# THE OPTIMIZATION PATH OF HIGHER EDUCATION RESOURCE ALLOCATION IN CHINA BASED ON FUZZY SET THEORY

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## ABSTRACT

*The use of fuzzy set theory to adjust the educational resource allocation model is the optimal path to achieve the allocation of educational resources. The optimal path realized by fuzzy set theory promotes the healthy development of education and addresses the current important and urgent tasks in the field of higher education in China. This study utilizes the basic theory of fuzzy sets and analyzes dynamic fuzzy set theory, fuzzy relations and fuzzy matrices. The indexes of optimal allocation are selected according to the classification of higher education resources, the fuzzy set multi-objective planning model is designed, and finally, the combination of factors of education production in colleges and universities is optimized. The experiment proves that: the average allocation efficiency of excellent colleges and universities is 0.186, and the average improvement is 35.41% after optimization. The average allocation efficiency of ordinary colleges and universities is 0.174, which is improved by 22.12% on average after optimization. It can be found that the resource allocation efficiency of excellent colleges and universities is generally higher than that of ordinary colleges and universities, and the role of excellent colleges and universities with more abundant resources themselves is greater after the optimization of college resource allocation. It indicates that by adjusting the quantity and structure of educational resources according to the optimization path, the optimization of educational resource allocation can be achieved. This verifies that: the emergence of optimal paths for solving resource allocation realized by fuzzy set theory has greatly expanded the application of fuzzy methods in the field of higher education and provided a new theoretical tool for solving resource allocation.*



## KEYWORDS

*Fuzzy set theory; optimization path; dynamic fuzzy set; resource allocation efficiency; fuzzy matrix*

# PAPER INDEX




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# 1. INTRODUCTION

Using fuzzy set theory to adjust the educational resource allocation model is the optimal path to achieve the allocation of educational resources. The optimal allocation of higher education resources in China refers to the integration and rational arrangement of educational resources in the area to be determined according to the principles of sustainability and resource sharing to achieve maximum benefits [1-4]. The priority allocation of educational resources is a condition and prerequisite for the development of education; without sufficient and compliant educational resources, the universalization of education and the improvement of educational standards cannot be discussed [5-9]. The allocation of educational resources reflects the degree of education adapting to social development in a certain period and also reflects the level of efficiency and fairness of education. Entering the era of the knowledge economy and talent competition, the development of colleges and universities affects all aspects of social and economic life, and the construction of talent in colleges and universities has been a problem that cannot be ignored in any country or region [10-11]. Educational activities consist of four factors, which are the objectives of educational activities, the basic principles or norms of educational activities, the conditions of educational activities, and the means of educational activities [12-14]. In summary, they can be divided into two categories: subjective factors and objective factors. Subjective factors include the goals and norms of educational activities, which are reflected in the meaning and value of educational activities [15-19]. Objective factors include the objective conditions and means of educational activities, which are the ways and means to achieve educational activities [20]. Higher education resource allocation reflects this characteristic. On the one hand, resource allocation is a subjective activity with strong purposefulness. On the other hand, it strictly depends on certain objective methods and is carried out with the help of certain means [21-23]. This is an important path in the analysis of higher education resource allocation and is of great significance for the study of the value theory of higher education resource allocation [24].

Fuzzy set theory is generally used to express inexact evaluation data and information in a fuzzy language in numerous decision problems with multiple attributes and multiple dimensions. This is because when solving decision problems, the use of fuzzy language can more accurately and efficiently reflect the information about the decision maker's preferences for each attribute in the decision solution. The literature [25] used fuzzy set theory to estimate the cognitive (or fuzzy) uncertainty that arises due to limited data samples when measuring small field output factors. The literature [26] conducted a questionnaire survey in which a total of 169 questionnaires were sent to participants using Google Forms based on the results of the literature review and interviews. The results of the linguistic fuzzy set approach identified three main conditions that influence the wage level in the automotive industry in Mexico City, including unskilled labor, the neoliberal economic model, and political and trade reforms. On the other hand, organizational conditions were not considered relevant for determining wage levels. Based on the findings, several recommendations were made. The literature [27] explored all necessary and sufficient combinations of the

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presence or absence of outcomes in the fuzzy dataset. Necessary causal conditions are those that produce an outcome, while sufficient combinations are those that always lead to a given outcome. Many face images feature extraction and dimensionality reduction algorithms, such as local graph embedding-based algorithms or fuzzy set algorithms, have been proposed in the literature [28] for linear and nonlinear data. However, the above algorithms are not very effective for face images because they always suffer from overlaps (outliers) and sparse points in the database. To solve these problems, a new effective dimensionality reduction method for face recognition is proposed: sparse graph embedding fuzzy sets for image classification. The purpose of this algorithm is to construct two new fuzzy Laplace scattering matrices using local graph embedding and fuzzy k-nearest neighbors. Finally, the optimal discriminative sparse projection matrix is obtained by adding elastic network regression. Many problems have been solved in the above literature using the basic theory of fuzzy sets with good results.

The construction of human resources education in colleges and universities has become a problem that cannot be ignored in any country or region. To be able to use resource allocation optimization to solve education construction problems, this study uses the basic theory of fuzzy sets and analyzes dynamic fuzzy set theory, fuzzy relations and fuzzy matrix. It elaborates to give specific higher education resource classification, and selects indicators for optimal allocation of education resources in Chinese universities according to education resource classification. And design the fuzzy set multi-objective planning model according to the known allocation indexes, and finally realize the combination optimization of higher education production factors and determine the optimal path of higher education resources allocation based on fuzzy set theory. Integrating fuzzy set theory into the construction of the optimal path of resource allocation can not only provide a theoretical basis for solving the dynamic fuzzy problem and create an important path for the value analysis of college teaching evaluation but also lay the foundation for the value theory research of college teaching evaluation.

# 2. A PATH GENERATION MODEL FOR RESOURCE ALLOCATION OPTIMIZATION BASED ON FUZZY SET THEORY

## 2.1. FUZZY SETS, FUZZY RELATIONS AND FUZZY MATRICES

Let a map be defined on the domain U of the argument:

$$\left(\overleftarrow{A},\overrightarrow{A}\right):\left(\overleftarrow{U},\overrightarrow{U}\right)\rightarrow[0,1]\times[\leftarrow,\rightarrow],\left(\overleftarrow{u},\overrightarrow{u}\right)\rightarrow\left(\overleftarrow{A}\left(\overleftarrow{u}\right),\overrightarrow{A}\left(\overrightarrow{u}\right)\right) \quad (1)$$

Recorded as:

$$\left(\overleftarrow{A},\overrightarrow{A}\right)=\overleftarrow{A}or\overrightarrow{A} \quad (2)$$

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Then call $\left(\overleftarrow{A},\overrightarrow{A}\right)$ the fuzzy set on $\left(\overleftarrow{U},\overrightarrow{U}\right)$, or $DFS$ for short, and call $\left(\overleftarrow{A}\left(\overleftarrow{u}\right),\overrightarrow{A}\left(\overrightarrow{u}\right)\right)$ the subordination of the subordination function to $\left(\overleftarrow{A},\overrightarrow{A}\right)$.

Note: Any number $a\in[0,1]$, can be fuzzy $a$ to

$a\overset{DF}{=}(\overleftarrow{a},\overrightarrow{a}), a\overset{DF}{=}\overleftarrow{a}\ or\ \overrightarrow{a},\ max(\overleftarrow{a},\overrightarrow{a})\triangleq\overrightarrow{a},\ min(\overleftarrow{a},\overrightarrow{a})\triangleq\overleftarrow{a}$.So that we can visualize the development trend of $a$ the state. If the teaching quality is good, it means good or bad, good means good teaching quality but with a downward trend, and bad means bad teaching quality and with an upward trend. The fuzzy theory can not only represent the fuzzy degree of the data but also can visualize the trend of the fuzzy data.

There can be more than one $DF$-set on the theoretical domain $U$, and the whole of the $DF$-set $U$ is $DF(U)$ as shown in Equation (3):

$$\begin{aligned}DF(U)&=\left\{\left(\overleftarrow{A},\overrightarrow{A}\right)\mid\left(\overleftarrow{A},\overrightarrow{A}\right),\left(\overleftarrow{u},\overrightarrow{u}\right)\to[0,1]\times[\leftarrow,\to]\right\}\\&=\left\{\left(A\times(\leftarrow,\to)\right)\mid\left(A\times(\leftarrow,\to)\right),\left(u\times(\leftarrow,\to)\right)\to[0,1]\times[\leftarrow,\to]\right\}\end{aligned} \tag{3}$$

There is a one-to-one correspondence between fuzzy relations and fuzzy matrices, and fuzzy matrices are an important tool for studying fuzzy relations. Let $\left(\overleftarrow{X},\overrightarrow{X}\right)$ and $\left(\overleftarrow{Y},\overrightarrow{Y}\right)$ are both fuzzy data, then the relationship between $\left(\overleftarrow{X},\overrightarrow{X}\right)$ and $\left(\overleftarrow{Y},\overrightarrow{Y}\right)$ is defined as follows:

If equation (4) holds, then $\left(\overleftarrow{R},\overrightarrow{R}\right)$ is a type $L$ type $DF$ relation from $\left(\overleftarrow{X},\overrightarrow{X}\right)$ to $\left(\overleftarrow{Y},\overrightarrow{Y}\right)$.

$$\left(\overleftarrow{R},\overrightarrow{R}\right)\in DF_L\left(\overleftarrow{X},\overrightarrow{X}\right)\times\left(\overleftarrow{Y},\overrightarrow{Y}\right) \tag{4}$$

If equation (5) holds, then $\left(\overleftarrow{R},\overrightarrow{R}\right)$ is the $DF$ relation from $\left(\overleftarrow{X},\overrightarrow{X}\right)$ to $\left(\overleftarrow{Y},\overrightarrow{Y}\right)$.

$$L=\left[\left(\overleftarrow{0},\overrightarrow{0}\right),\left(\overleftarrow{1},\overrightarrow{1}\right)\right] \tag{5}$$

Let the $DF$-relationship from $\left(\overleftarrow{X},\overrightarrow{X}\right)$ to. $\left(\overleftarrow{Y},\overrightarrow{Y}\right)$ be a $DF$-matrix and expressed as Equation (6).

$$\left\{\left(\overleftarrow{X_n},\overrightarrow{X_n}\right)\right\},\left(\overleftarrow{Y},\overrightarrow{Y}\right)=\left\{\left(\overleftarrow{y_1},\overrightarrow{y_1}\right),\cdots,\left(\overleftarrow{y_n},\overrightarrow{y_n}\right)\right\} \tag{6}$$

## 2.2. CLASSIFICATION OF HIGHER EDUCATION RESOURCES

All the elements that can play an influence and role in the allocation of educational resources in higher education can become educational resources, and their content composition is relatively complex and can be classified according to their different qualities. As shown in Table 1.

**Table 1.** Classification of higher education resources

| Classification category | Higher education resources |
|---|---|
| Own attribute | Land space resources |
| | Financial resources |
| | Equipment resources |
| | Time resources |
| | Human resources |
| | Information resources |
| Existential form | Dominant resources |
| | Recessive resources |
| Time node | Traditional resources |
| | Real resources |
| | Future resources |

The higher education resources under different classification levels are detailed below:

1. Land and space resources: Land and space resources are the most traditional resources and the most basic elements that enable education and teaching to take place. It mainly includes natural resources such as suitable teaching land and teaching space [29-30]. However, with the development of the times and the advancement of network technology, its basic role has not changed but its importance is weakening.

2. Financial and material resources: The progress of all disciplines needs financial and material support. Financial resources refer to the financial investment to support the development of university education, including research funds and public funds. Financial resources are characterized by the diversity of sources, continuity of supply and professionalism of management. Physical resources refer to all material elements that support the development of university education, including teaching places, libraries, dormitory buildings, logistic facilities and so on. There are man-made and natural physical resources, and this paper refers to physical resources in a narrow sense.

3. Equipment resources: This resource refers to the sum of various teaching equipment that assists teaching and learning to be carried out effectively, with the characteristics of the times, and the complete teaching equipment has begun to play and will continue to play its important role in today's teaching. Equipment resources mainly include advanced multimedia teaching facilities, abundant library

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materials and retrieval equipment, experimental equipment, etc. It provides more possibilities for the development of big data teaching.

4. Time resources: Time resources are a more important factor than space resources because they control the trajectory of all human development, and time is also our wealth. The improvement of an idea is an accumulative process, so time and resources must play a very important role and are one of important factors for educational development.
5. Human resources: Broadly speaking, it refers to all the people involved in the educational process to achieve the educational goals, including the implementers of the goals and the goal bearers. For example, teachers, counselors, administrators and all students in the university.
6. Information resources: Information resources are the collective term for all information that has a positive impact on the achievement of educational purposes and can be used. Educational information resources are characterized by the wide range of sources, the timeliness of dissemination, and the comprehensiveness of content.
7. Explicit resources: Explicit resources are all the public and direct educational processes conducted by education for college students. They undertake the main task of systematic and formalized teaching, and the theoretical nature of the information they contain cannot be replaced by other resources.
8. Implicit resources: Implicit resources generally refer to all the resources that have indirect educational effects on students in education. Generally speaking, we call all resources other than "two courses" teaching in colleges and universities that can have a positive effect on the improvement of students' thinking level as hidden educational resources in colleges and universities.
9. Traditional resources: Traditional resources refer to the rich human heritage that has been accumulated in history and can be utilized by educational disciplines. Our traditional culture is extremely rich and provides a constant source of cultural support and inspiration for educational teaching.
10. Realistic resources: Realistic resources are the general term for the resources that are updated from the traditional resources in the context of the new era. Real resources generally cover the healthy spiritual achievements formed in the process of socialist modernization.
11. Future resources: Future resources are the sum of all resources that will be needed and used by the future society and can be predicted to be used in education and teaching. With the acceleration of globalization, the exchange of information is everywhere, and the earth has become a "village", which creates conditions for the exchange of educational resources between countries of different regions.


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## 2.3. RESOURCE ALLOCATION OPTIMIZATION MODELING

### 2.3.1. SELECTION OF CAPITAL INDICATORS

In this paper, we measure the efficiency of educational resources allocation in colleges and universities according to the attributes of Chinese educational resources in 2.2.1 and finally determine six indicators: $x1$ teacher-student ratio (%), $x2$ average management-teacher ratio (%), $x3$ the total value of teaching instruments and equipment assets (million yuan), $x4$ the average amount of special funds invested (million yuan), $x5$ the average area of practice platform room (m2) and $x6$ average area of the educational base (m2). To quantify the allocation efficiency, the values of the above indicators are used to calculate the resource utilization efficiency of universities, and the calculation formula is shown in Equation (8):

$$S = C_1 * \underline{A_1} + C_2 * \underline{A_2} + C_3 * \underline{A_3} + C_4 * \underline{A_4} + C_5 * \underline{A_5} + C_6 * \underline{A_6} \quad (7)$$

where $\underline{A_i}$ is the rating of $A_i$ and $c_i$ is $(i = 1,2,\cdots,6)$. Since the determination of weights is subjectively influenced by individuals, this paper de-quantifies some indicators and establishes a fuzzy set multi-objective planning model.

### 2.3.2. MULTI-OBJECTIVE PLANNING MODEL

According to the fuzzy set correlation theory in Section 2.1, suppose $f(x) = \left(f_1(x), f_2(x), \cdots, f_9(x)\right)$ denotes the vector of objective functions of nine indicators of higher education resources, and $g(x) = \left(g_1(x), g_2(x), \cdots, g_9(x)\right)$ denotes the vector of constraint functions of each indicator. The problem of optimal allocation of resources can be transformed into the following fuzzy set planning model, as shown in Equation (9):

$$max = \left\{\left(Z_1 = f_1(x), Z_2 = f_2(x), \cdots, Z_9 = f_9(x)\right)\right\} \quad (8)$$

In the feasible domain as shown in Eq. (10):

$$Z = \left\{z \in R^n \,|\, z_1 = f_1(x), z_2 = f_2(x), \cdots, z_9 = f_9(x)\right\} \quad (9)$$

where $S^m$ is the feasible domain of decision space and $R^n$ is the feasible domain of target space.

### 2.3.3. OPTIMIZATION OF THE COMBINATION OF PRODUCTION FACTORS IN HIGHER EDUCATION

Higher education resources are influenced by multiple factors such as time, geography and social structure, and the problem of their allocation is not a simple linear distribution. Among the factors of production, quality is the life and ultimate measure of higher education, and its ultimate goal is to maximize the benefits in terms of student output, knowledge output and social output. Assuming that $z$ is the quantity of educational output and $x$ is the different forms of the factors, then:


https://doi.org/10.17993/3ctic.2023.121.308-328

$$P = \sum_{j=1}^{m} Z_j / \sum_{i=1}^{n} X_i \tag{10}$$

Where, $P$, $X$ and $Z_j$ denote the input-output ratio, the combination of different educational factors and the quantity of educational output respectively. From the above equation, it can be seen that when $P$ is larger, the combination of educational production factors is more reasonable, so the combination with the largest input-output ratio should be selected. However, at the same time, as the input increases, the cost of education will also increase. Therefore, it is also necessary to consider the cost issue.

### 2.3.4. A GENERATIVE MODEL OF THE OPTIMIZED PATH

The objective function is obtained from the above analysis as:

$$max\ R_1 = \sum_{i=1}^{n} x_f / \sum_{i=1}^{n} y_f \quad max\ R_2 = \sum_{i=1}^{n} y_f / \sum_{i=1}^{n} z_f \quad max\ R_3 = \sum_{i=1}^{n} D_f / \sum_{i=1}^{n} y_f \tag{11}$$

$$max\ R_4 = \sum_{i=1}^{n} E_f / \sum_{i=1}^{n} y_f \quad max\ R_5 = \sum_{i=1}^{n} F_f / \sum_{i=1}^{n} x_f \quad max\ R_6 = \sum_{i=1}^{n} x_f \tag{12}$$

Where: $X_{uv}, Y_{uv}, D_{uv}, E_{uv}, F_{uv}, H_{uv} \geq 0, \forall uv$ The following constraints should be satisfied at the same time:

$$\text{S.t. } \alpha_{11} \leq \sum_{i=1}^{nj} x_{ij} \leq \alpha_{12} \quad \alpha_{21} \leq \sum_{i=1}^{nj} y_{ij} \leq \alpha_{22} \quad \alpha_{31} \leq \sum_{i=1}^{nj} y_{ij} \leq \alpha_{32} \tag{13}$$

$$\alpha_{41} \leq \sum_{i=1}^{nj} y_{ij} \leq \alpha_{42} \quad \alpha_{51} \leq \sum_{i=1}^{nj} y_{ij} \leq \alpha_{52} \tag{14}$$

The above model is developed for each indicator of higher education in China. Where, $n_j$ denotes the number of colleges and universities in $j$ regions, and other indicators in $j$ regions are represented by annual totals $\sum$. The different meanings of these optimization indicators are represented in Table 2.

**Table 2.** Representative meanings of optimization path indicators based on fuzzy set theory

| Value of U | Representative meaning |
|---|---|
| X | Total number of students in school |
| Y | Total number of annual management teachers |
| Z | Total assets of teaching instruments and equipment |
| D | Annual special fund input |
| E | Annual floor area of practice platform |
| F | Annual education base area |


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# 3. EXPERIMENTS AND ANALYSIS OF OPTIMAL PATHS UNDER THE FUZZY SET THEORY

Six excellent colleges and universities and six general local colleges and universities in a province are used as research samples to integrate the optimization objective functions and constraints of multi-objective higher education resource allocation in China. The multi-objective planning model based on fuzzy set theory is used to calculate the optimal path of the combination of higher education production factors. When the configuration optimization model tends to be stable and the fitness function tends to the minimum value, the six sets of optimal paths obtained at this time are shown in Table 3. The optimal paths 1-3 indicate the highest efficiency of educational resource utilization and allocation when the educational resources of general colleges and universities are allocated in such a ratio. The optimal paths 4-6 indicate that when the educational resources of excellent colleges and universities are allocated in this way, the educational resources are used and allocated with the highest efficiency.

**Table 3.** Optimization path of higher education resource allocation in China based on fuzzy set theory

| Measurable index | Optimal path 1 | Optimal path 2 | Optimal path 3 | Optimal path 4 | Optimal path 5 | Optimal path 6 |
|---|---|---|---|---|---|---|
| Teacher student ratio/% | 1:220 | 1:215 | 1:213 | 1:201 | 1:198 | 1:189 |
| Ratio of management teachers per student/% | 1:320 | 1:311 | 1:300 | 1:298 | 1:290 | 1:287 |
| Total assets of teaching instruments and equipment per student/10000 yuan | 0.0895 | 0.0845 | 0.0823 | 0.0811 | 0.0802 | 0.0800 |
| Special fund input per student/ 10000 yuan | 0.0095 | 0.0091 | 0.0084 | 0.0082 | 0.0080 | 0.0071 |
| Room area of practice platform per student/$m^2$ | 1.15203 | 1.15201 | 1.15198 | 1.15186 | 1.15166 | 1.1502 |
| Area of education base per student/$m^2$ | 0.3860 | 0.3854 | 0.3823 | 0.3811 | 0.3802 | 0.3799 |

To illustrate the positive utility of the optimization path in depth, further analysis is conducted in three aspects: faculty staffing resources, resource utilization efficiency, and resource allocation efficiency, respectively.

## 3.1. FACULTY STAFFING RESOURCES

To be able to use resource allocation optimization to solve the problem of equipping resources for faculty in educational construction, the average number and structure of faculty in educational resource allocation in 12 universities were analyzed according

https://doi.org/10.17993/3ctic.2023.121.308-328

to the classification of higher education resources using the resource allocation optimization model of fuzzy set theory, and the following analysis results were obtained:

1. In terms of the overall number of teaching and research staff on board and the number of different titles, the total number of teaching and research staff has steadily increased from 2017 to 2021, and the number of the four titles has tended to stabilize. Among them, the number of associate professors tends to increase slightly, the number of professors and lecturers remains unchanged, and the number of assistant professors gradually decreases, as shown in Figure 1.

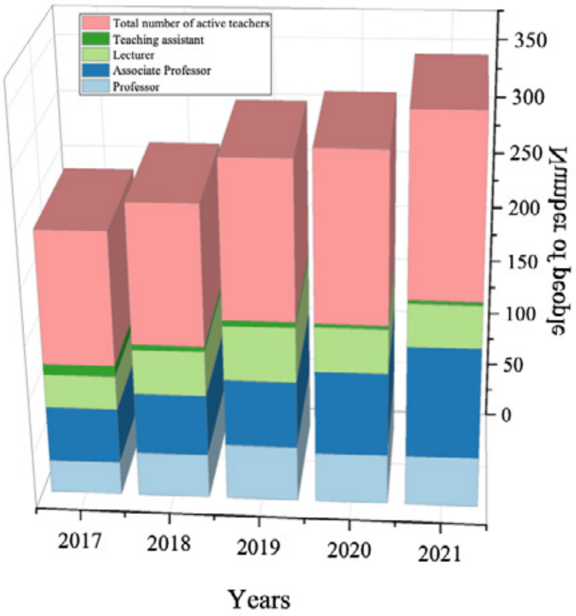


**Figure 1.** Statistics on the number of active teaching and research staff in the optimization path

2. The situation of student-teacher ratio shows a general downward trend. Due to the adjustment of enrollment policy, it leads to the increase in the number of undergraduate and master students in 2018-2019, while it returns to a stable state in 2020, and the student-teacher ratio decreases to 20:1. The ratio of the total number of graduate students to the total number of professors and associate professors decreases to 15:1 from more than 20:1 in previous years. The ratio of doctoral students to professors is higher than 20, which is caused by the expansion of universities in the early stage on the one hand, and the lack of faculty on the other hand The ratio of Ph. The specific situation is shown in Table 4.


https://doi.org/10.17993/3ctic.2023.121.308-328

**Table 4.** Percentage of students and faculty under the optimized pathway (Unit:%)

| | Student-teacher ratio | Ratio of students to the number of professors, associate professors and lecturers | Ratio of graduate students to the number of professors and associate professors | Ratio of the number of doctoral students to professors |
|---|---|---|---|---|
| 2017 | 23 | 22 | 25 | 21 |
| 2018 | 23 | 22 | 20 | 23 |
| 2019 | 21 | 24 | 22 | 25 |
| 2020 | 20 | 23 | 25 | 21 |
| 2021 | 22 | 25 | 20 | 22 |

3. In terms of the title structure of the active faculty and researchers, the share of professors remained unchanged from 2017 to early 2021, the share of associate professors increased, while the share of lecturers and assistant professors decreased. The details are shown in Table 5.

**Table 5.** Structure of teaching and research staff titles in the optimization path (unit:%)

| | Professor | Associate Professor | Lecturer | Teaching Assistants |
|---|---|---|---|---|
| 2017 | 0.25 | 0.38 | 0.25 | 0.08 |
| 2018 | 0.27 | 0.38 | 0.26 | 0.07 |
| 2019 | 0.27 | 0.38 | 0.25 | 0.09 |
| 2020 | 0.27 | 0.45 | 0.26 | 0.07 |
| 2021 | 0.25 | 0.38 | 0.25 | 0.07 |

4. In terms of the academic structure of the teaching and research staff in post, as shown in Figure 2, 67% of the total number of teaching and research staff have doctoral degrees. Among them, 56% of the professors have Ph. D.s, 72% of the associate professors and 80% of the lecturers. Since the current policy stipulates that faculty and researchers who stay in the university must have a doctoral degree, the academic structure at the beginning of 2021.


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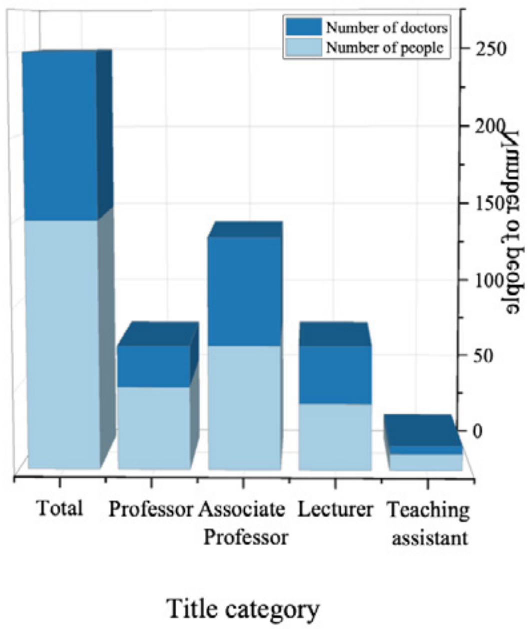


**Figure 2.** Statistics on the educational structure of faculty and researchers in the optimization path

5. Looking at the age structure of the faculty and research staff with a reasonable allocation of higher education resources in China, it is shown in Figure 3. 46% of the faculty and research staff are less than 40 years old. Thirty-five percent of the teaching and research staff are between 40 and 50 years old, and only 15% of them are older than 50 years old, and they are mainly professors. Professors are all older than 40 years old, and 50% of them are older than 50 years old. The age of associate professors is mainly below 50 years old, among which 46% and 47% of associate professors are above and below 40 years old respectively. Lecturers and assistant professors are relatively younger, generally under 40 years old. In terms of age structure, the age distribution is relatively reasonable.

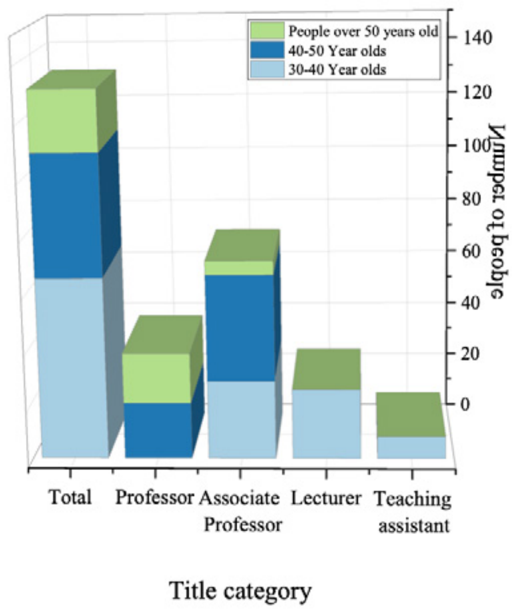


**Figure 3.** Statistics on the age structure of faculty and researchers in the optimization path


https://doi.org/10.17993/3ctic.2023.121.308-328

6. The gender structure of in-service Chinese higher education researchers with reasonable resource allocation is shown in Figure 4. Women account for 35%. Among them, 21% of professors are female, 40% of both associate professors and lecturers are female, and 33% of assistant professors are female.

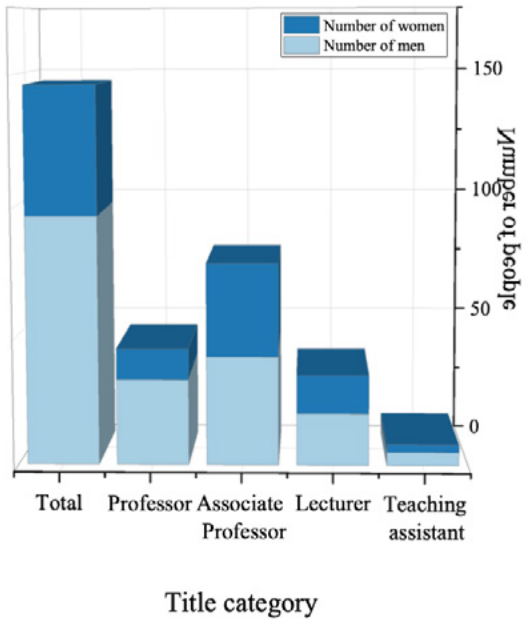


**Figure 4.** Statistics on the gender structure of Faculty and Researchers in the optimization path

## 3.2. RESOURCE UTILIZATION EFFICIENCY

Six excellent universities and six general local universities in a province were used as the research samples, and the data of China's higher education resources from 2017-2021 were counted. To verify whether the resource allocation optimization path generated by the fuzzy set multi-objective planning model improves the resource utilization efficiency, optimal path 1 and optimal path 3 are used as examples for the analysis of experimental results. According to the calculation of the resource utilization efficiency of each university before and after the experiment, it is found that the resource utilization efficiency of each university before and after the experiment has improved, with an average increase of 18.25%, and the resource utilization efficiency of each university tends to be in a balanced state. The experimental resource utilization efficiency of excellent schools is shown in Figure 5(a), and the resource utilization rate of ordinary colleges and universities is shown in Figure 5(b). The resource utilization efficiency of excellent colleges and universities and general colleges and universities are improved from 48.302 and 0.523 before optimization to 1.057 and 1.068, respectively, with an improvement rate of 32.3% and 52.4%. It can be found that the resource utilization rate of ordinary colleges and universities is generally higher than that of excellent colleges and universities, which indicates that resource allocation optimization is more useful for ordinary colleges and universities with scarce resources.


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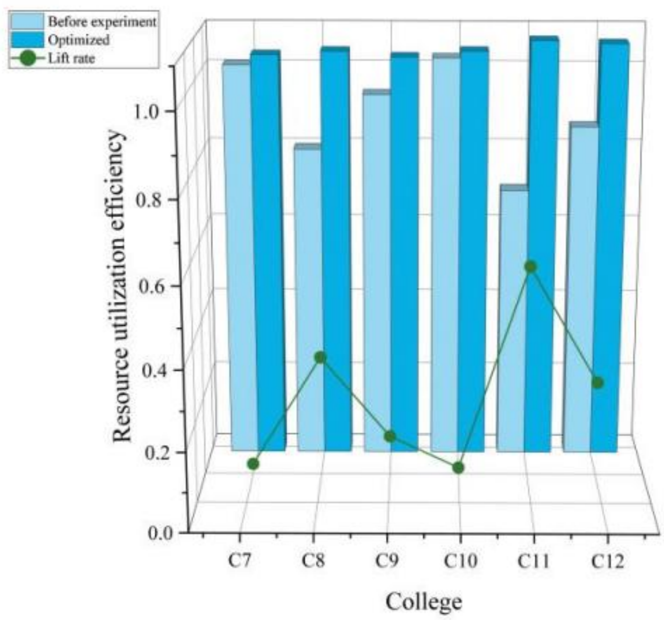
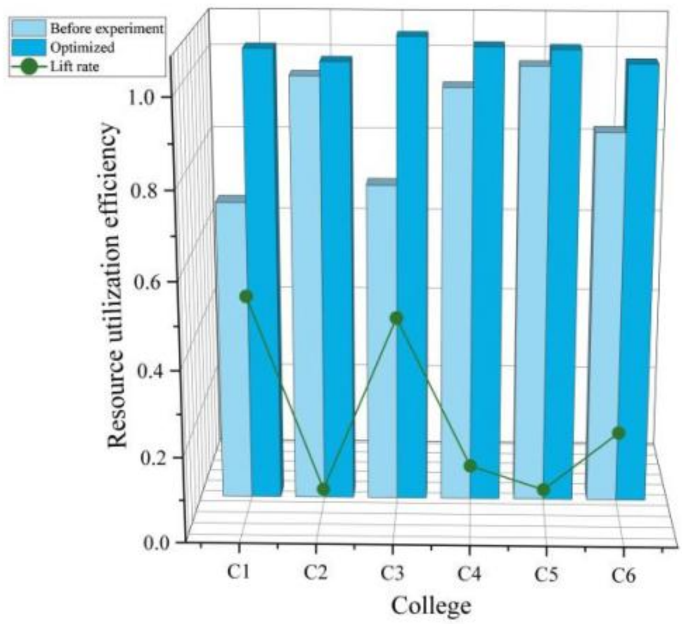



(a) Resource utilization rate of excellent universities




(b) Resource utilization rate of general universities

**Figure 5.** Comparison of resource utilization of universities before and after the implementation of the optimized path

## 3.3. RESOURCE ALLOCATION EFFICIENCY

To verify whether the optimized paths generated by the fuzzy set multi-objective planning model improve the resource allocation efficiency, the overall resource allocation efficiency of the original data and the optimized allocation solutions (optimal path 1 and optimal path 3) of each university are calculated before and after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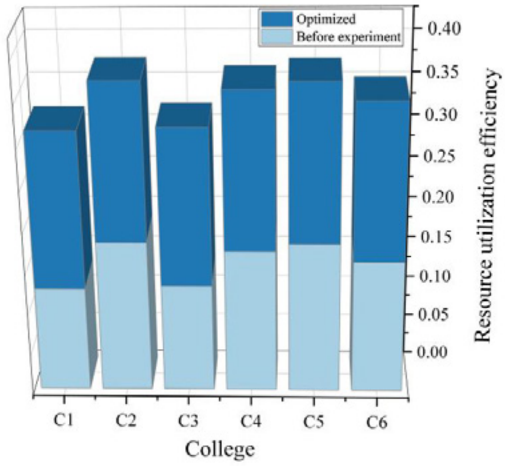
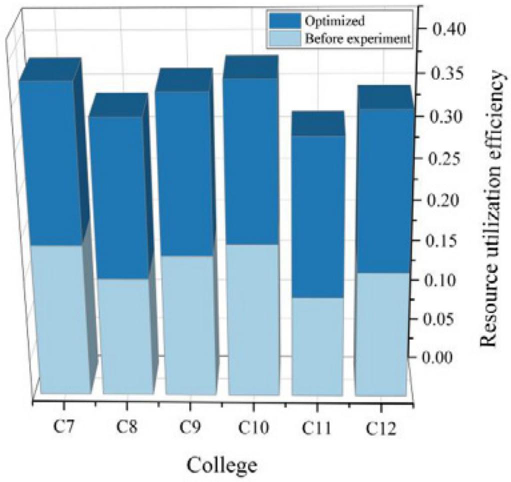
optimization, respectively. The resource allocation efficiency of excellent universities is shown in Figure 6(a), and the resource allocation efficiency of ordinary universities is shown in Figure 6(b).




(a) Excellent university resource allocation efficiency




(b) Resource allocation efficiency of general universities

**Figure 6.** Comparison of resource allocation efficiency of universities before and after the implementation of the optimized path

As can be seen from Figure 6, the difference in resource allocation efficiency between excellent universities and ordinary universities before implementing the optimized path is large, with a minimum value of 0.125 and the maximum value of 0.192. The average allocation efficiency of excellent universities after optimization is 0.186, with an average improvement of 35.41%. The average allocation efficiency of ordinary colleges and universities is 0.174, with an average increase of 22.12%. It can be found that the resource allocation efficiency of excellent colleges and universities is generally higher than that of ordinary colleges and universities, and after the optimization of college resource allocation, the role of excellent colleges and universities with more abundant resources themselves is greater. It indicates that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adjusting the quantity and structure of educational resources according to the optimization path can achieve the optimization of educational resource allocation.

# 4. CONCLUSION

Using fuzzy set theory to adjust the education resource allocation mode is the optimal path to achieve education resource allocation. This paper analyzes dynamic fuzzy set theory, dynamic fuzzy relationship and dynamic fuzzy matrix according to the basic theory of fuzzy sets. Combined with the classification of higher education resources, indicators for the optimal allocation of educational resources in Chinese universities are selected and a fuzzy set multi-objective planning model is designed. Based on the combination optimization form of higher education production factors and the fuzzy set multi-objective planning model, the fuzzy model for generating the optimal path is structured. The research results obtained are as follows:

1. The content composition of educational resources is relatively complex and can be classified according to their different qualities. First, according to the different attributes of ideological and political education resources, they can be classified into various kinds of resources with different attributes. Secondly, educational resources are classified into explicit resources and implicit resources according to their different forms of existence. Thirdly, according to the different times of their existence, they can be divided into traditional, real and future resources.
2. The average resources of excellent colleges and universities and the resource utilization efficiency of general colleges and universities are improved from 48.302 and 0.523 before optimization to 1.057 and 1.068, respectively, with an improvement rate of 32.3% and 52.4%. It can be found that the resource utilization efficiency of ordinary colleges and universities is generally higher than that of excellent colleges and universities, which indicates that resource allocation optimization is more useful for ordinary colleges and universities with scarce resources.
3. The average allocation efficiency of excellent colleges and universities is 0.186, and the average improvement after optimization is 35.41%. The average allocation efficiency of ordinary colleges and universities is 0.174, which is improved by 22.12% on average after optimization. It can be found that the resource allocation optimization path generated by the adjustment of the multi-objective planning model based on the fuzzy set theory makes the excellent colleges and universities with more abundant resources get higher resource allocation efficiency.

# DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

# CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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