

# Courses Arrangement Based on Optimization Model under New College Entrance Examination Reform

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**Abstract**—The new reform of college entrance examination has given students the right to choose subjects freely, but it puts forward higher requirements for school resources. This paper establishes the course scheduling optimization model to give the optimal courses arrangement which can help schools use their resources most effectively. What's more, we used the model to forecast the shortage other provinces may meet when implementing the reform. And we found that in Zhejiang province although a small number of schools have some resource gaps, they can solve the problem easily. However, if provinces in poor economic condition implement the reform, such as Jiangxi province, they will have relatively large resource gaps. The course scheduling optimization model can help to promote the implementation of the new reform by providing them with optimal course arrangements.

**Keywords**—the course scheduling optimization model; teaching resource gaps; new college entrance examination reform

## I. INTRODUCTION

In order to change the basic education of our country from exam-oriented education to quality-oriented education and pay more attention to the individualized and comprehensive development of students, our country has put forward the new policy of college entrance examination reform. Under the new reform, senior high schools no longer divide courses into arts and science and students can choose electives and take exams based on their own interests and strengths. Most provinces and cities implementing the reform in China, such as Shanghai, Beijing and Tianjin have adopted a policy of choosing three out of six subjects (physics, chemistry, biology, politics, history, geography), while Zhejiang Province has added "Technology" to the 6 electives and implemented the policy of choosing 3 out of 7 subjects. When students are given the freedom to choose subjects, there will be a lot of compound modes. And Students with diverse choices have different classes, which makes it difficult for schools to schedule classes. Moreover, it greatly increases the demand for teaching resources such as teachers and classrooms, which is also an important reason why the new college entrance examination reform cannot be implemented in regions with relatively backward economics and educational development. In different years, students' selection of subjects will be different.

It may lead to the shortage of teachers of some subjects whose number could exactly meet the needs of students before the reform as well as the redundancy of teachers of other subjects. This results in the uneconomic running of schools.

Considering the above problems, many schools offer the "menu" options which just provide several selection combinations of different subjects for students to choose. In this case, some students may not be able to choose their favorite subjects so it will limit the individualized development of students to some extent. Currently, the implementation of the new college entrance examination is facing great difficulties. Most of the provinces that were originally expected to launch the new college entrance examination in the third batch worry that their resources cannot meet the needs of reform and delay the reform. However, there is still no appropriate way to accurately evaluate the resource gaps of schools in the case of free subject selection so as to help solve the resource problems caused by the new policy in advance. The complexity of course arrangements has greatly increased in schools that have implemented free subject selection. In this situation, how to arrange courses and how to improve the utilization rate of school resources through reasonable course arrangements are problems worth attention. In recent years, a lot of research has been done on the problem of course arrangements at home and abroad[1] and most scholars use genetic algorithm, simulated annealing algorithm and other intelligent algorithms to obtain the approximate optimal solution of class scheduling scheme[2][3]. However, there are some new features of the course arrangements under the new reform, such as the diversification of students' combinations of subjects, so new research still needs to provide theoretical guidance for the current high school curriculum arrangements.

In the second part, this paper establishes the course scheduling optimization model to minimize the comprehensive gaps in high schools so as to give the optimal course arrangement scheme with the most effective use of teaching resources. In order to synthesize the teacher and classroom gaps, this paper calculates the weights of them based on the fund and time needed to solve them respectively and then takes the minimum of the comprehensive gaps as the objective function. We introduce the 0-1 variable to represent the class attendance of students and the integer variable to show the number of classrooms occupied by each subject in each period of time. And we take the number of classes required by each subject, the non-conflict of courses and the maximum capacity of classrooms and so on as constraints. Therefore, the course scheduling optimization model is established. In the third part of the paper, a high school in Wenzhou, Zhejiang Province is taken as an example to solve the model. By analyzing the results of the model, we can know that there is a little shortage of

teachers and classrooms in this school and give the optimal course arrangement scheme to the school. This model provides convenience for high schools in the provinces under the new reform of college entrance examination to arrange curricula and improve the utilization rate of teaching resources. Moreover, this paper also uses this model to estimate the possible reform situation of provinces that have not implemented the reform, for example, estimating resource gaps they may have, so that these provinces can be fully prepared before the reform. And the paper provides theoretical help for the province to better implement the reform.

## II. ESTABLISHMENT OF THE COURSE SCHEDULING OPTIMIZATION MODEL

Through analysis, the resource gaps of classrooms and teachers can be reflected in the course arrangements. If the course arrangement scheme is favorable, the resources of the school can be utilized most effectively, and the resource gaps of the school can be minimized in the case of free selection of subjects. This paper establishes an optimization model of course arrangements so as to obtain the minimum number of classrooms and teachers needed for teaching in the case of free selection of subjects, as well as the most reasonable way of course arrangements.

### A. Variables and Constants

In the model, class  $j$  is expressed as  $j$ ; subject  $i$  is expressed as  $i$ , and we number each subject according to the rules in table 1 below (Since the new college entrance examination reform has not increased the demand for physical education, music and art teachers, to simplify the model, we take such classes as self-study classes and then arrange classes of all subjects together.); let the smallest number of classrooms needed be  $a$  and the number of classrooms in the school be  $a_0$ .

TABLE I. SUBJECT NUMBERING RULES

$i$	1	2	3	4
Subject	Physical	Chemistry	Biological	Political
$i$	5	6	7	8
Subject	History	Geographic	Technology	Chinese
$i$	9	10	11	12
Subject	Math	English	Self-study 1	Self-study 2

We put students with different subject selection into different classes. And the number of the classes is denoted as  $k$  (If the class is too large, students can be divided into several classes; if the class size is too small, classes can be combined.). And class numbers are arranged according to sequences of the permutations and combinations of subject numbers.

Other variables and constants defined in this paper are as follows:

#### Decision variable:

$$b_{ijk} = \begin{cases} 1, & \text{students in class } k \text{ learn subject } i \text{ in lesson } j \\ 0, & \text{otherwise} \end{cases}$$

$C_{ij}$ : integer variables, which represents the number of classrooms occupied by the subject  $i$  in the lesson  $j$ .

$t_i$ : integer variables, which represents the number of teachers required for subject  $i$ .

$$P_{ij} = \begin{cases} 1, & \text{the students in class } k \text{ select the subject } i \\ 0, & \text{otherwise} \end{cases}$$

#### Constant:

$r_k$ : the number of students in class  $k$ ;

$n_i$ : the number of students selecting subject  $i$ ;

$N_0$ : the classroom capacity;

$s_i$ : the number of available teachers of subject  $i$ .

### A. The Objective Function

In order to know the shortage of school resources in the case of efficient utilization of school resources, we take the minimum gaps of classroom and teachers as the objective function. The expression is as follows:

$$\min v = a - a_0, \quad \min w = \sum_{i=1}^n (t_i - s_i)$$

We calculate the weights of the two types of gaps according to the capital and time needed to improve them respectively and synthesized them into a comprehensive gap. Then the above dual goals are transformed into the following single goal:

$$\min w = k(a - a') + (1 - k) \sum_{i=1}^n (t_i - s_i)$$

### B. The Constraint

#### 1) The constraint on classroom usage

The number of classrooms for each lesson is no more than the required number of classrooms  $a$ . The expression is as follows:

$$\sum_{i=1}^n c_{ij} \leq a \quad (j = 1, 2, \dots, m)$$

#### 2) The constraint on the class quantity of a subject

The number of students contained in classes of one subject in one day should not be less than the number of students who select the subject. The expression is:

$$N_0 \sum_{j=1}^m c_{ij} \geq n_i \quad (i = 1, 2, \dots, n)$$

#### 3) The constraint of course setting on students' attending classes

If the class of a subject is not arranged in a period of time, students cannot attend the course during that time. It is represented as:

$$c_{ij} = 0 \Rightarrow b_{ijk} = 0 \quad (i = 1, \dots, n; j = 1, \dots, m; k = 1, \dots, l)$$

That is:

$$b_{ijk} \leq c_{ij} \quad (i = 1, \dots, n; j = 1, \dots, m; k = 1, \dots, l)$$

4) *The constraint on the frequency of students' taking the same class*

If students select subject  $i$ , they need to learn it once a day (It can be modified slightly according to the arrangements of different schools). So we have:

$$\sum_{j=1}^m b_{ijk} = p_{ij} \quad (i = 1, \dots, n; k = 1, \dots, l)$$

$$p_{ij} = \begin{cases} 1, & \text{the class } k \text{ select the subject } i \\ 0, & \text{otherwise} \end{cases}$$

5) *The constraint on the number of students taking class*

The number of students taking classes of each subject should not exceed the classroom capacity. This is represented as:

$$\sum_{k=1}^l b_{ijk} r_k \leq N_0 c_{ij} \quad (i = 1, \dots, n; j = 1, \dots, m)$$

6) *The constraint on the number of teachers*

The same class cannot take two courses at the same time. That is:

$$\sum_{i=1}^n b_{ijk} = 1 \quad (j = 1, \dots, m; k = 1, \dots, l)$$

7) *The constraint on teacher demand in each subject*

a) The number of teachers required for a subject should not be less than the number of classrooms for the subject in each period of time.

$$t_i \geq c_{ij} \quad (i = 1, \dots, n; j = 1, \dots, m)$$

b) To facilitate the gaps calculation, we stipulate that the number of teachers required in each subject should not be less than the actual number of teachers:

$$t_i \geq s_i \quad (i = 1, \dots, n)$$

8) *The constraint on teachers' work intensity*

A teacher should not have more than four classes a day.

$$\sum_{j=1}^m \frac{c_{ij}}{4} \leq t_i \quad (i = 1, \dots, n)$$

To sum up, we get **the Course scheduling optimization model**:

$$\min w = k(a - a') + (1 - k) \sum_{i=1}^n (t_i - s_i)$$

$$\text{s.t.} \begin{cases} \sum_{i=1}^n c_{ij} \leq a \quad (j = 1, \dots, m) \\ N_0 \sum_{j=1}^m c_{ij} \geq n_i \quad (i = 1, \dots, n) \\ b_{ijk} \leq c_{ij} \quad (i = 1, \dots, n; j = 1, \dots, m; k = 1, \dots, l) \\ \sum_{j=1}^m b_{ijk} = p_{ki} \quad (i = 1, \dots, n; k = 1, \dots, l) \\ \sum_{k=1}^l b_{ijk} r_k \leq N_0 c_{ij} \quad (i = 1, \dots, n; j = 1, \dots, m) \\ \sum_{i=1}^n b_{ijk} = 1 \quad (j = 1, \dots, m; k = 1, \dots, l) \\ \sum_{j=1}^m \frac{c_{ij}}{4} \leq t_i \quad (i = 1, \dots, n) \end{cases}$$

This course arrangement model is suitable for the new college entrance examination and it is relatively easy to solve because it is an integer linear programming model. From the results of the model, we can know about the gaps of teachers and classrooms in a school and give the optimal course arrangement scheme with the smallest comprehensive gap. Apart from that, we can further estimate outcomes of the students' subject selection in the next few years and use this model to obtain information about the changes of teaching resource gaps in the future so as to help improve the overall management of teaching resources.

### III. SOLUTION OF THE COURSE SCHEDULING OPTIMIZATION MODEL

We take a high school in Rui'an city of Wenzhou as an example to solve the course scheduling optimization model. We substitute the statistical results of students' free selection of subjects in this school into the course arrangement optimization model and then use MiniZinc[4][5] and Or-tools to solve it. The results are shown in table 2. Each row in the table represents the number of courses of a subject in each period of time. For example, there is one physics class in the fourth period and another one in the eighth period. According to the analysis, this school needs at least one physics teacher. Similarly, we get the number of teachers needed for each subject, as shown in the last column of table 3. And the last row of the table lists the total number of classrooms required for each time period. According

to the results, this school needs at least ten ordinary classrooms and one computer room. In conclusion, there is a shortage of one technical teacher in the school and some physics teachers are redundant while the teachers of other subjects have been well utilized, and the school's optimal course arrangement plan has been obtained.

In the same way, we can use the model to acquire the multi-school optimal course scheduling schemes and obtain the information on the utilization of these schools' resources.

TABLE II. CURRICULUM ARRANGEMENT AND CLASSROOM OCCUPANCY OF A HIGH SCHOOL IN RUI'AN

Subject	1st	2nd	3rd	4th	5th	6th	7th	8th	Quantity Demanded
Physical	0	0	0	1	0	0	0	1	1
Chemistry	2	0	1	0	1	0	0	2	2
Biological	0	0	1	2	1	0	1	1	2
Political	1	0	0	0	1	1	0	1	1
History	0	1	0	1	0	0	0	2	2
Geographic	0	1	0	0	0	0	2	2	2
Technology	1	1	1	0	0	1	0	1	1
Chinese	4	0	0	0	0	3	2	0	4
mathematics	0	2	1	1	3	0	3	0	3
English	0	2	2	3	2	0	0	0	3
Self-study 1	2	2	1	1	1	3	0	0	3
Self-study 2	0	1	3	1	1	2	2	0	3
Summation	9	9	9	10	10	9	10	9	9

#### IV. CONCLUSION

Most high schools in Zhejiang Province have sufficient teaching resources, which can meet the demands of students' free selection of subjects under the "3 out of 7" policy through effective course arrangements. A small number of teacher and classroom gaps exist in a small number of schools, and the gaps are generally caused by lack of technical teachers. The new college entrance examination reform in Zhejiang Province includes technology into electives, and there are fewer knowledge points of this subject than others so that the test is relatively less difficult. As a result, the number of students who select technology for the examination recent years has increased greatly compared with the number before the reform, causing the shortage of technology teachers. However, most high schools in Zhejiang Province can solve the problem of lacking teaching resources easily by recruiting teachers and transforming non-teaching space into teaching one.

This paper further estimates the impact of the reform in provinces where the new college entrance examination has not yet been implemented. According to the data of students' selection of subjects in Zhejiang Province, this paper estimate outcomes of the students' subject selection in provinces where the reform has not been implemented through logistic regression. After putting the data into the course scheduling optimization model, we found that some provinces in poor economic condition will have a relatively large shortage of teaching resources if they implement the reform. Even though the resources of this school are most effectively utilized based on reasonable course arrangements, the demand of students' free selection of subjects cannot be quickly met.

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