J. COMBIN. MATH. COMBIN. COMPUT. 127a (2025) 1509-1528

Journal of Combinatorial Mathematics and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Combinatorial Press

Research on Teaching Resource Allocation Model Based on Optimization Algorithm in Higher Vocational Education

Dongling Zhou[1,✉]

[1] School of Preschool and Art Education in Zhoukou Vocational and Technical College, Zhoukou, Henan, 466001, China

ABSTRACT

Higher vocational colleges and universities should realize the optimal allocation of teaching resources to provide the necessary guarantee for the improvement of talent cultivation quality. The study puts forward the evaluation index system of teaching resource allocation for teaching resource allocation in higher vocational education, constructs the multi-objective allocation optimization model of teaching resources on this basis, determines the index weights by using the objective combination assignment method combining the principal component analysis method and entropy weight method, and applies NSGA-II algorithm to solve the model. Simulation analysis is carried out with several higher vocational colleges and universities in a city as an example, and the allocation optimization results of multiple teaching resources in higher vocational colleges and universities are obtained. After the optimization of resource allocation, the utilization efficiency and allocation efficiency of teaching resources in each college and university as a whole have been improved by 16.6% and 3.4%, respectively, and all of them tend to be in the state of equilibrium of allocation. The constructed teaching resource allocation optimization model can realize the optimization of teaching resource allocation and promote the reasonable allocation and utilization efficiency of teaching resources in higher vocational education.

Keywords: teaching resource allocation, NSGA-II; multi-objective optimization, index system, higher vocational education

1. Introduction

Higher vocational education resources refers to the sum of all human resources, material resources and information resources invested by the whole society in the field of vocational education and used to cultivate skilled and applied talents [1-2]. At present, the rapid development of higher vocational education, as an important part of higher vocational education, there are many problems in the status quo of the optimal allocation of teaching resources. The lack of teachers causes the lack of educational resources, and many higher vocational colleges and universities have the phenomenon of disproportionate teacher-student

✉ Corresponding author.
E-mail address: 15893659988@163.com (D. Zhou).
Received 10 June 2024; Revised 16 September 2024; Accepted 11 November 2024; Published Online 15 April 2025.
DOI: 10.61091/jcmcc127a-087

ratios, mismatch between the number of teachers and the scale of education, which makes the practical teaching work of higher vocational colleges and universities affected, and restricts the development of higher vocational education and teaching [3-6]. The problem of practical teaching equipment configuration is an important problem plaguing the development of higher vocational colleges and universities, with the rapid development of social and economic development, the experimental requirements of higher vocational colleges and universities have increased accordingly, the utilization rate is low and the input and output are disproportionate to the configuration of the practical equipment to produce an imbalance [7-9]. Even though many higher vocational colleges and universities on-campus training base facilities are complete, the configuration is in place, but there is a difference with the real job practice, ignoring many objective factors that affect the effect of student practice [10-12]. In addition, some higher vocational colleges and universities equipment management is chaotic, equipment utilization and custody rate is greatly reduced, resulting in a waste of equipment resources [13-14]. In the development of higher vocational colleges and universities, the concept of education must keep pace with the times and fall into place. However, many higher vocational colleges and universities have the phenomenon of ideological concepts not being put into practice, and the hours of theoretical classes are far greater than the proportion of practical teaching, resulting in the phenomenon of "empty ideas" [15-17]. The optimal allocation of teaching resources in higher vocational institutions is not only a natural requirement to enhance the comprehensive strength of institutions, but also an inevitable choice to resolve the contradiction of schooling resources. In order to realize the rational use of teaching resources in higher vocational education, so as to give full play to the utilization efficiency of teaching resources and enhance the social service level of higher vocational education, higher vocational colleges and universities need to actively explore the path of optimal allocation of teaching resources based on optimization algorithms [18-19].

Kong, X. et al. proposed a stochastic educational resource management model to solve the problem of educational resource allocation in uncertain environments, which is capable of integrating constraints characterized by uncertainty and generating an optimal educational resource allocation strategy under the constraints of outputs. The model is able to integrate the constraints characterized by uncertainty and generate the optimal educational resource allocation strategy under the constraints of output, personnel and technology [20]. Han, X. In response to the problem of uneven distribution of teaching resources, he proposed to build a diversified and shared teaching resource system, to increase education investment in terms of policy support, to promote education informatization in terms of social support, and also emphasized that higher vocational colleges and universities should strengthen the internal resource management and integration, to promote education equity and to improve the quality of education [21]. Kong, Y. et al. use the time series principle to construct a nonlinear demand prediction model for online teaching resources, which improves the balanced allocation of resources by accurately predicting the demand for teaching resources and effectively solves the dilemma of uneven distribution of online educational resources [22]. Han, Y. et al. showed that the gap between supply and demand among regions of higher vocational education resources has seriously affected the process of supplying high-quality higher education, so they used entropy weight TOPSIS method and coupled coordination degree model to explore the characteristics of the development of higher vocational colleges and universities' education from the perspective of supply and demand and provide a theoretical basis for the optimization of higher vocational education resources [23]. Ding, N. et al. explored the role played by data mining technology in teaching management in higher vocational colleges and universities, which can not only improve teaching efficiency and resource utilization, but also significantly enhance students' learning experience by analyzing students' learning behaviors and effects and formulating reasonable teaching strategies and resource allocation [24]. Chen, J. Taking resource proximity, resource utilization efficiency and resource allocation efficiency as constraints, the multi-objective function of innovative educational resource allocation is constructed, and the NSGA-II algorithm is used to solve the problem and realize the optimal allocation of innovative educational resources [25]. Zhou, N. introduced a simulation-optimized coupling method in the process of

integration and sharing of educational resources in colleges and universities, which is highly operable and scalable, effectively solves the problems of duplicated construction of educational resources and information islands, and promotes the balanced and overall development of educational resources [26]. Xu, H. Integrate the improved genetic algorithm with school-enterprise practice teaching platform and use the algorithm to solve the multi-objective platform optimization problem model. It significantly improves the resource scheduling efficiency, which is of great significance for promoting school-enterprise cooperation, improving the quality of education and cultivating technical talents [27]. Liang, Y. introduced the material point method (MPM) to improve the computational accuracy of Apriori algorithm in the optimization of teaching routes and teaching resources in colleges and universities, and the experiments showed that the improved Apriori algorithm has a high query search efficiency for data and resources, which provides support for the teaching management and course design, and improves the quality of teaching [28]. Shen, Q. From the perspective of optimizing the allocation of scientific and technological talents and training resources, a comprehensive grading index system for resource input and output was established, and a resource allocation algorithm was used to provide university management decision makers with an allocation strategy that has the highest efficiency in resource utilization [29].
This paper identifies eight indicators as the basic elements of teaching resource allocation in higher vocational education from the consideration of human, material and financial resources. Based on the optimization goal of teaching resource allocation, the corresponding mathematical model is constructed by combining the eight indicators, and the principal component analysis and entropy weight method are selected as the methods to solve the corresponding weights of the indicators, and the multi-objective model is transformed into a single-objective model to solve the problem. Next, simulation experiments are carried out for the teaching resource allocation model in higher vocational education, and NSGA-II algorithm teaching model is selected for solving. Taking the statistical data of higher vocational colleges and universities in recent years in a certain city as the research object, the constructed model is used to find out the optimization results of teaching resource allocation in the sample colleges and universities. Then analyze the teaching resource allocation before and after the experiment, and make a comparative analysis of the utilization efficiency and allocation efficiency of teaching resources before and after the optimization. Finally, optimization strategies are proposed for teaching resource allocation in higher vocational education to promote the coordinated development of higher vocational education.

2. Multi-objective optimal allocation of higher vocational teaching resources

2.1. *Multi-objective optimization analysis*

2.1.1. Construction of the indicator system. The evaluation indexes of teaching resources allocation include: the area of teaching and auxiliary rooms per student, the area of physical education and sports venues per student, the number of books per student, the number of computers per student, the value of the assets of teaching instruments and equipment per student, the number of full-time teachers per student, the number of teachers with intermediate or above professional and technical positions per student, and the number of teachers with academic qualifications higher than the prescribed level per student.

2.1.2. Increased level of resource allocation. Enhancing the level of allocation of educational resources means that the limited educational resources can be maximized to increase the proportion of newly allocated educational resources in each district. Therefore, the objective function of the performance in enhancing the level of allocation of educational resources is as follows.
1) The area of teaching and auxiliary rooms per student:

$$\max lev_1 = \frac{A_i + newA_i}{S_i} \tag{1}$$

A_i denotes the total area of teaching and support rooms of the i nd college in the city, $newA_i$ denotes the total area of teaching and support rooms newly allocated to the ith college in the city, and S_i denotes the number of students in the ith college in the city. Analyzing the data, the per capita teaching and support space needs to satisfy the following constraints, i.e., $\max lev_i > 1$.

2) The area of sports and physical education halls per student:

$$\max lev_2 = \frac{G_i + newG_i}{S_i} \tag{2}$$

G_i denotes the total area of sports and physical education venues of the ind college in the city, $newG_i$ denotes the total area of sports and physical education venues newly allocated to the ith college in the city, and S_i denotes the number of students in the ith college in the city. By analyzing the data the per capita area of sports and physical education grounds needs to satisfy the following constraints, i.e., $\max lev_2 > 1$.

3) Number of books per student:

$$\max lev_3 = \frac{B_i + newB_i}{S_i} \tag{3}$$

B_i denotes the total number of books of the ind college in the city, $newB_i$ denotes the total number of books newly allocated to the ith college in the city and S_i denotes the number of students in the ith college in the city. The number of books per student is analyzed by the data to satisfy the following constraints, i.e. $\max lev_3 > 1$.

4) Number of computers per student:

$$\max lev_4 = \frac{C_i + newC_i}{S_i} \tag{4}$$

C_i denotes the total number of computers in the ind college in the city, $newC_i$ denotes the total number of computers newly allocated to the ith college in the city and S_i denotes the number of students in the ith college in the city. Analyzing the data the number of books per student needs to satisfy the following constraints i.e. $0 \le \max lev_4 \le 1$.

5) The value of teaching equipment per student:

$$\max lev_s = \frac{E_i + newE_i}{S_i} \tag{5}$$

E_i denotes the total value of teaching equipment of the ind college in the city, $newE_i$ denotes the total value of teaching equipment newly allocated to the ith college in the city, and S_i denotes the number of students in the ith college in the city. The data are analyzed to satisfy the following constraints on the value of teaching equipment per student, i.e., $\max lev_s > 1$.

2.1.3. Increased utilization of resources. Improving the utilization rate of compulsory education resources requires realizing the rational allocation of teacher teams in the schools where the districts and counties are located. Therefore, for individual districts or schools, the objective function of the indicators related to teacher strength in improving the ability to improve the utilization of educational resources is as follows:

1) Number of full-time teachers per student:

$$\max eff_1 = \frac{T_i + newT_i}{S_i} \tag{6}$$

T_i denotes the number of full-time faculty at the ind college, $newT_i$ denotes the number of full-time faculty newly assigned to the ith college in the city, and S_i denotes the number of students at the ith college in the city. The number of full-time faculty per student needs to satisfy the following constraint,

which is $\max eff_1 < 1$.
2) The number of teachers with middle-level or higher professional and technical positions per student:

$$\max eff_2 = \frac{M_i + newM_i}{S_i} \tag{7}$$

M_i denotes the number of teachers with professional and technical positions at mid-level and above in the i nd university in Xi'an, $newM_i$ denotes the number of teachers with professional and technical positions at mid-level and above newly assigned to the i th university in the city, and S_i denotes the number of students in the i th university in the city. Then the following constraints need to be satisfied, i.e., $\max eff_2 < 1$.
3) The number of teachers with per pupil higher than the required qualifications:

$$\max eff_3 = \frac{H_i + newH_i}{S_i} \tag{8}$$

H_i denotes the number of teachers with higher than required qualifications in the i nd college, $newH_i$ denotes the number of teachers with higher than required qualifications newly assigned to the i th college in the city, and S_i denotes the number of students in the i th college in the city. Then the following constraint needs to be satisfied, i.e., $\max eff_3 < 1$.

2.2. *Construction of the resource allocation optimization model*

2.2.1. Assumptions of the model. In order to remove the disturbing factors, and make the model can be reasonably convenient to find the relative Pareto optimal solution, the model needs to meet the following conditions:
1) Ensure that the original teaching resources data of the higher vocational education schools under the jurisdiction of each district and county are not adjusted during the research process.
2) Determine the eight indicators of teaching resources of schools under the jurisdiction of each district and county, and be able to carry out data processing, so as to facilitate the simulation experiment.

2.2.2. Objective function of the model
1) Enhance the level of educational resource allocation and establish the following objective function:

$$\max F_{lev} = \sum_{i=1}^{m}\sum_{j=1}^{5} \varphi_j lev_{ij} \tag{9}$$

2) Reduce the differences in resource allocation among higher vocational institutions by establishing the following objective function:

$$\min F_{diff} = \frac{1}{\overline{F_{lev}}}\sqrt{\sum_{i=1}^{m}\frac{1}{m}\left(\sum_{j=1}^{5}\varphi_j lev_{ij} - \overline{F_{lev}}\right)^2} \tag{10}$$

$\overline{F_{lev}}$ denotes the average of all colleges and universities under the jurisdiction of the city, and m denotes the number of colleges and universities under the jurisdiction of the city.
3) Improve the utilization rate of educational resource allocation and establish the following objective function:

$$\max F_{eff} = \sum_{i=1}^{m}\sum_{j=6}^{8} \varphi_j eff_{ij} \tag{11}$$

The resource allocation model of higher vocational education in this section aims to realize the rationality, fairness and efficiency of teaching resource allocation at the same time. Therefore, the objective function for teaching resource allocation in this section integrates these three objectives, as shown in equation (12):

$$\begin{cases} \max\left(\sum_{i=1}^{m}\sum_{j=1}^{s}\varphi_j lev_{\hat{y}}\right) \\ \min\left(\sum_{i=1}^{m}\frac{1}{i^2}\left(\sum_{j=1}^{s}\varphi_j lev_{\hat{y}} - \overline{F_{lov}}\right)^2\right) \\ \max\left(\sum_{i=1}^{m}\sum_{j=6}^{s}\varphi_j eff_{ij}\right) \end{cases} \tag{12}$$

Among them, i represents the number of each higher vocational school within the jurisdiction of the city, j represents the weight number of the relevant indicators of educational resources, m represents the number of colleges and universities within the jurisdiction of the city, φ represents the weight of the relevant indicators of educational resources, $\overline{F_{lev}}$ represents the average value of the allocation level of teaching resources of each higher vocational school, lev_{ij} represents the ability performance of the ith university in the jth index of educational resource allocation level, and eff_{ij} represents the ability performance of the ith university in the allocation and utilization rate of teaching resources in the jth index.

2.2.3. Constraints of the model.Based on the above specific description of the resource allocation problem for higher vocational education in each district and county, the constraints of the optimization model for the allocation of teaching resources in each district and county are as follows:

1) Ensure that the teaching resources to be allocated to each higher vocational school in the city are allocated only once:

$$\sum_{h=0}^{m} D_{hi} = \sum_{j=1}^{m+1} D_{ij} = 1 (i = 1, 2, \ldots, n) \tag{13}$$

2) The area of newly configured teaching and support rooms at each university needs to be less than or equal to the area of teaching and support rooms to be configured and optimized:

$$0 \le \sum_{i=1}^{n} newA_i \le L\_A \tag{14}$$

3) The area of newly configured sports venues at each university needs to be less than or equal to the area of sports venues to be configured and optimized:

$$0 \le \sum_{i=1}^{n} newG_i \le L\_G \tag{15}$$

4) The number of newly configured books in each university needs to be less than or equal to the number of books to be configured and optimized:

$$0 \le \sum_{i=1}^{n} newB_i \le L\_B \tag{16}$$

5) The number of newly configured computers in each university needs to be less than or equal to the number of computers to be configured and optimized:

$$0 \le \sum_{i=1}^{n} newC_i \le L\_C \tag{17}$$

6) The asset value of newly configured teaching instruments and equipment in each university needs to be less than or equal to the asset value of teaching instruments and equipment to be configured and optimized:

$$0 \le \sum_{i=1}^{n} newE_i \le L\_E \tag{18}$$

7) The number of new full-time faculty at each college needs to be less than the number of full-time faculty to be optimized:

$$0 \le \sum_{i=1}^{n} newT_i \le L\_T \tag{19}$$

8) The number of newly deployed teachers in intermediate and above professional and technical positions in each university needs to be less than or equal to the number of full-time teachers to be deployed and optimized:

$$0 \le \sum_{i=1}^{n} newM_i \le L\_M \tag{20}$$

9) The number of new higher-than-mandatory-degree faculty at each college needs to be less than or equal to the number of higher-than-mandatory-degree faculty to be optimized:

$$0 \le \sum_{i=1}^{n} newH_i \le L\_H \tag{21}$$

10) The cost of new instructional resources allocated to the five indicators is less than or equal to the total price of the highest instructional resources to be allocated greater than or equal to the total price of the lowest instructional resources to be allocated, and the total cost of new instructional resources allocated to faculty is less than or equal to the total price of the highest instructional resources to be allocated to faculty greater than or equal to the total price of the lowest instructional resources to be allocated to faculty:

$$\begin{gathered} sumP\_low \le newA_iP_a + newG_iP_g + newB_iP_b + newC_iP_c + newE_iP_e \le sumP\_hight \\ sumW\_low \le newT_iW_i + newM_iW_m + newH_iW_h \le sumW\_hight \end{gathered} \tag{22}$$

2.3. *Solving for the weights of the indicators*

For the eight indicators in the teaching resource allocation model will have different impacts on the higher vocational education in the district and county, this paper adopts the objective combination of assignment hair to solve the weight of the indicators.

2.3.1. Principal Component Analysis.The basic idea of principal component analysis is to use orthogonal transformations to convert the original data into multiple indicator variables to achieve the effect of dimensionality reduction, while at the same time making the principal components reflect most of the information of the original variables, and the information variables are not related to each other. The basic principle of the assignment is to analyze the variance contribution rate of each indicator factor in the indicator factor loading matrix to the weight value of the indicator, the more information the component can reflect, the greater the corresponding variance contribution rate, the greater the weight of the component. The idea of dimensionality reduction of principal component analysis, to a certain extent, the objective division of the degree of influence of the indicators, after proving that the indicators are not related to each other, it will make the objective weighting results more accurate.

The analyzing steps of principal component analysis:

1) Standardization of indicators

In order to exclude the influence of the different orders of magnitude and the outline, the raw data need to be standardized first, so that the average value of each indicator is 0 and the variance is 1.

2) Calculate the sample correlation matrix R.

3) Calculate the eigenvalues and unit eigenvectors of the correlation matrix R:

Let $|R-\lambda_i I|=0,\ldots\ldots,|R-\lambda_p I|=0$ solve the equation to obtain p non-negative eigenvalues $\lambda_1,\lambda_2\ldots\lambda_p$ actually the variance of the principal component $y_1, y_2\cdots y_p$.

4) Calculate the eigenvalue contribution rate and cumulative contribution rate:

The variance contribution rate of the i th principal component y_i is:

$$\alpha_i=\frac{\lambda_i}{\sum_{i=1}^{p}\lambda_i} \tag{23}$$

The cumulative contribution of principal component $y_1, y_2 \ldots y_m$ is:

$$\frac{\sum_{i=1}^{m}\lambda_i}{\sum_{i=1}^{p}\lambda_i} \tag{24}$$

The corresponding variance contribution of the component is the weight of the indicator.

2.3.2. Entropy weight method.Entropy is an index of information theory representing the degree of disorder of the system, if the information entropy value of an indicator is smaller, it indicates that the amount of information provided by the indicator is larger, i.e., the influence effect on a certain result is higher. Therefore, the principle of entropy right method is: according to the degree of variation of the indicator, calculate the entropy right of the indicator, and use the entropy right of the indicator for empowerment, to get more objective evaluation results.

The analyzing steps of entropy weight method:

1) Determine the evaluation matrix

The first thing is to determine the evaluation matrix of the evaluation index system, i.e., if there is an evaluation system with m evaluation object and n evaluation indexes, the evaluation matrix will be standardized first:

$$B=\begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{11} \\ \vdots & \vdots & \ddots & \vdots \\ b_{m1} & b_{m1} & \cdots & b_{mn} \end{bmatrix} \tag{25}$$

2) Calculation of information entropy value

The information entropy of the i st evaluation index is defined as:

$$H_i=-\frac{1}{\ln n}\sum_{j=1}^{n} b_{ij}\ln b_{ij}\ (i=1,2\cdots,m) \tag{26}$$

3) Determine the information entropy weights of the indicators:

$$\omega_i=\frac{1-H_i}{m-\sum_{j=1}^{m}H_i}(i=1,2\cdots,m) \tag{27}$$

2.3.3. Objective weight combination assignment. The principal component analysis method of weighting is through the idea of dimensionality reduction, however, the principal component analysis needs to ensure that the cumulative contribution rate of the first few principal components extracted reaches a high level (i.e., the information content of the variable after dimensionality reduction must be maintained at a high level), otherwise, the weights will be concentrated on a few indicators. Secondly, the number of indicators studied in this paper is relatively small, and the application of principal component analysis may lead to the problem of over-allocation of the weights of the main indicators, which affects the results of indicator assignment to a certain extent.

The entropy weight method, as an objective weight analysis method, utilizes the information entropy characterization of the degree of disorder reacting to the amount of information to be assigned. However, the entropy weighting method only highlights the local differences, and when the level difference between the assessment objects is greater, the greater weight the indicator receives, and the greater the impact on the assessment results. When all the entropy values tend to be close to 1, even a very small difference will cause a great change in the entropy weights, resulting in some indicators being given weights that do not match the degree of their influence (a situation in which the weights are almost uniformly distributed), which to a certain extent affects the results of the indicator assignment.

Through the above analysis, it can be seen that the principal component analysis method and the entropy weight method have a certain complementarity when dealing with a small number of indicators and the information entropy value of the indicator data is close to and tends to be 1. Therefore, this paper adopts the objective combination assignment method to assign weights to the teaching resource allocation evaluation indexes of higher vocational education, circumvents the defects of the principal component analysis method and the entropy weight method, and expresses the sexual combination of the two kinds of weights as the integrated weight $\omega = \alpha U + \beta V$, in which $U = (\mu_1, \mu_2, \dots \mu_n), V = (\varphi, \varphi_2, \dots \varphi_n), \alpha \geq 0, \beta \geq 0$ and α, β satisfy the unitary constraint $\alpha^2 + \beta^2 = 1$. With the results obtained by assigning the two objective weights determined separately, the final combined weight vector is formed $\omega = (\omega_1, \omega_2, \dots \omega_n)$. In this paper, the idea of maximizing the variance is used to determine the value of α, β so that the results are more faithful to the objective data.

Variance is a statistical indicator of the degree of variation. Based on the idea of maximizing variance, the weight vector should maximize the total variance of all indicators for all decision options. Steps of objective weight analysis based on the idea of variance maximization:

1) Construct a linear programming model:

$$\max Z = \sum_{j=1}^{m}\sum_{i=1}^{n}(r_{ij} - \overline{r}_{ij})^2 \omega_j = \sum_{j=1}^{m}\sum_{i=1}^{n}(r_{ij} - \overline{r}_{ij})^2 (\alpha u_j + \beta v_j) \tag{28}$$

$$s.t. \quad \alpha^2 + \beta^2 = 1, \quad \alpha, \beta > 0 \tag{29}$$

2) Solve the model optimal solution

Construct the Lagrangian function such that $\frac{\partial L}{\partial \alpha} = 0, \frac{\partial L}{\partial \beta} = 0$, and $\alpha^2 + \beta^2 = 1$ can be found:

$$\alpha = \frac{1}{\sqrt{1 + \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}(r_{ij} - \overline{r}_{ij})^2 u_j}{\sum_{j=1}^{m}\sum_{i=1}^{n}(r_{ij} - \overline{r}_{ij})^2 v_j}}} \tag{30}$$

$$\beta = \frac{1}{\sqrt{1 + \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}(r_{ij} - \overline{r}_{ij})^2 v_j}{\sum_{j=1}^{m}\sum_{i=1}^{n}(r_{ij} - \overline{r}_{ij})^2 u_j}}} \tag{31}$$

The combination weight $\omega = (\omega_1, \omega_2, \dots \omega_n)$ is obtained by normalization.

2.4. NSGA-II based model solving

NSGA algorithm is based on genetic algorithm, and its core technology lies in two aspects: one is to classify the individuals in the population by adopting the principle of non-dominated sorting. The second is to calculate the virtual crowding distance of each individual through the principle of shared small habitat.NSGA algorithm is based on the above two technical principles of the "selection" link to the multi-objective evaluation and selection of the population, so as to achieve multi-objective optimization, and in the field of multi-objective optimization, NSGA algorithm has shown a strong advantage of the strong search ability, good robustness and other strong advantages. However, as the complexity of the problem increases, the NSGA algorithm also reveals such defects as high computational complexity, the excellent individuals are easily covered in the iterative process, and the sharing parameters need to be specified artificially.

For the shortcomings of NSGA scholars proposed NSGA-II algorithm. That is, the computational complexity of the algorithm is reduced from $O(mM^3)$ to $O(mM^2)$ by introducing the fast non-dominated sorting technique, the elite retention technique, and the use of crowding and crowding comparison operators, m being the number of operations, and M being the population size). At the same time, the distribution range of the Pareto solution set is extended.

The flow of NSGA-II algorithm in solving multi-objective optimization problems is shown in Fig. 1, including the following basic operations:

1) Setting of algorithm parameters and input of variable ranges.
2) Encoding, i.e., mapping decision variables to individual chromosomes, while randomly generating an initial population P_0 that satisfies the constraints.
3) Calculate each objective function value corresponding to each individual in the current population.
4) Perform fast non-dominated sorting, and calculate the sorting rank of each individual i_{rank}. Given the number of objective functions as $M(M>1)$ and the population size as N, the specific method of sorting the population according to the dominance relationship among individuals is as follows:

Step1: Initialize counter $j=1$.

Step2: Calculate the fitness function value of an individual. Determine the dominance relationship between individual χ^j and individual χ^n ($j=1,2,\cdots,N$, and $j \neq n$) from the fitness function value. If there is no χ^n is better than χ^j, then χ^i is a non-dominated individual.

Step3: Make $j=j+1$ and go to Stepl until all non-dominated individuals are found.

All non-dominant individuals found by the above loop are assigned a rank i_{rank} of 1. These individuals are then removed from the population and the above loop is performed on the remaining subpopulations to find all individuals assigned a rank i_{rank} of 2, and so on until all individuals are assigned the corresponding rank i_{rank}. And so on until all individuals are assigned the corresponding 3.

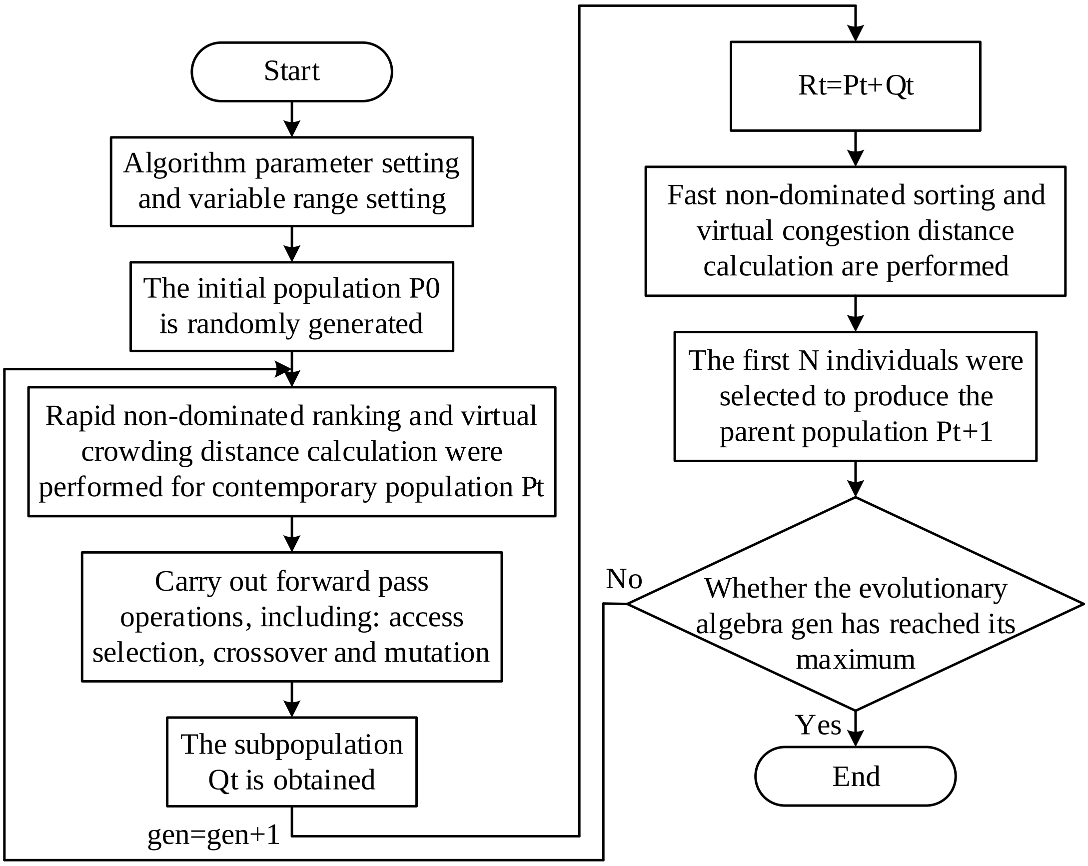

Fig. 1. Flowchart of the NSGA-Ⅱ algorithm

5) Calculation of virtual crowding distance i_d. In order to maintain population diversity and prevent premature maturation, NSGA-II proposes the concept of "virtual fitness". Virtual crowding distance i_d is the crowding distance between solution i and two neighboring solutions $i-1$ and $i+1$ of the same level. Representing each solution in the target space as a point, the crowding distance i_d of solution i is the sum of the lengths of the long and short sides of the dashed rectangle. This technique can automatically adjust the small habitat, so that the solution set is evenly distributed in the target space, to prevent "bunching", to ensure that the algorithm is globally optimized. The specific steps for calculating i_d are as follows:

Step1: Initialize the distance of individuals in the same layer: $L[i]_d = 0$.

Step2: Sort the individuals in the same layer in ascending order by the m nd objective function value: $L = sort(L, m)$.

Step3: To keep individuals on the edge from being left out, given a large number $L[0]_d = L[l]_d = M$.

Step4: For the individuals in the middle of the ranking, find the crowding distance: $L(i)_d = L[l]_d + (L[i+1]_m - L[i-1]_m)$, where $L[i]_m$ is the m th objective function value for the i th individual.

The formulation of the crowding distance for a two-objective optimization problem can be expressed as follows:

$$L[i]_d = \frac{(L[i+1] \cdot f_1 - L[i-1]) \cdot f_1)}{f_1^{\max} - f_1^{\min}} + \frac{(L[i+1] \cdot f_2 - L[i-1]) \cdot f_2)}{f_2^{\max} - f_2^{\min}} \tag{32}$$

For the optimization problem containing r objective, the formula for calculating the congestion distance for individual i can be expressed as:

$$L[i]_d = \sum_{k=1}^{r} (L[i+1] \cdot f_k - L[i-1]) \cdot f_k) / (f_k^{\max} - f_k^{\min}) \tag{33}$$

$$L[i]_d = \sum_{k=1}^{i} (L[i+1] \cdot f_k - L[i-1]) \cdot f_k) / (f_k^{\max} - f_k^{\min}) \tag{34}$$

Step5: Repeat steps Step2~Step4 for different objective functions.

6) Selection operation. The "selection" is the core step of the algorithm, which is equivalent to the gradient vector and ensures that the algorithm iterates in the direction of the Pareto optimal solution. The selection method based on the ordering i_{runk} and crowding distance i_d is: when $i_{rank} < j_{rank}$, or $i_{rank} = j_{rank}$ and $i_d > j_d$, then individual i is better than individual j, choose i. i.e.: preferred i_{rank} smaller individuals, if the two bodies of i_{rank} the same, then choose to congestion i_d larger, i.e., sparser around the individual. From the selection mechanism, it can be seen that the principle of non-dominated selection is to select according to the dominance relationship and the degree of crowding, i.e., on the one hand, select the individual that is significantly better for the goal, and on the other hand, select the individual that is significantly better for the convergence of the algorithm.

7) Elite strategy. This technique is to retain the superior individuals in the parent generation directly into the next generation. The preferred elite individuals are added to the parent population and then selection is made in this composite population to produce the next generation population. The elite strategy prevents the optimal individuals from being omitted and helps to ensure the convergence speed of the algorithm. Because the selection operation is a probabilistic behavior, the elite individuals may also fail to be selected. Therefore, this strategy is conducive to the fast convergence of the algorithm.

3. Experimental results and analysis of resource allocation models

In this paper, the teaching resource allocation optimization model of higher vocational education is analytically modeled, and this chapter will analyze and validate the resource allocation optimization model by taking the resource allocation optimization of higher vocational education in a city as an example.

3.1. Experimental design

This experiment takes a certain city as the research object, optimizes the resource allocation of higher vocational education in the districts and counties of the city, and solves the optimal configuration of each index of the corresponding teaching resources of higher vocational schools in each district and county in the case of meeting the standards, which meets the highest efficiency and the smallest discrepancy, so as to validate the validity of the model.

In order to solve the problem of optimizing the allocation of higher vocational education resources in a city, the resource data of higher vocational education in the city's districts and counties are selected, and the experimental data come from the reporting platform of a city's basic database of education statistics.

3.2. Indicator weighting results

In the process of teaching resource allocation in higher vocational education, the eight indicators have different impacts in higher vocational education. Therefore, in order to make the allocation of higher vocational education resources more reasonable, for the resource allocation optimization model with weights, each indicator is solved using the objective combination assignment method.

In 2023, the number of full-time teachers (T), the number of full-time teachers with higher than required academic qualifications (M), the number of intermediate and above professional and technical vocational teachers (S), the number of computers (F), the value of teaching instruments and equipment (E), the number of books (B), the area of teaching and auxiliary rooms (X), and the area of sports halls (Y) of higher vocational schools in various districts and counties in a certain city will be statistically collected and processed, and the weights of each evaluation index will be calculated and processed. The weights of each evaluation index are shown in Figure 2. The area of teaching and auxiliary rooms (X), the area of sports venues (Y) and the value of teaching equipment assets (E) have the greatest influence on the allocation of teaching resources in higher vocational schools, with weights of 0.1550, 0.1514 and 0.154.

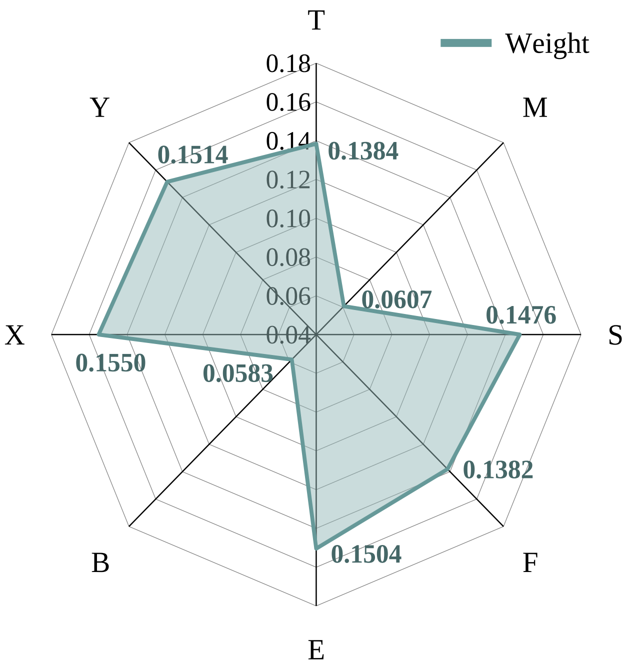

Fig. 2. The weight of each evaluation index

3.3. *Simulation Analysis*

In this paper, NSGA-II algorithm is used to conduct experimental tests, and the test data come from a city's education statistics basic database reporting platform. The NSGA-II algorithm is applied to solve the optimization model of teaching resource allocation for higher vocational education proposed in this study. The iteration of the algorithm is shown in Figure 3, which shows that the experiment tends to stabilize at about 180 generations, indicating that the optimal solution of the model is obtained at this time, and the value of the fitness function at this time is 28745.2.

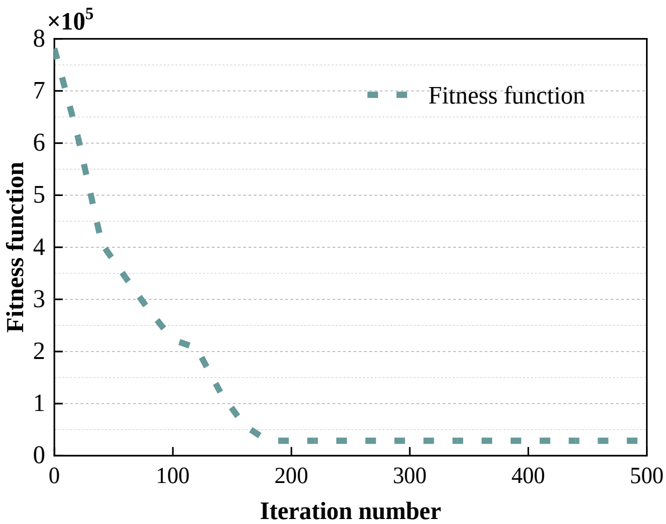

Fig. 3. The iteration of algorithm

The experiment obtained the results of teaching resources allocation of 12 higher vocational colleges and universities (S1~S12) in various districts and counties of a city, and the existing resources of each higher vocational college and university plus the allocated resources are the optimized resource allocation results of higher vocational colleges and universities. Therefore, the optimized results of educational resource allocation in each higher vocational institution are shown in Table 1. Each row in the table represents the optimal allocation of teaching resources for each higher vocational institution, and each column represents the number of optimal resources for that kind of teaching resources for that higher vocational institution. For example, for higher vocational institution S1, the allocation of its eight resources is analyzed:

1) The existing full-time teachers T of higher vocational institution S1 is 3522, and the new full-time teachers that should be assigned to higher vocational institution S1 after the simulation experiment of the model resource allocation optimization model is 460, so the full-time teachers of this school after the resource allocation optimization is 3982.

2) The existing number of teachers M above the required degree in higher vocational institution S1 is 4253, and the number of new teachers above the required degree assigned to S1 after the experiment is 117, so the number of teachers above the required degree after resource allocation optimization in this school is 4370.

By analogy, the allocation of other higher vocational institutions is similar.

Table 1. The resource allocation optimization results of higher vocational school

	T	M	S	F	E	B	X	Y
S1	3982	4370	1975	14356	14668	142377	136491	179446
S2	5347	4401	2361	13874	14492	140769	150277	140914
S3	4575	1892	4440	2472	3645	160574	215122	191772
S4	5460	4632	5502	2625	3150	207862	160062	158288
S5	3415	3628	1334	17722	16345	217403	184679	152881
S6	3108	5985	3712	4818	4876	126333	212361	203591
S7	4714	1546	4073	2711	4586	214436	198319	160429
S8	5074	3307	1193	14535	17242	126976	176452	210861
S9	4377	4402	3085	4257	4594	200217	165275	141632
S10	6055	3501	2483	1305	4430	131891	172330	139690
S11	2609	3319	3714	5005	1181	161676	140600	200049
S12	1435	5434	3643	11843	13778	170943	168480	128098

3.4. *Comparative analysis of experimental results*

3.4.1. Resource utilization efficiency.In order to verify whether the model improves the utilization efficiency of resources, the analysis of experimental results is carried out to calculate the resource utilization efficiency of each higher vocational college before and after the experiment. The resource utilization efficiency of each college before and after the experiment is shown in Figure 4. The resource utilization efficiency of each college and university before and after the experiment has been improved, with an average increase of 16.6%, and the resource utilization efficiency of each college and university tends to be in a balanced state. S1, S3, S5 and S8, the colleges and universities with lower resource utilization efficiency, have improved their resource utilization efficiency from 0.742, 0.788, 0.763 and 0.774 before optimization to 1.034, 1.015, 1.053 and 1.025 respectively, with an improvement rate of 29.2%, 22.7%, 25.8% and 25.1%.

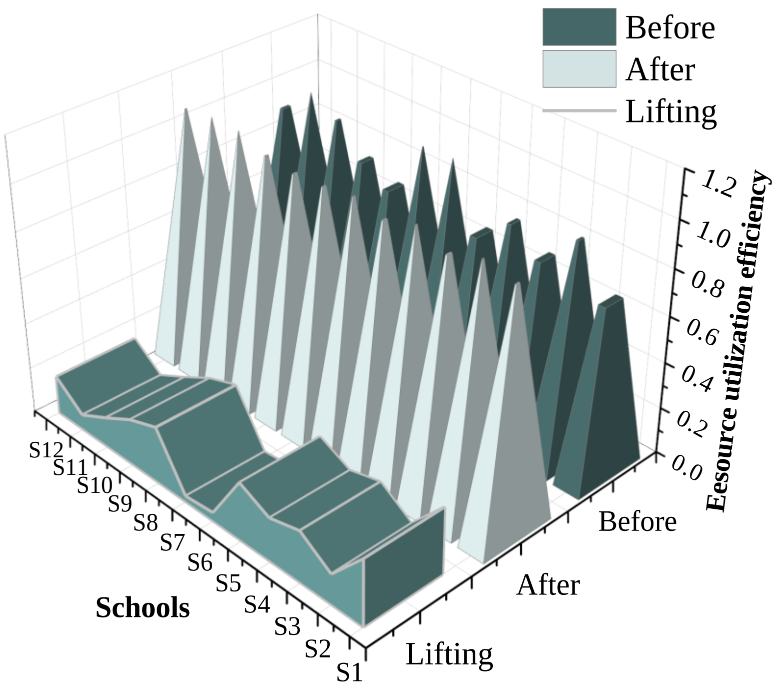

Fig. 4. The efficiency of resource utilization before and after the experiment

3.4.2. Resource allocation efficiency. In order to verify whether the model improves the resource allocation efficiency, the original data of each higher vocational college and the optimized configuration scheme are substituted into the model, and the overall resource allocation efficiency of each college before and after the optimization is calculated respectively, and the resource allocation efficiency of each college before and after the experiment is shown in Figure 5. The difference in teaching resource allocation efficiency among higher vocational colleges and universities before the experiment is large, with a minimum value of 0.129 and a maximum value of 0.184. The allocation efficiency after optimization is 0.192, with an average improvement of 3.4%, indicating that the optimization of teaching resource allocation in higher vocational education can be achieved by adjusting the quantity and structure of teaching resources.

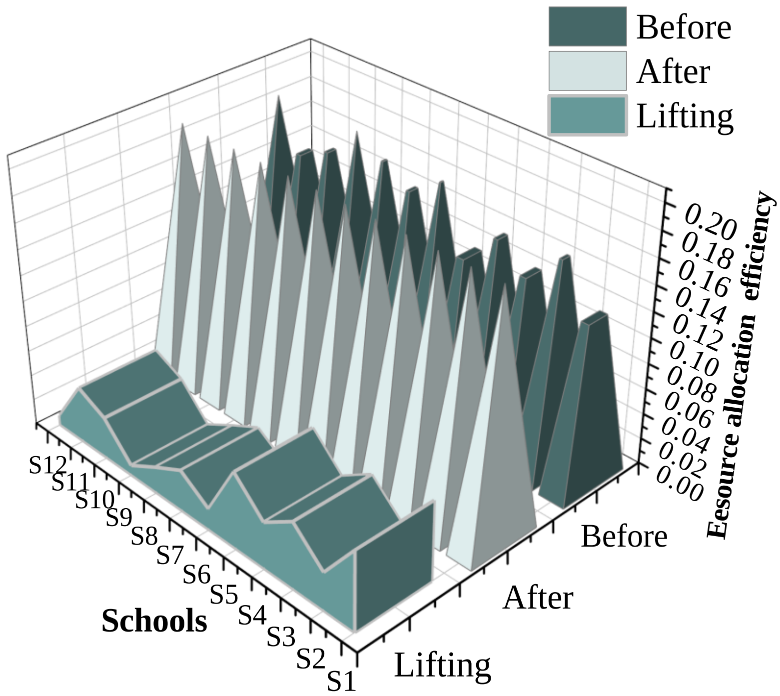

Fig. 5. The efficiency of resource allocation before and after the experiment

Taking the input single indicator full-time teachers as an example, calculate the full-time teacher resource allocation efficiency of colleges and universities before and after optimization, after normalization of this data, the results of full-time teacher resource allocation efficiency of colleges and universities before and after the experiment are shown in Figure 6. Before the experiment, the full-time faculty resource allocation efficiency interval of each university is large, indicating that there are large differences in resource allocation between and within universities, and there is no clear standard. After optimization the level of faculty allocation are 0.752, reaching a more reasonable ratio and standard.

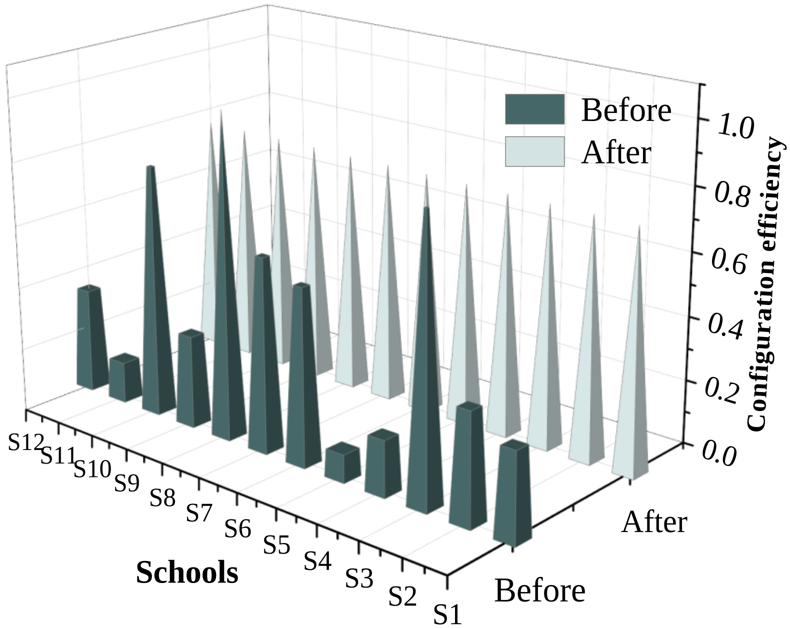

Fig. 6. The efficiency results of the teachers' resource allocation before and after the experiment

4. Strategies for Optimizing the Allocation of Higher Vocational Teaching Resources

Higher vocational education should make fair and reasonable use of higher vocational teaching resources, improve the quality of teaching, maximize the efficiency of its higher vocational teaching resources utilization, and maximize the role of the region or institution, so as to complete the construction of higher vocational education. Combined with the modeling and analysis of teaching resource allocation in the above article, the strategy of optimizing the allocation of higher vocational teaching resources is proposed.

4.1. Government involvement in resource allocation

First of all, the government must clarify its own main position, in the development of higher vocational education to take the initiative to assume a part of the financial burden, increase the investment in education funds, to ensure that education funding and resource allocation "synchronous growth". In order to rationally allocate education funds, the government should introduce relevant financial policies, for the lack of education resources in the region to make the corresponding financial subsidies. Secondly, the government can fully mobilize financial means to build a diversified channel of capital investment. For example, relevant preferential policies should be introduced to encourage and support enterprises and social organizations to participate in the construction of higher vocational education.

4.2. Optimizing the mix of educational resources

The resource allocation of higher vocational colleges and universities should be based on the social productivity, the development level of the regional economy and the school's own schooling reality, so as to attract students in a targeted manner and to open specialties according to the actual needs of the region. Can also be through cooperation with high-tech enterprises, for its output of professional talents, give full play to the advantages of higher vocational education in scientific research, management, faculty, etc., a clear positioning, differentiated from the general colleges and universities in the training of personnel objectives, so as not to cause the phenomenon of the pile up of talent training. At the same time, it can also flexibly adjust the education structure according to the demand for talents in the social market.

4.3. Improve relevant policies and regulations

Higher vocational colleges and universities should pay attention to the construction of relevant rules and regulations, and further divide the education system and mechanism to clarify the responsibilities of the educated and the educators, and improve the utilization efficiency of resource allocation. Governments at all levels and education authorities should strengthen the planning and management of resource allocation, and integrate the structure of higher vocational education into the development of local economy and education, so as to rationalize the allocation of educational resources and the structure of regional economic development in the region.

4.4. Optimize the structure of the faculty

In terms of faculty strength, reform the personnel recruitment system of higher vocational colleges and universities, set up a regional sharing of teachers, open professorial titles for teachers, establish a human resources system system, reduce personnel mobility and lack of talent, improve the closed state of the previous faculty management, and create a fair and reasonable faculty management model, so as to complete the sharing of faculty resources in higher vocational colleges and universities.

5. Conclusion

In order to realize the rational use of teaching resources in higher vocational education and give full play to the utilization efficiency of teaching resources, a multi-objective optimal allocation model of higher vocational teaching resources is constructed, and the model is solved using NSGA-II algorithm. The usability and reasonableness of the designed teaching resources allocation optimization model are verified through simulation analysis and comparison before and after the experiment.

Different proportions of each evaluation index will lead to different allocation results of teaching resources, so weights are added to the teaching resource allocation optimization model proposed in this study. The model is also simulated and analyzed in combination with the actual teaching resource situation of a city's higher vocational college, which confirms that the model is practical and feasible. The experimental comparison results show that the utilization efficiency of teaching resources in higher vocational colleges and universities before optimization is low, and there exists the phenomenon of high input and low output, and low input and low output. There are large differences in the allocation of all resources between schools and within colleges and universities, and there is no clear standard. After optimization, the resource utilization efficiency of colleges and universities increased from 0.742 to 1.019 to 1.015 to 1.087, with an average increase of 16.6%, and tended to be balanced. The efficiency of resource allocation also increased from 0.129 to 0.184 to 0.192, with an overall improvement of 3.4%, and the adjustment of the quantity and structure of teaching resources has realized the optimization of teaching resource allocation in higher vocational education.

Optimizing the allocation of teaching resources in higher vocational colleges and universities is not only a due requirement to enhance the comprehensive strength of institutions, but also an inevitable choice to resolve the contradiction of schooling resources. On the basis of the correct cognition of the reality of higher vocational education resources, it is necessary for the government to participate in optimizing the allocation of educational resources as well as combining educational resources, improving the utilization rate of educational resource allocation, and promoting the sustainable development of higher vocational education by improving policies and regulations and optimizing the structure of the teaching staff.

References

[1] Wagiran, M., Pardjono, M., Suyanto, W., & Sofyan, H. (2017, September). Vocational Education Development Framework in 21st Century. In International Conference on Technology and Vocational Teachers (ICTVT 2017) (pp. 395-398). Atlantis Press.

[2] Ling, Y., Chung, S. J., & Wang, L. (2023). Research on the reform of management system of higher vocational education in China based on personality standard. Current Psychology, 42(2), 1225-1237.

[3] Nissilä, S. P., Karjalainen, A., Koukkari, M., & Kepanen, P. (2015). Towards competence-based practices in vocational education-what will the process require from teacher education and teacher identities?. CEPS Journal, 5(2), 13-34.

[4] Wang, D. (2019). Opportunities, challenges and strategies for the internationalization development of higher vocational education in the new situation. Creative Education, 10(10), 2174-2185.

[5] Schmidt, T. (2021). Teacher as person: the need for an alternative conceptualisation of the 'good'teacher in Australia's Vocational Education And Training sector. Journal of Vocational Education & Training, 73(1), 148-165.

[6] Noguera, I., Barrientos, D., Torres-Sánchez, M., & Pineda-Herrero, P. (2024). Exploring Pedagogical and Digital Practices in Vocational Education and Training: Comparing Teacher and Student Perspectives. Education Sciences, 14(7), 734.

[7] Zhao, H. (2022). Teaching mode in the management of higher vocational colleges in the era of big data. Mobile Information Systems, 2022(1), 8100495.

[8] Chen, M. (2024). Research on the Development Status of Higher Vocational Education in China. International Journal of Education and Humanities, 13(2), 108-110.

[9] Po, Y., & Yunbo, L. (2017). Balanced Development for Provincial-Level Coordination and Higher Vocational Education. Chinese Education & Society, 50(5-6), 469-498.

[10] Li, Y., Zhen, X., Ma, J., & Wang, X. (2024). Challenges and Teaching Reform Strategies in Vocational College Engineering Training Courses. Journal of Contemporary Educational Research, 8(7), 323-330.

[11] Cui, J. (2023). Optimal allocation of higher education resources based on fuzzy particle swarm optimization. International Journal of Electrical Engineering & Education, 60(2_suppl), 312-324.

[12] Ye, H. (2015). Optimization of resource scheduling based on genetic algorithm in cloud computing environment. Metall Min Ind, 7(6), 386-391.

[13] Azman, A., SIMATUPANG, W., Karudin, A., & Dakhi, O. (2020). Link and match policy in vocational education to address the problem of unemployment. International journal of multi science, 1(07), 76-85.

[14] Wu, X. (2021, April). Application of artificial intelligence in modern vocational education technology. In Journal of Physics: Conference Series (Vol. 1881, No. 3, p. 032074). IOP Publishing.

[15] Rulong, L. (2018). Analysis of the Development Strategy of China's Higher Vocational Education from the Perspective of" The 13th Five-Year Plan. International Journal of New Developments in Engineering and Society, 2(1), 127-131.

[16] He, X. (2022). The innovative development of chinese vocational education from the perspective of the metaverse. Journal of Education and Educational Research, 1(2), 8-12.

[17] Khrapatyi, S., Tokarieva, K., Hlushchenko, O., Paramonova, O., & Lvova, I. (2024). Research on performance evaluation of higher vocational education informatization based on data envelopment analysis. STEM Education, 4(1), 51-70.

[18] Rustamova, N. R. (2020). Development of technology based on vitagenic experience using media resources in higher educational institutions students teaching. International Journal of Scientific and Technology Research, 9(4), 2258-2262.

[19] Guo, Y. (2022, August). Research on cloud platform construction and resource sharing system of virtual simulation training in Higher Vocational Education. In 2022 14th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC) (pp. 211-215). IEEE.

[20] Kong, X., Wang, D., Wang, Y., & Wang, N. (2020, September). A stochastic programming method for resources allocation in education of higher vocational college. In Journal of Physics: Conference Series (Vol.

1637, No. 1, p. 012090). IOP Publishing.

[21] Han, X. (2024). Integration and Optimization of Teaching Resources for Electronics and Communications Courses in Higher Vocational Education. Transactions on Comparative Education, 6(3), 157-163.

[22] Kong, Y., Li, Y., & Liu, Y. (2024). A balanced allocation of network teaching resources in higher vocational colleges based on demand prediction. International Journal of Continuing Engineering Education and Life Long Learning, 34(1), 66-76.

[23] Han, Y., Ni, R., Deng, Y., & Zhu, Y. (2023). Supply and demand of higher vocational education in China: Comprehensive evaluation and geographical representation from the perspective of educational equality. Plos one, 18(10), e0293132.

[24] Ding, N., & Zhang, H. (2024, June). Research on the application of data mining technology in teaching management of higher vocational colleges. In Proceedings of the 2024 International Conference on Intelligent Education and Computer Technology (pp. 83-87).

[25] Chen, J. (2024). An innovative educational resource allocation method based on NSGA-II algorithm. International Journal of Reasoning-based Intelligent Systems, 16(3), 231-239.

[26] Zhou, N. (2024, May). A Path of Integrating and Sharing Higher Education Resources Through Simulation Optimization Coupling. In International Conference on Artificial Intelligence for Society (pp. 164-173). Cham: Springer Nature Switzerland.

[27] Xu, H. (2024, March). Construction of Personalized Practice Teaching Platform for School-Enterprise Integration Based on Improved Genetic Algorithm. In 2024 International Conference on Interactive Intelligent Systems and Techniques (IIST) (pp. 20-25). IEEE.

[28] Liang, Y. (2023, December). Analysis and Optimization of Teaching and Learning Paths in Universities Based on Association Data Mining. In International Conference on Educational Technology and Administration (pp. 257-267). Cham: Springer Nature Switzerland.

[29] Shen, Q. (2023, April). Research on Intelligent Allocation and Optimization Algorithm of Higher Education Resources Based on PSO. In 2023 IEEE 3rd International Conference on Electronic Communications, Internet of Things and Big Data (ICEIB) (pp. 396-399). IEEE.