic Genetic Model

We define two variables Ω and Δ to represent sustainability and health respectively. The mutual relations are shown in Eq. 12.

$$\begin{cases} \Omega = \sum d_i \cdot w_i \\ \Delta = \sum p_j \cdot w_j \end{cases} \tag{12}$$

Where Ω is sustainability objective function and Δ is health objective function. wi and wj are the weight of objective in sustainability and health. di and pj are the indicators of sustainability and health.

In order to combine two objectives (health and sustainability), we define the rule Q to estimate whether the society is ideal. Q is also called the fitness for environment. The individuals with higher fitness have more opportunities to pass their genes to further generations. Q is represented as:

$$Q = \ln(\Omega + \Delta) \tag{13}$$

4.4 Constraints

Due to limitations in the real world, financial and human resource constraints were added to make the model more accurate. The constraint formula can be shown as follows:

$$Ax \leq b \tag{14}$$

$$A = \begin{bmatrix} c_{11}c_{12} & \cdots & c_{1n} \\ c_{21}c_{22} & \cdots & c_{2n} \\ \cdots & & \\ c_{m1}c_{m2} & \cdots & c_{mn} \end{bmatrix} \tag{15}$$

where, A is constraint matrix, which has information of linear inequality constraints, specified as a real matrix. A is an M-by-nvars matrix, where M is the number of inequalities. x is the column vector of nvars variables, and b is a column vector with M elements.

As shown in Fig. 9 and Fig. 8, we get the final result for the optimal factors. Fig. 9 show the status between and after optimization. As for Fig. 8, increase rate is shown.

In Fig. 9, yellow bar shows indicators before optimization and blue bar shows optimal results. It is obvious that most indicators had an increase after optimization. However, there are three indicators had a drop(faculty level, gender equality and tuition), which are illustrated in orange. It is worth noting that factors of tuition and gender equality increased, but when they get a decrease, efficiency of system will get better in this structure.

In Fig. 8, increase rate is illustrated. It is observable that indicators of stability, International student rate and patent have obvious increase. As for faculty level, gender and tuition, they have decreases of -15.9%, -25.82% and -24.62%, respectively.

To improve our policy plan, vision is considered in two conditions, both country with sufficient resource or not. This results is shown in Figure. 10.

From this figure, it could be observed that when a country is lack of resource, it will take more time to get as far as government has planned. However, with limited period, it can still get to a

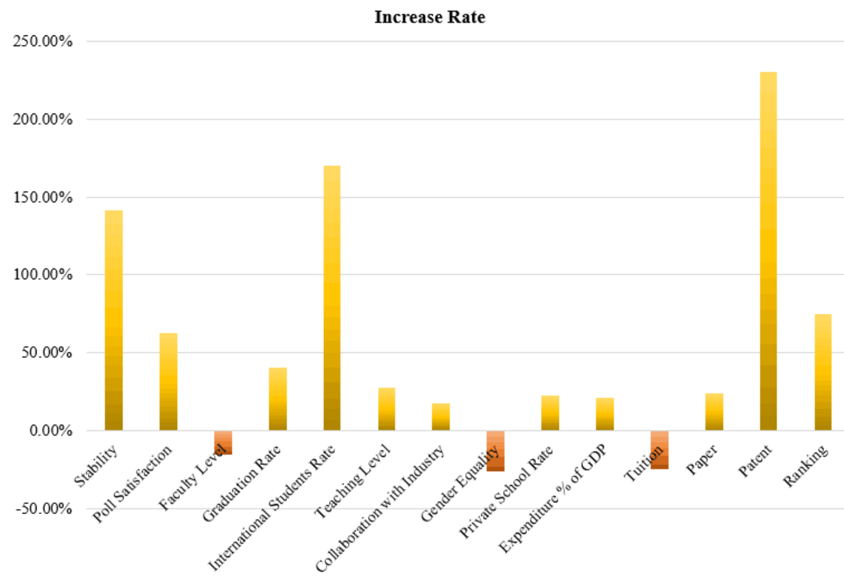

Figure 8: Status changes

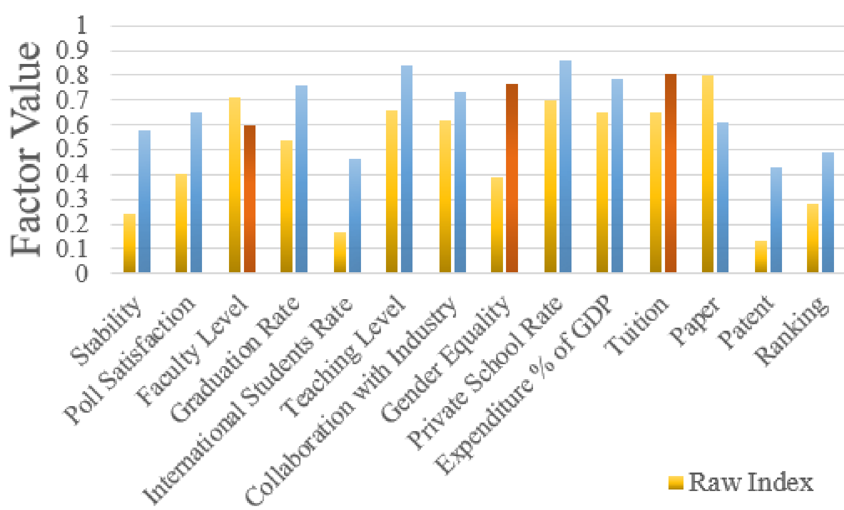

Figure 9: Increase Rate

relatively satisfying status. In all, our optimization model for higher education system behaves especially friendly to those developing countries with the lack of resource.

4.5 Higher Education System Optimization

After optimizing the resources of India, we got an almost new India. Based on the gene algorithm, the scores of India higher education are reevaluated. A dramatic increase can be seen in consideration of both health and sustainability. As the result, the comprehensive score surpass the world average level which is provided by the UN. This demonstrates the efficiency and effectiveness of our proposed gene algorithm. The results are illustrated in Fig. 11.

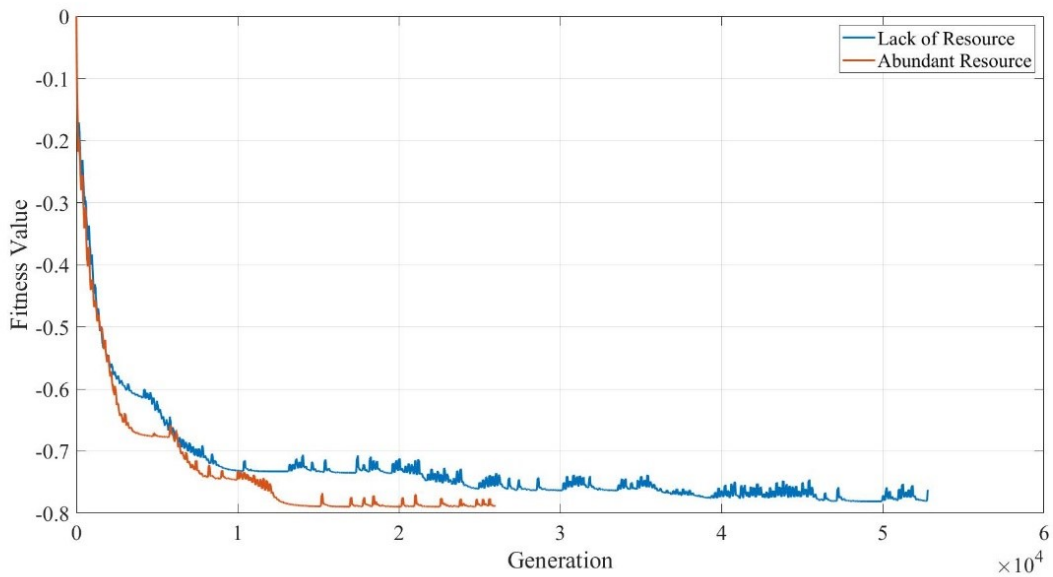

Figure 10: Fitness value of gene algorithm.

Before the above results were optimized, the comparison after optimization with the results recommended by the United Nations is shown in the Fig. 11. As can be seen from the Fig. 11, there is a significant improvement before and after optimization, and the result after optimization exceeds the level recommended by the United Nations, indicating that India's education system after optimization is in a healthy state and sustainable development. In conclusion, the optimized results are effective.

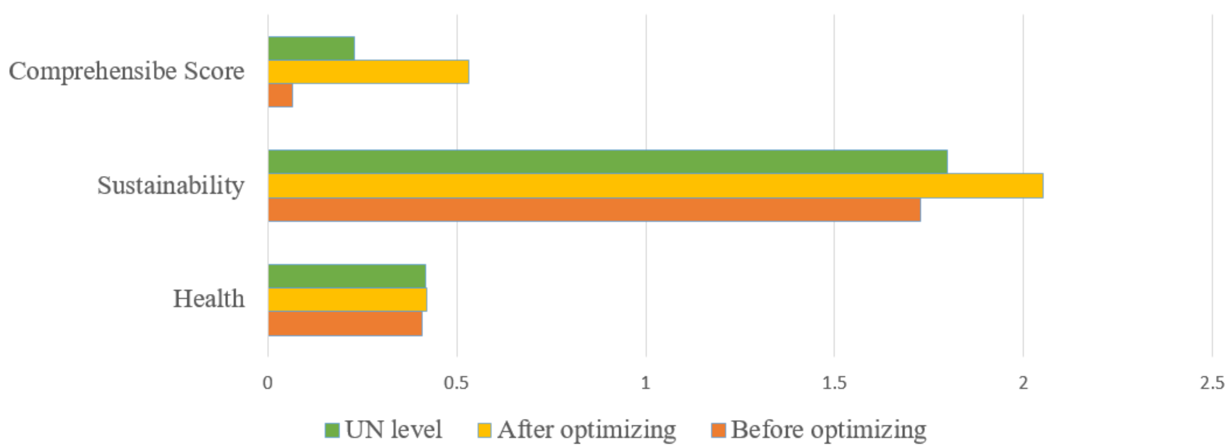

Figure 11: Comparison among before optimizing, after optimizing and UN level

5 Policy timetables and evaluations based on state space

In this task, the changing process of the state of the education system and its matching policies need to be considered. Since state change and policy implementation need to be considered in a large spatial and temporal scale, this model is a time-varying model. State space is a method to analyze and describe the dynamic changes of the system and control reliability. It can meet the task requirements for the following reasons:

- Two factors can be entered as states of the state space representation. State can be influenced by both its past state and other states.
- State is affected by the formula with the change of time.

5.1 Basic policy unit construction

In this paper, we set the policy of unit strength In the four indicators respectively, and add influence to the system. Since the application of high policy frequency is approximately equivalent to the increase of single policy intensity, this model adopts the application of policy at the same time interval and with the policy intensity over time.

Academic level:

- Drastic tuition hikes challenge the accessibility of higher education. This threat poses efficiency questions, not only for students financing high tuition, but also for universities attempting to deliver quality education while maximizing their profits. Therefore, tuitions should have a drop in logarithmic curve.

CEPE:

- Universities need to think broadly about interdisciplinary education and begin to consider transdisciplinary research and teaching.
- Everything that happens inside classrooms between students and between students and professors is a part of the curriculum of higher education.
- Ideally, evaluation strategies should be integrated into the planning of educational projects and programs
- Disclosure of the related financial interests to study team and collaborators. And with the results of more teams, collaborators between industry and higher education system should have a increase almost linear.
- It is true that there are far more students nowadays and the majority are women. This does not mean that there is more than formal equality in terms of the numbers game. To develop a more feminist-friendly future, we need to transform the rules of the game. Therefore, it is a option that there could be more women in management of higher education system, and this increase could be a logarithmic curve.

5.2 Constructing State Space Equation

Three different states $(x1, x2, x3)$ are constructed to describe system factors.

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \Leftrightarrow \begin{bmatrix} \text{Health} \\ \text{Sustainability} \\ \text{Resource} \end{bmatrix} \tag{16}$$

Therefore, these factors can be represented by state space representation:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} \mathrm{b}_1 \\ \mathrm{b}_2 \\ \mathrm{b}_3 \end{bmatrix} u \tag{17}$$

Where$A = [a_{ij}]_{3x3}$ is a state transition matrix.$B = [b_{ik}]_{31}$ is input matrix, which will represent policy input in this model. In this representation, differential form of each state can be influenced by its state, other related state and input u.

Assume that the higher education system can be stable without external input ($b_n = 0$) until a policy performs. Higher education system will change the relationship among states, and will also change state transition matrix A. Therefore, the stability of constructed system needs to be re-judged. The sensitivity of the system can be reflected by the stability of the system. Three different methods are provided below to judge system stability under different conditions.

5.3 Eigenvalues of State Transition Matrix

For linear time-invariant systems (matrix A is constant), system stability can be determined by finding the Eigenvalues of state transition matrix:

$$|\lambda I - A| = 0 \tag{18}$$

In a complete state space representation:

$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx + Du \end{cases} \tag{19}$$

The eigenvalues of A corresponds to the pole of the system represented by the state space equation. Therefore, if eigenvalues in system are all negative, then the system is stable. The convergence rate of a system mainly depends on the maximum eigenvalue. The smaller the maximum eigenvalue, the faster the convergence rate of the system is disturbed. It also indicates that the system dynamic performance is better and the system sensitivity is lower.

5.4 Lyapunov Stability in State Space Equation

Lyapunovs stability criterion is widely used for judging system reliability. It can judge both time invariant and time-varying systems, but cannot judge system poles location.

For a positive definite of real symmetric matrix $Q(t)$, if the system is stable, there must be a positive definite matrix P, which satisfies equation:

$$\dot{P}(t) = -A^T(t)P(t) - P(t)A(t) - Q(t) \tag{20}$$

If the positive definite matrix $P(t)$ can be obtained during iterations, then the system is stable and insensitive.

5.5 Time and Steady State Value

For a system is internally stable, the value of states will approach to zero when $t \to +\infty$. In our task, suppose each iteration represents one year. Therefore, 100-year plan corresponds that states passes through 100 iterations, 10-year plan corresponds to 10 iterations. We regulate that response reach to and remain at steady error value with 5% error is stable.

5.6 State Space Model Simulation

The simulation is used to analyze the influence of different policy plans and estimate future status. Firstly we assume that policy will be applied in the 5th, 10th, 15th or 20th years of the program. Assume the impact scale of each unit policy is the same.

The impact of policy at different times will lead to different outcomes, because the higher education system is changing as the time goes. Therefore, the J type growth model is used here to simulate higher education system growth:

$$N(t) = N_0 \times e^{at} \tag{21}$$

Where N_0 is initial status; Symbol a represents a growth constant. In the early stage, because the higher education system is lack of development and resource, policy may lead to instability. When system develops to a certain stage, policy will not have a fatal impact on the society.

Here we separately use the three methods to solve the sensitivity of the system.

5.7 Eigenvalues

The outcomes can be obtained by solving eigenvalues, Lyapunovs stability criterion and state response curve. From eigenvalues, we found there are two negative eigenvalues (-0.86, -2.55), (-0.67, -0.55), and (-0.86, -3.97) respectively when the intensity of policy is from 0.9 to 1.1. Besides, other eigenvalues are positive value. This result demonstrates that intensity of policy is less than 0.9 or larger than 1.1 will lead to system breakdown.

5.8 Lyapunovs stability criterion

This criterion can be used to judge state transition matrix A. For instance, matrix P of 1.1 times policy intensity is:

$$\begin{bmatrix} 2.31 & 1.76 \\ -0.43 & 3.57 \end{bmatrix} \tag{22}$$

Since $P11 = 2.31 > 0$, $\begin{vmatrix} 2.31 & 1.76 \\ -0.43 & 3.57 \end{vmatrix} = 9.0035 > 0$. As the result, the system is stable.

5.9 State response curves

Another results were shown in Fig. 12 and Fig. 13. We plot response curves of the same state for the eight different state transition matrices. Fig. 12 is the state response curve of health ; Fig. 13 represents the state response curve of sustainability; It also can be concluded that when intensity of policy is less than 0.9 or larger than 1.1, response of health and sustainability will have a shift more than 5% compared with target value, and this will lead to higher education system breakdown . In

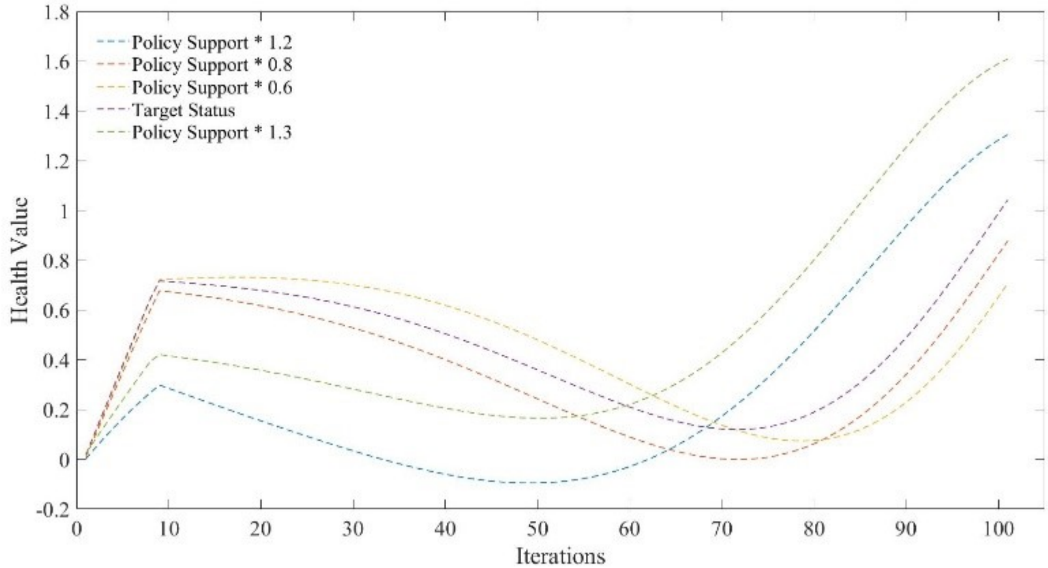

Figure 12: Health States Response Curve of Policy

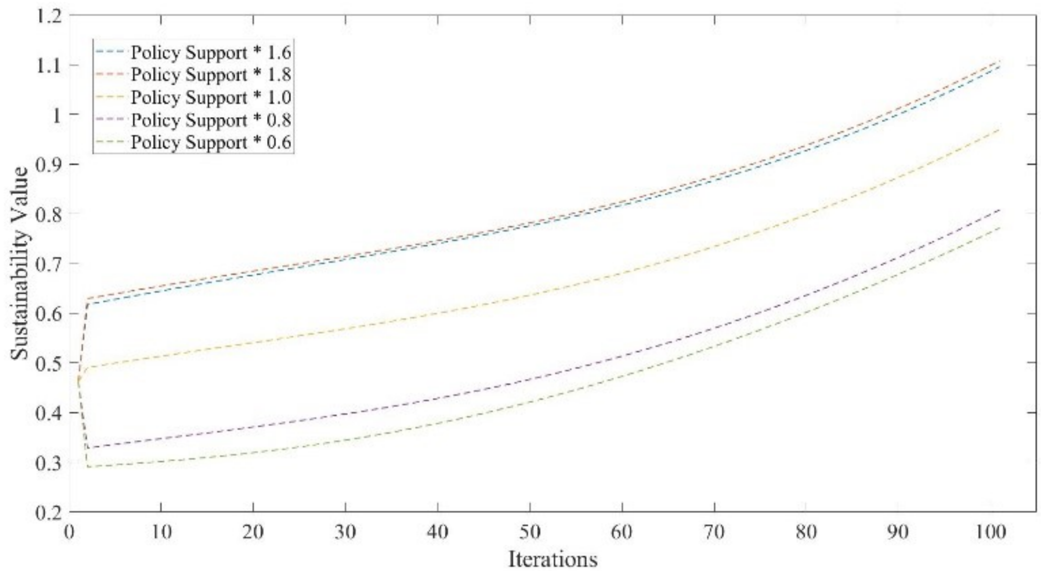

Figure 13: Sustainability States Response Curve of Policy

addition, in the same intensity of policy, the later the policy is applied, the smaller the impact on the state stability (the closer the maximum value to 0), the shorter time approaches to the steady state (0).

5.10 Timetable of Policy Intensity

With the conclusion that policy intensity should in interval $[0.9 - 1.1]$, GA algorithm is applied to get the optimal plan so that higher education system could get to targeted status with less time cost.

In Fig. 14,several feasible solutions of policy intensity have been illustrated there. It could be observed that policy intensity will have an obvious increase in the first two years. This is because at the beginning of the policy, more investment is usually needed, and the highest value is close to the critical value of 1.1, so as to maintain continuous improvement of the system. It can be observed that after the third year, the policy intensity is basically stable at about 1. The higher education system has continued to improve with policies that stabilize standards.

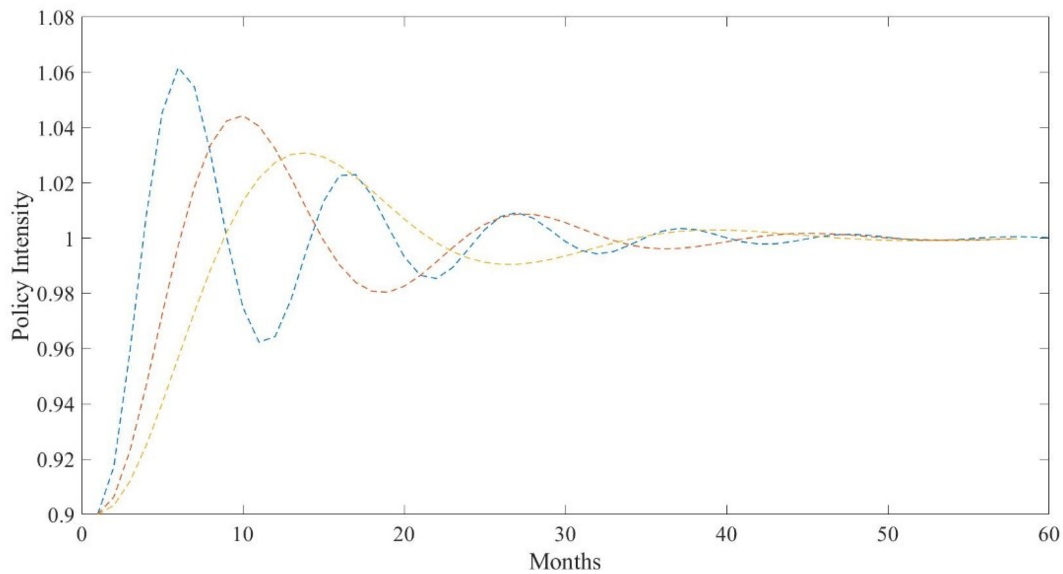

Figure 14: Various Policy Intensity for Certain Expectation

6 Test of policy effectiveness

6.1 ARIMA based predictive outcome scoring test

When get the data, this article failed to get data in 2020. Because of the need to contrast before optimization and after optimization results after five years of higher education in India scores used to check whether its healthy and sustainable performance more obvious change, so this article uses the first 10 years of data and using the method of ARIMA predict got India in 2020, and in the future the indicators data in 2021-2025, on the basis of the comprehensive score results were obtained contrast diagram, as shown in Fig. 15. As can be seen from the chart above, after the implementation of the policy in India, its score is much higher than that of the predicted data without any changes, indicating that the policy is favorable for the higher education system. And before the implementation of policies for two years, its growth is not fast, but only during the third and fourth year growth faster, growth rate of the first five years of its rating and slowly down then tends to be stable, the Fig. 15 and the state space by above policy strength curve Fig. 14.

6.2 Coordination test based on coupling degree analysis

The coupling coordination degree model is used to analyze the coordination development level of things. This can reflect the degree of interdependence and mutual restriction among the compre-

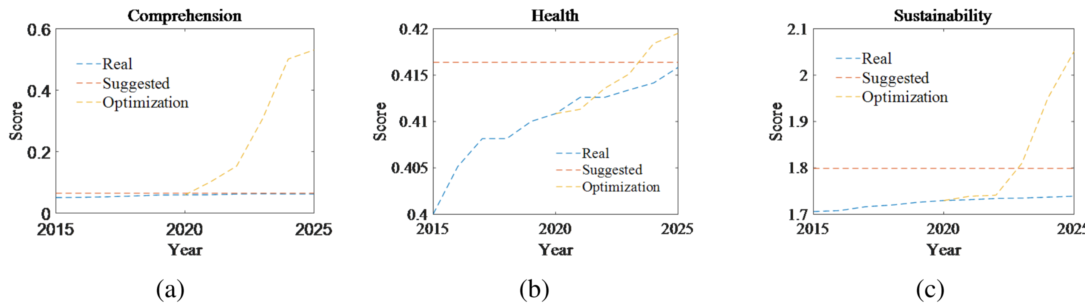

Figure 15: Comparison chart of predicted scores

hensive scores of health, sustainability and education system, and show the degree of quality of higher education system under various circumstances. Coupling degree analysis results are shown in Table. 4. It can be concluded from the above table that the degree of coupling coordination between the previous optimization and the following prediction is lower than the level suggested by the United Nations, which proves that it needs to be changed. After optimization, India's higher education system is in a well-coordinated state and exceeds the level recommended by the United Nations, indicating that all indicators are above the recommended level after optimization, which indicates that the policy formulation is coordinated after complete implementation.

6.3 Test of policy rationality based on sensitivity analysis

Sensitivity analysis is a method to study and analyze the sensitivity of state or output changes of the model to changes in system parameters or surrounding conditions. In this paper, GA algorithm was used to optimize the results, so it is necessary to use sensitivity analysis to test whether the policies provided in this paper can effectively change the scoring results. The results are shown in Table. 5. According to the sensitivity coefficient illustrated in Table. 5, changing the service level, Property of Higher education System and CEPE has a greater impact on the scoring result than changing the academic level, which is corresponding to the fact that India is far lower than the index size recommended by the United Nations in the Fig. 14, which also proves that policies are conducive to changing the situation of Higher education System in India.

6.4 Efficiency test based on DEA

The DEA model is used here to test the results of 2015-2019, prediction and optimization, and the results are shown in Table. 6. It can be concluded from the Table. 6 that the efficiency before optimization is pretty low. while after optimizing, it can reach the highest efficiency, that is, the policy can make the relationship between input and output reach the optimal state after the

Table 4: Coupling degree of compatibility

Item	Coupling degree	Coordination exponent	Coordination degree	Level
Before optimizing	0.488	0.734	0.498	5
After optimizing	0.77	1.001	0.878	9
The UN level	0.719	0.834	0.774	8
Prediction	0.692	0.79	0.639	7

Table 5: Sensitivity coefficient

Criterion	Normalized sensitivity coefficient
Academic level	0.05
CEPE	0.21
Property	0.49
Service level	0.25

Table 6: The efficiency of inspection

Year	2018	2019	2020 (Prediction)	Optimization
Efficiency	0.343	0.353	0.358	1.000
Conclusion	Inefficient, increase	Inefficient, increase	Inefficient, increase	Efficient, stable

implementation of the policy.

7 Analysis of Policy Implementation based on State Space

Analysis on the difficulty of policy implementation based on the controllability of state space. The

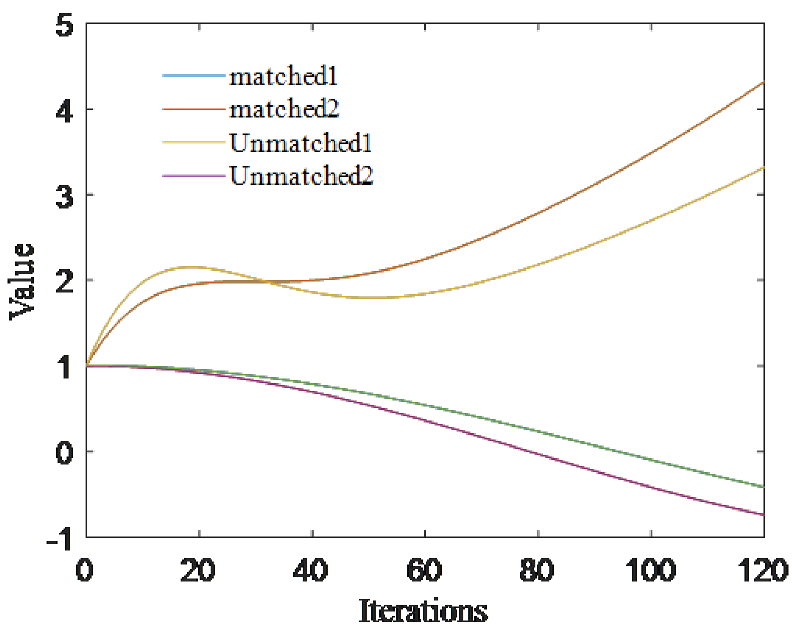

Figure 16: States response curve of time-varying system

following analysis is made from Fig. 16

1. Uncontrollable system will finally lead to system breakdown. As is shown in Fig. 1, high policy intensity with limited resource will cause state of higher education system to be unstable, and finally lead to system breakdown since all states become unstable. In conclusion, system will be stable only when the policy intensity is suitable with resource.

2. The proposed results require India to provide 20% of India's total GDP to provide the education system, but after providing, it will lead to the tension between supply and demand in other aspects, and will make the capital chain of other domestic public construction in a broken state, but will make the higher education system in a state of abundant funds. Obviously, in terms of funding, it is impossible.

3. The proposed result requires that the number of papers and patents published by India's higher education system should exceed that of the United States within five years, and its education level should reach the same level as that of China, which will far exceed the limit that students and teachers can reach. Obviously, it is absurd for the development of India's higher education.

4. The proposed results require that the equity of higher education in India should be raised to the same level as that in the United States, which is beneficial to India with serious discrimination between men and women, but it is obviously difficult to change the strict hierarchy system in a short time.

8 Strength and Weakness

8.1 Strength

1. The weight of each index can be obtained directly through the model proposed in this paper.

2. The method is flexible, and different weight methods can be selected according to different evaluation indexes.

3. The scoring standard is reasonable and intuitive, and the specific scores are obtained, which also compared with the recommended indicators of the United Nations.

4. The testing methods are varied and accurate, and the testing is carried out from four aspects of coordination, rationality, efficiency and scoring.

5. The proposed algorithm can combine qualitative and quantitative assessments, including factors that are difficult to quantify and non-material factors.

6. The model can quantify the intensity of policy implementation and provide a relatively specific implementation plan.

8.2 Weakness

1. Because it is difficult to obtain all the original data of each country, the model fluctuates to a certain extent in practical application.

2. The optimization algorithm of the time-limited model only considers resource constraints, while the actual situation is too complex to cover all aspects.

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