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# Provide an integer linear programming model (For optimal allocation of teacher, class, student by considering a completely different planning method)

**Mohammad Mehdi Taheri**
**mohamadmehditaheri7@gmail.com**

**Abstract**
In this article, we intend to discuss the place of the issue of course and university scheduling in the structure of the educational system and seek a way to solve this problem with a linear program. The objectives of the present study are to provide general studies and studies in Related articles, books, and research, as well as research on the Internet and analysis of the data obtained, for the general purpose of preparing a schedule of accepted and appropriate academic courses and schedules, taking into account a set of requirements, limitations, and preferences. Students, professors and educational institutions were achieved according to the local conditions in Iran. Also in this research, software and model input and data have been used to review and solve the answers with manual and traditional planning of the educational institute to improve the scheduling problem. In this research, an integer linear programming method and an allocation method to a completely different programming method for scheduling university courses are presented. In this article, the performance findings of the two models are compared and it is concluded that in the same conditions in terms of equality of the number of parameters and the amount of parameters and model data, the number of decision variables in two-part conditions is much less than the first part model. This comparison is made in the case of increasing the number of courses under the same conditions for scheduling. It should be noted that the model is solved by Cplex solver in Gams software using branching and cutting algorithm and the answers and decision variables are displayed.
**Keywords:** Lesson scheduling, educational system structure, traditional planning, linear planning, teacher, class, lesson

## Introduction

Differences in existing rules on the problem due to differences in educational systems as well as the large number of variables and requirements and limitations in the issue of scheduling university courses, provide efficient models to solve such problems is inevitable. The issue of scheduling and modeling of university courses consists of "scheduling a number of sessions and educational activities, for specific groups of professors and a group of students during time courses taking into account the requirements of resources, such as classrooms "And restrictions such as the availability of these resources."

Scheduling modeling in its general form is a model with four parameters of resources, time, activities and a set of requirements that is done with the aim of connecting resources and time to activities and meeting the requirements (Burke, 2013).

The issue of scheduling has many applications in today's world and industry, such as scheduling, exams, sports competitions, courses, projects, train and bus movement and taxis in the transportation system and He mentioned transportation, work shifts and flights. Researchers, scientists and scholars have studied and studied the various applications mentioned, such as the research of Rowan and (Peters, 2003), (Q and Burke, 2009), Burke, Marsk, Parks, and (Rodova, 2010), Shafia, (Aghaei and Sajjadi, 2012), (Mir Hassani and Habibi, 2013).

As with other problems, the problem of modeling and scheduling lessons into time periods falls into the NP_Complete problem group (George, 2014). In general, this type of modeling, optimization and binary and binary modeling in very large dimensions and is considered. Researchers have also proposed different approaches to modeling and solving them.

The timeline is part of a specific set of scheduling issues (Lewis, 2008). Preparing a timeline as a matter of placing specific resources, according to requirements, in a small number of time periods and locations, with the aim of satisfying a set of Describe and examine the objectives as much as possible. This general definition is a description of the timing issues that have been generally accepted.

The timetable works on issues with large and varied groups and domains, such as transportation issues, sports competitions, training issues, meeting scheduling, staff work schedules and shifts, and process scheduling.

The schedule of university courses is the allocation and connection of a certain number of resources such as courses, professors to a limited number of time periods and classes at a specific time, taking into account a set of

requirements and limitations into two soft groups and Hard to split. Hard limits and requirements are limitations that must be considered and guarantee the certainty and feasibility of the answer. And do not necessarily have to be met as generally as strict requirements and constraints. In order to obtain a quality timeline, we must have a problem and a model that has the least errors and violations in the requirements and soft constraints (Rodova, 2010).
The strict general and general requirements and restrictions applied to the issue of course scheduling are as follows:
A) In each time period, the available resources should be sufficient for the items that have been timed and modeled.
B) A resource (teacher, course, student) can not be used in several units at the same time (period and period of time, class).
Soft requirements and constraints also vary according to preferences and type for each issue and model.
At present, in most universities and institutes of higher education, the scheduling of courses is done manually and traditionally by experienced and experienced people. In manual and traditional planning, lessons are scheduled in a repetitive way so that in each repetition, one lesson is selected and modeling and scheduling start from two lessons that more and the majority of students at the same time They have registered for both courses, so that these two courses should not be offered in the same time period, and the time period and the teacher should be selected and assigned in a way that meets the other requirements. This algorithm continues to allocate entire courses to the teacher, class, and time (Genown et al., 2012).
Because scheduling in this way is manual, traditional, and time-consuming and does not necessarily meet all the demands of students and faculty in the best and most effective way, the use of computer modeling and programming methods in a limited time , Creates and satisfies a good answer and output, seems appropriate.
The timeline refers to the method of allocating limited time and space resources to the number of activities and events due to the satisfaction of a large number of requirements and constraints. This table is used in different groups to assign and schedule different issues. Given that in this study, we have focused and focused on creating a timeline for the optimal allocation of teacher, class, student in an educational system, we in this section review the work of past researchers in terms of content and methods We have solved the problem of the schedule of university courses.

**Literature review**

The issue of scheduling has many applications in today's world and industry, such as scheduling, exams, sports competitions, courses, projects, train and bus movement and taxis in the transportation system and He mentioned transportation, work shifts and flights.
Researchers, analysts and researchers in a comprehensive review of this issue can be presented (Mir Hassani and Habibi, 2013), (Lewis, 2008), (Serini Vasan, Sinf and Kumar, 2011), (Karimpour And Hadidi, 2015) pointed out. In domestic research, the issue of scheduling the educational system has been considered and researched. In these studies, mathematical modeling techniques and meta-heuristic algorithms have been used to solve this problem. Today, scheduling is in the group of inevitable duties of human life. In the general and comprehensive programs of the first and developed world countries, one of the parts that has shown and played an effective role in achieving the realization of their programs and goals is the educational system. Therefore, considering the effective and important role of the educational system in each country, the importance of proper planning, modeling and scheduling can increase the quality of education and the satisfaction of its employees and staff. The timeline is a special case in point. The problem of modeling and scheduling in universities and higher education institutions such as this is divided into two groups: schedule for exams and schedule for courses. The purpose of timing in this study is the second group.
(Alvarez, Valdes et al., 2002) modeled and presented a timeline and used the forbidden search algorithm to solve the problem for the first time. They solved the problem and the model in two steps, the first step is to allocate time periods. To the courses and students and in the second stage, the classes are assigned to the courses. In the first stage, a first answer was created for assigning students and using the forbidden search algorithm, the timing was improved and in the second stage, using this algorithm to assign classes and improve it, but without manipulation. In assigning the first stage of the period to the courses has been used. In general, several neighborhood strategies and structures are compared.
(Gnaun et al., 2012) developed the Carter model on the course schedule. Their model was an integer model. The issue was considered in such a way that students, faculty, and faculty preferences were present at the time of enrollment, but students were not allowed to register, but their preferences were not established in the model. The purpose of this model is to prefer the presence of professors and the timing of courses so that the preferences of professors are considered to the maximum. They used Lagrangian method to obtain the initial solution and to achieve it and the refrigeration simulation algorithm to improve the answer. The simulated refrigeration algorithm has been used in one of the universities of Indonesia and the results have been favorable after comparison.

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(Aladag et al., 2007) developed the proposed Alvarez-Valdez model and modeled and solved it using the forbidden search algorithm. (Aladag et al., 2009) with four neighborhood strategies solved the same model by the same algorithm. The first method: assigning an empty class to the lesson in a periodicity, the second method: moving two lessons together, the third method: using the first and second methods in parallel and simultaneously in each course and selecting the most effective answer and the fourth method The method starts with the first step and if you do not find a better answer after repeated repetitions, it uses the second method once. In the end, the solutions obtained from the solution are compared and evaluated with all methods. Evaluation of the results shows that the fourth method is superior to the other three methods and is more desirable.
Optimization problems fall into two general categories:
A) One-objective optimization issues
B) Multi-objective optimization issues
In single-objective problems, the main purpose is to improve a performance index that is uniquely defined, the maximum or minimum value of which fully reflects the quality of the output obtained. However, in some cases, it is not possible to analyze a general answer to the optimization problem based on one parameter. In this case, we have to define several performance indicators and parameters and optimize the value of all of them at a specific time. So far, several algorithms havebeen proposed to solve such problems, among which, innovative and meta-heuristic methods have a special place. For such multi-objective problems, no optimal solution can be found that optimizes all the objectives of the problem in one environment. When we find an answer, we may come up with other answers that improve on one goal will lead to worse goals on the other. Parato optimization is an answer to a multi-objective optimization problem if it cannot be replaced by another one, which improves one index without worsening the other. The search for such Parato answers is intended to solve such problems.

**A variety of optimization solution methods**

In general, optimization problems are divided into two categories: continuous and combined. In the continuous category, several classical algorithms for general optimization are presented. But these features are useful in certain cases. For example, if the objective function of the problem is not convex, it usually does not answer. Such continuous methods are divided into linear and nonlinear groups. Hybrid problem solving methods can also be divided into two groups of exact and approximate algorithms. Nonlinear optimization and approximate methods of discrete problems fall into the category of complex problems.

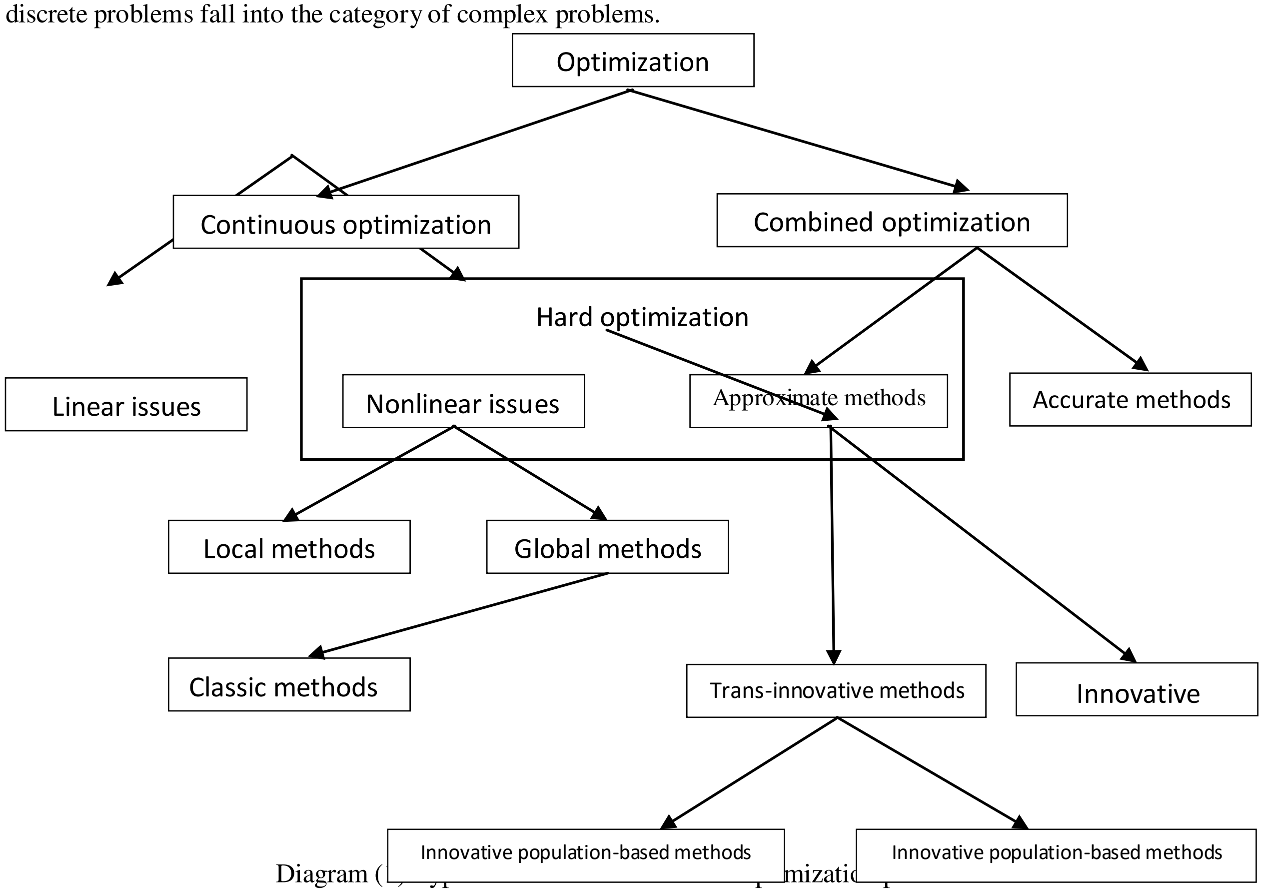


Diagram (

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Scheduling issues generally involve a large number of professors, classes, classes, and students engaging with a variety of goals, locations, and situations; However, the process of solving such problems is faced with a large number of parameters and variables of decision and requirements. In addition, due to the differences in the educational laws of the countries, the law of the time schedule of the universities will be different from one table to another and from one country to another. Even in a single educational system structure, different differences are observed depending on the specific educational methods. (Lewis, 2008), (Past et al., 2014).
In the process of assigning professors, classes, students and lessons to time, courses and classes in the educational structure are allocated taking into account the requirements of available resources, including the professor and the student group. Courses are an educational unit taught by a professor in a course. The courses defined in the educational system are composed of self-study, laboratory, theoretical and practical. Some courses are compulsory and optional. A student group is a group of students admitted to a field of study. The number of working days of the educational institution is organized by the university education management within a time window.
The classroom can also be considered as a laboratory, seminar hall, regular classroom, etc., depending on the situation. Lessons such as instructor and eligible training space should be provided for courses. While considering all the conditions for the professors, their access time and presence in the faculty are also suggested by them. Education management determines classrooms by considering the conditions and type of class. There should be no interference in the allocation of resources and the timetable should be completed. This means that all sessions related to a course, which is determined based on its type and number of units, must be planned for all departments. Other requirements may be considered as follows.
A) The table should be as concise as possible,
B) Reduce the movement of resources, especially professors and students, and make allocations to centralized locations possible in one day, and
C) The request of teachers to attend the educational system should be done as much as possible.
In addition, all the general rules and requirements and limitations of the educational system must be done and applied in the model.

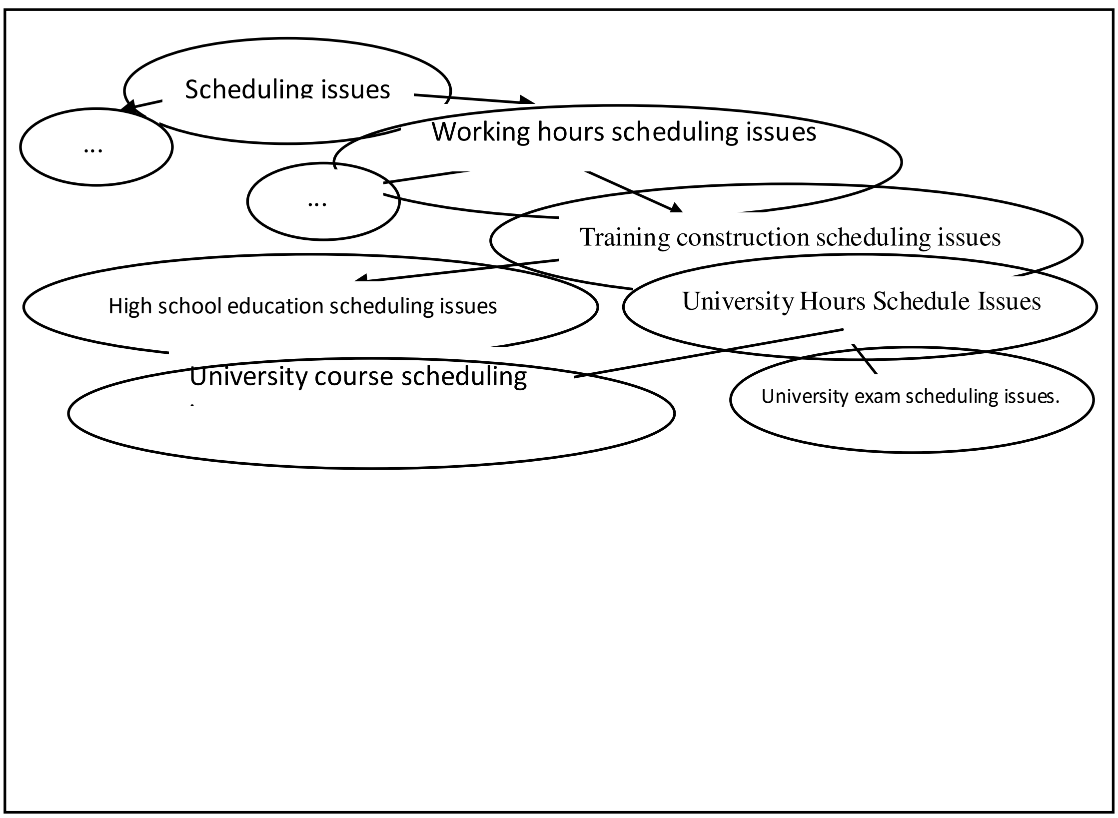


Diagram (2) The position of the problem of scheduling university courses

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**Methodology**:
Considering the parameters and indicators, the presentation of the activity-based model is as follows.
Decision variable
y_idsr: Assigning and scheduling a lesson for the i-th activity in period s in class r
From day d it is considered one and otherwise it is zero.
The requirements of the problem and the objective function are as follows.

(1-3) $\text{Max} \sum_{t\epsilon T}\sum_{g\in G}\sum_{i\epsilon AT_t}\sum_{d\epsilon D}\sum_{r\epsilon R}\sum_{s\epsilon S}(\lambda_t\sigma_{ds}^t + \lambda_g\sigma_{ds}^g)y_{idsr}$

(2-3) $\sum_{r\epsilon R}\sum_{s\epsilon S} y_{idsr} \leq 1, \forall g\epsilon G, i\epsilon\bar{A} \cap AG_g, d\epsilon D$

(3-3) $\sum_{d\epsilon D}\sum_{r\epsilon R}\sum_{s\epsilon S} y_{idsr} = \emptyset_I, \forall g\epsilon G, i\epsilon AG_g$

(4-3) $\sum_{r\epsilon R}\sum_{i\epsilon AT_t} y_{idsr} \leq TDS_{ds}^t, \forall\ t\epsilon T, s\epsilon S, d\epsilon D$

(5-3) $\sum_{r\epsilon R}\sum_{\substack{\acute{d}\epsilon D \\ \acute{d}\neq d}}\sum_{s\epsilon S} y_{i\acute{d}sr} \geq \sum_{r\epsilon R}\sum_{s\epsilon S} y_{idsr}\ , \forall g\epsilon G, t\epsilon T, d\epsilon D\ i\epsilon(\bar{A} \cap AGT_{gt})$

(6-3) $\sum_{r\epsilon R}\sum_{i\epsilon AG_g} y_{idsr} \leq GDS_{ds}^g, \forall\ g\epsilon G, s\epsilon S, d\epsilon D$

(7-3) $\sum_{i\epsilon A} y_{idsr} \leq RDS_{ds}^r, \forall\ r\epsilon R, s\epsilon S, d\epsilon D$

(8-3) $t_t \leq \sum_{d\epsilon D}\sum_{r\epsilon R}\sum_{i\epsilon AT_t}\sum_{s\epsilon S} y_{idsr} \leq u_t, \forall\ t\epsilon T$

(9-3) $\sum_{s\epsilon S}\sum_{d\epsilon D}\sum_{i\epsilon A} y_{idsr} = 1\ ,\ \ r\epsilon R$

$: (\gamma_i < \varepsilon_r | \varphi_i = \mu_r)$

(10-3) $\sum_{r\epsilon R}\sum_{i\epsilon AC_c} y_{idsr} \leq CDS_{ds}^c, \forall\ c\epsilon C, s\epsilon S, d\epsilon D$

Limit (3-2) guarantees the planning of a maximum of one activity per day for the relevant student group. Limit (3-3) guarantees that for each group of students should be included in the weekly work schedule of all sessions related to an activity. An activity is assigned. Limitation (3-5) All activities related to a course should be provided by a single instructor. Limit (3-6) prevents and assigns more than one activity to each group of students in a single time period. Limit (3-7) prevents one class from being assigned to more than one activity at a time. The maximum and minimum number of sessions allowed per week for each professor is specified by Equation (3-8). And the capacity limit and the type of classrooms are controlled by the limit (3-9). Limit (3-10) indicates that at each time point in the day each course feature is assigned a maximum of one activity. The Objective Function (3-1) maximizes the sum of the weights of preferences and desires of faculty and students regarding the time periods allotted to it during the work week.

**Describe matrices and tables of integer linear programming model**

The first table that will be described in this section is the table of specifications of the courses offered in a semester. The columns of this table, from right to left, represent the course, the number of units related to the course, the number of sessions, the number of students, the type of course (theoretical, practical, ...), the student group (industry, mechanics, civil engineering, .. .), Professors are candidates for teaching. The schematic is shown in Table 4-1.

Table 4-1- Details of the courses offered in a semester.

| Lesson | Number of units | Number of sessions | Number of students | Course type | Student group | Candidate professors teaching |
|---|---|---|---|---|---|---|
| $C_1$ | 3 | 2 | 25 | Theoretical | $G_1$ | $T_4, T_9$ |
| $C_2$ | 3 | 2 | 21 | Theoretical | $G_2$ | $T_7, T_1$ |
| .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. | .<br>.<br>. |
| $C_{30}$ | 2 | 1 | 7 | Theoretical | $G_{35}$ | $T_{13}$ |
| $C_{31}$ | 2 | 1 | 6 | Theoretical | $G_{36}$ | $T_7, T_2$ |
| $C_{31}$ | 2 | 1 | 5 | Theoretical | $G_{37}$ | $T_{15}, T_6$ |

Note that the data in the table above is assumed. The specifications of the number of courses intended for scheduling can be seen in the table above. In the sample hypothesis, a number of courses with other specifications and the number of students to register those courses and the course presentation details for student groups and candidate

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professors to teach that course will be made available to the faculty educational planners. In the first column to the right of the course is the candidate for the semester, day, and time period. In the next two columns, the number of course units and the number of sessions are 45 minutes, respectively, according to the time period. So that if the courses are one unit, they will be held for 90 minutes and a week in between. If the lesson is 2 credits, it will be held in two sessions of 45 minutes, which becomes 90 minutes, every week. If the lessons are three credits, they will be held in 3 to 45 minutes, which will be 135 minutes, in other words, 2 hours and 15 minutes, every week.
In the next column, the number of students who are assigned to the department and the class and the teacher after assigning the course is specified. In the next column, the type of lesson presented is specified in terms of practicality and theory. In the next Tsun, a group of candidate students (industry, civil engineering, mechanics, electricity, etc.) will be placed. In the last column of the table, the teaching teachers are nominated for that lesson to schedule and hold training sessions.
The next table shows the master preferences. Teachers' preference for time periods and their degree of importance (based on work experience, academic degree, type of employment, etc.). The following table is an example for a teacher. The table below contains four time periods s on the days of week d hypothetically considered. For example, the number entered in the hour and time period of 10-12 days on Tuesday (0.0477) is equal to the product of the degree of importance of this professor in the score assigned to the time period of 10-12 days on Tuesday.
In the objective function of the linear programming model, integers mean λ and σ mean weight and degree of significance, and this value is defined between zero and one. The closer the value is to one, the greater the degree of importance, and the lower the value to zero, the lower the degree of importance.
$0 \leq \sigma \leq 10 \leq \lambda \leq 1$
The schematic of the table whose data is hypothetical is Table 4-2.

Table 4-2- Hypothetical example of teacher preferences $\boldsymbol{t}$ $(\boldsymbol{\lambda_t \sigma_{ds}^t})$

| Professor number $t$ | $s_1$ 8-10 | $s_2$ 10-12 | $s_3$ 13-15 | $S_4$ 15-17 |
|---|---|---|---|---|
| Saturday $d_1$ | 0.0532 | 0.0375 | 0.0375 | 0.0165 |
| Sunday $d_2$ | 0.0717 | 0.0670 | 0.0751 | 0.0547 |
| Monday $d_3$ | 0.0434 | 0.0770 | 0.0665 | 0.0395 |
| Tuesday $d_4$ | 0.0258 | 0.0747 | 0.0098 | 0.0834 |
| Wednesday $d_5$ | 0.0623 | 0.0335 | 0.0838 | 0.0473 |
| Thursday $d_6$ | 0.0583 | 0.0139 | 0.0319 | 0.0410 |

Table 4-3 shows the time of the sessions related to a professor, based on the model solution results. For example, the phrase inserted at 1:15 pm on Tuesday from the table below means that Lesson 7 is scheduled for a group of 8 students in 4th grade. The data are hypothetically shown in Table 4-3.

Table 4-3- Master class schedule $t$

| Professor number $t$ | $S_1$ 8-10 | $S_2$ 10-12 | $S_3$ 13-15 | $S_4$ 15-17 |
|---|---|---|---|---|
| Saturday $d_1$ | | $C_1, G_2, R_3$ | | |
| Sunday $d_2$ | $C_2, G_1, R_{11}$ | | | |
| Monday $d_3$ | | | $C_{17}, G_5, R_9$ | |
| Tuesday $d_4$ | | | $C_7, G_8, R_4$ | |
| Wednesday $d_5$ | $C_{11}, G_9, R_2$ | | | $C_{12}, G_6, R_7$ |
| Thursday $d_6$ | | | | |

Table 4-4 shows the class schedule of group g. For example, the phrase hypothetically included in this table representing lesson 7 was scheduled by Master 9 at 1 to 3 pm on Wednesday for group g in Class 10.

Table 4-4- Group class schedule g

| group number g | $S_1$ 8-10 | $S_2$ 10-12 | $S_3$ 15-13 | $S_4$ 15-17 |
|---|---|---|---|---|
| Saturday $d_1$ | | $C_2, T_1, R_{11}$ | | |

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| | | | | |
|---|---|---|---|---|
| Sunday $d_2$ | | | | $C_6, T_7, R_8$ |
| Monday $d_3$ | | $C_{10}, T_2, R_1$ | | |
| Tuesday $d_4$ | $C_3, T_4, R_9$ | | | $C_8, T_{11}, R_2$ |
| Wednesday $d_5$ | | | $C_7, T_9, R_{10}$ | |
| Thursday $d_6$ | | | $C_1, T_3, R_7$ | |

Table 4-5 also shows the schedule of meetings in class r. For example, the phrase hypothetically listed in this table represents lesson 4 for a group of students 6 scheduled by professor 10 at 8-10 a.m. Sunday in class r. The schematic is in the form of Table 4-5.

Table 4-5 - Scheduling of meetings in class r

| group number r | $s_1$ 8-10 | $s_2$ 10-12 | $s_3$ 13-15 | $S_4$ 15-17 |
|---|---|---|---|---|
| Saturday $d_1$ | | | | $C_3, G_3, T_3$ |
| Sunday $d_2$ | $C_4, G_6, T_{10}$ | | $C_5, G_2, T_4$ | |
| Monday $d_3$ | | | | $C_9, G_5, T_1$ |
| Tuesday $d_4$ | $C_8, G_9, T_2$ | | | |
| Wednesday $d_5$ | | $C_2, G_4, T_6$ | | |
| Thursday $d_6$ | | | | $C_1, G_7, T_9$ |

**research findings**

In this article, the efficiency of the two models is compared and it is concluded that in the same conditions in terms of equality of the number of parameters and the amount of parameters and model data, the number of decision variables in two-part conditions is much less than the first part model. This comparison is made in the case of increasing the number of courses under the same conditions for scheduling. It should be noted that the model is solved by Cplex solver in Gams software using branching and cutting algorithm and the answers and decision variables are displayed.

In the examples, it is assumed that the activity depends on 1 group of students and 2 professors. The number of time courses in the working days of the educational institution is equal to four time periods and the number of working days of the institute is equal to five days a week, six classrooms are available and five professors and three groups of students are considered. Table 4-6 compares the number of variables of the two models for examples.

Compare the number of variables in changing the number of lessons

| Number of lessons | | | | | Model | |
|---|---|---|---|---|---|---|
| 30 | 20 | 15 | 10 | 5 | | |
| 7200 | 5670 | 4320 | 2880 | 1440 | Number of lessons | |
| 432 | 288 | 216 | 144 | 72 | Class allocation stage | Two-part model |
| 1440 | 960 | 720 | 480 | 240 | Activity allocation stage | |
| 1872 | 1248 | 936 | 624 | 312 | Total | |

According to the table above, it can be concluded that in the two-part mode, the performance of the model is better and the time, timing and number of decision variables are reduced, and the model has a better application and efficiency in the second case. Under the same conditions and with increasing the number of lessons for scheduling and allocating the number of decision variables in the activity-based model mode and the first part of integer linear programming modeling, assuming 30 lessons available, the number of decision variables for scheduling becomes 7200 variables. However, under the same conditions and using a two-part model and a fixed number of parameters such as the first part model assuming 30 lessons available, the number of decision variables for the class assignment stage to 360 variables and the number of decision variables for the scheduling part and Allocation of activities to intervals and time periods on working days to 1200 variables, the total of variables in the two-part model to 1560 variables. Compared to the first model, integer linear programming has a significant reduction. This makes scheduling more efficient and easier, and as a result, problem-solving time and decision variables are reduced in two-part mode, and the model performs better and more efficiently than the first model, and the allocations are properly considered. The capacity of the classes and the type of class should be proportional to the type of lesson taught, and the empty capacity of the classes should be minimized and students should be properly allocated in the classes, thus increasing the efficiency and satisfaction of professors and students and finally increasing system productivity and reduce dissatisfaction.

**Assignment to a completely different planning method modeling**

To build a model of a natural device, assumptions must be made, and it can almost be argued that a natural device is rarely modeled without considering the assumption.

The hypothetical real world results from the real world. The only difference is that the focus is on the dominant variables in the real machine. A mathematical model is assumed to represent the mathematical form of the real world.

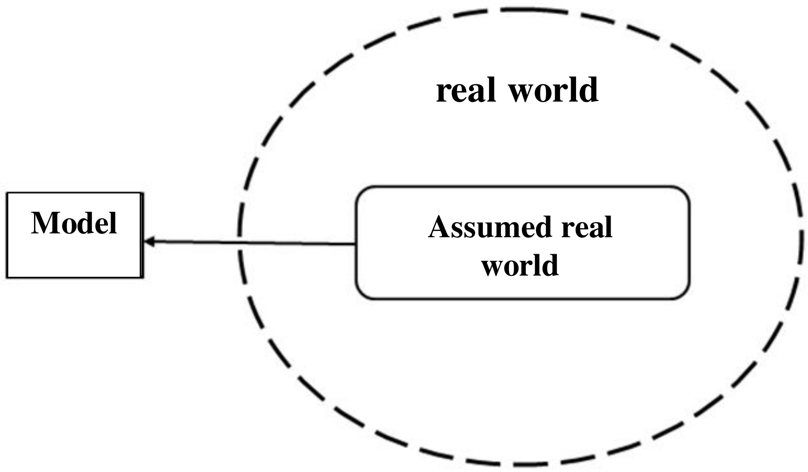


Figure 4-2-Modeling

Building a model is a team effort. To build a mathematical model, operations research analysts must work with client-side experts as a team. Experts on behalf of the customer, knowing the expertise in that particular industry, can be a good complement to operations research analysts to build a mathematical model.

As a decision-making tool, operations research is both a science and an art. Research in the operations of scientists is due to the fact that it involves mathematical techniques, and the success of the results depends on the creativity and art of the modeling team.

The main steps in applying real-world operations research are as follows:

A) Problem definition,

B) Model making,

C) model solving,

D) model validation, and

E) Using model solving.

Of the above 5 steps, only the third step is related to model solving and is the easiest part in studying research in operations. Other stages are more art than theory.

A) Definition of the problem. Problem definition deals with defining the scope of the problem under study. This step is done by a team. The output of this step contains the following three main elements:

A) Description of decision variables,

B) Determining the purpose of the study,

C) specify the characteristics of the constraints,

D) Model construction. Model construction deals with the transformation of problem definitions into mathematical relations. If the obtained model is consistent with one of the standard mathematical models, such as linear programming, the solution is also obtained using existing algorithms. But if the mathematical relationship is very complex and cannot be adapted to standard mathematical models, the operations research team must first simplify it and then use innovative models to solve it. In this case, modeling can be used. In some cases, a combination of mathematical, innovative, and simulation models must be used to solve the problem.

E) Solve the model. Solving the model is the easiest step in all stages of operations research. This step deals with the application of defined algorithms. The most important part of the model is sensitivity analysis. Sensitivity analysis is

often needed when model parameters cannot be accurately estimated. In this situation, it is very important to study the optimal response behavior when the estimated variables change.
F) Model validation. Model validation examines whether a built-in model fully predicts system behavior. First, the operations research system first examines whether the results seem logical. The general method for model validation is to check the results of the model with historical data. This means that the model is valid. If historical data is not available in this field, simulation can be used to validate the model results.
J) Using model solving. Applying model solving by translating results into operational instructions in a form understandable to those involved deals with that part. This is also one of the tasks of operations research.
Now consider the example of the backpack problem in operations research.
The general form of the backpack problem, assuming there are n types of material and b units of capacity of the backpack and a unit of capacity of the material that we want to put in the backpack and carry will be as follows:

(4-4) $\text{Max } Z = \sum_{j=1}^{n} C_j X_j$
(5-4) $\sum_{j=1}^{n} a_j X_j = 1$
$X_j = 0$ یا $1 \quad (j = 1,2, \dots, n)$
Now consider the simple allocation model, n × n, i → j where allocations are made at the cost of C_ij with the variable X_ij.

(6-4) $X_{ij} = \begin{cases} 1 & \textit{if the job of ith is assigned to applicant jth} \\ 0 & \textit{if the job of ith is not assigned to applicant jth} \end{cases}$
(7-4) $\sum_{j=1}^{n} X_{ij} = 1 \quad \text{for } i = 1,2, \dots, n$
(8-4) $\sum_{i=1}^{n} X_{ij} = 1 \quad \text{for } j = 1,2, \dots, n$
Now we want to formulate the allocation model using a completely different planning method, which is modeled as follows.

(9-4) $\text{Min } Z \sum_{i=1}^{n} Z_I$
(10-4) $\text{s.t}: \{\text{element } (y_I, [c_{i1}, c_{i2}, \dots, c_{in}], Z_i) \quad \text{for } i = 1,2, \dots, n$
(11-4) $\text{all} - \text{different } (y_1, y_2, \dots, y_n)$
$y_i \epsilon \{1,2, \dots, n\} \quad \text{for } i = 1,2, \dots, n$

This model has n2 variables and 1+ n constraints, plus a range for all model variables, which will be significantly reduced compared to the linear and simple allocation model.
Now that we are familiar with modeling and using a completely different programming method for the i → j allocation problem and how to interpret it, we will examine the triple allocation model mentioned in Chapter Three. The triple assignment of teacher to class and the assignment of class to lesson and the assignment of teacher to lesson are done in the form of three indices i, j and k with a decision variable X. Index i is related to the desired teacher, index j is related to the desired class and index k is related to the desired course. These three parameters are defined by an X variable and are connected to each other at an allocation cost of C. The limitations of the modeling method are completely different in order for the allocations to be made individually. So that a teacher is assigned to a separate class, a class to a separate lesson, and a separate lesson to a teacher. The purpose of the problem is to state the triple allocation so that the allocation cost is minimized.

**Check the model in Simplex software**
The teacher, class, and lesson allocation model is entered into the software and coded in a completely different way. To test the model, we consider the indices i, j and k to be 4, which means that we have 4 professors, 4 lessons and 4 classes. To import data into the model, we need 64 cost data for testing. These triple allocation costs are assumed to be from 1 to 9, the schematic of which is as follows:
i = 1,2, ... Professors
j = 1,2, ... Classes
k = 1,2, ... Lessons
1≤C_ijk≤9 allocation fee
By entering the data into the model and the software, it drives the model and the software starts solving the model. The time to solve the model in the software depends on the power of the software and the computer and its Ram and Cpu. After solving the model and specifying the answers and Xs that are output and answers from the software, it

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shows that the answers are X_ijk and instead of variable indexes X, the number of professors, classes and courses are considered. And coded, it becomes clear that the process of these allocations is according to the data and that is the triple allocation cost that we have considered. For example, the answers given below mean that Professor No. 2 and Class No. 4 and Lesson No. 1 have been assigned to each other, or Professor No. 4 and Class No. 2 and Lesson No. 3 have been assigned to each other. have became.

$X_{241}$, $X_{423}$

The planning model is completely different and the optimal allocation of the teacher, class and lesson is facing a problem. Because completely different planning models are often used for n × n allocations, and we have n × n × n allocation in our problem, the model has problems and the model constraints are not fully observed, and only the purpose of examining the allocation model. It is triple and keep the three parameters together, and the completely different planning model does not fully comply with the limitations of the model and the issue of teacher, class and lesson allocation, and some of the answers and outputs of the model are irrational. Appears. The purpose of presenting this model in detail is optimal allocation with the help of this method, and this method in general and completely does not satisfy all the limitations and demands of the model and the problem, because it is not defined in its ability to allocate and program. It is more applicable to problems with n × n allocation and cost C, which we will mention in Chapter Five.

**sensitivity analysis**

The general definition of sensitivity analysis is the study of the effect of output variables on the input variables of a statistical model. In other words, it is a way to change the inputs of a statistical model in an organized (systematic) way that can show and predict the effects of these changes on the output of the model. In most practical applications, some of the problem data is not exactly known and is therefore estimated as much as possible. When other estimates of some of the problem data become available, it is important to find a new optimal solution without having to incur costly re-solving problems from the beginning. This and other related topics form a sensitivity analysis, and we explore some of the ways to optimize the response under various modifications. To analyze the sensitivity of the topic, we have made changes to the model in a completely different way. These minor changes are that we do not consider the allocation cost and remove the objective function of the model and define an X variable. We have added the student group parameters and time to the other parameters of the model, and finally, the changes are applied and the model parameters are rewritten and modeled as follows:

Index i includes the set of student groups, index j includes the set of classes available for scheduling. The k index includes a set of professors to be assigned to the educational system. Index s includes a set of courses offered for teaching. And the t index specifies the set of time intervals. These parameters are connected by an X variable and the X variable is placed in a completely different programming method. Modeling is shown below.

i = 1,2, ... group of students
j = 1,2, ... set of classes
k = 1,2, ... set of masters
s = 1,2, ... set of lessons
t = 1,2, ... time intervals
$X_{ijkst}$variable
$\text{all} - \text{different}\ (X_{ijkst})$

| | | |
|---|---|---|
| $X_{11211}$ | $X_{11221}$ | $X_{12121}$ |
| $X_{22121}$ | $X_{21211}$ | $X_{22221}$ |
| $X_{12221}$ | $X_{21112}$ | . . |
| $X_{21221}$ | $X_{21122}$ | . . |

As mentioned in the previous section, a completely different planning model does not fully comply with the constraints and requirements of the system. It gives us only one possible answer so that irrational answers should be ignored. Due to the general and complete nature of the variable, the problem cannot be modeled. Because a completely different planning method is a technique in constraint planning, constraint planning is a logical constraint that enters the modeling set.

**Conclusions and research achievements:**

In this study, in general, three models were presented for the problem of optimal allocation of teacher, class, student in an educational system and scheduling of university courses. The first two models were modeled and presented considering the integer linear programming method and the third model was assigned to a completely different programming method. The efficiency of the models was evaluated by comparing several data and entering it into the first and second models and comparing the number of decision variables; The overall results of the activity-based two-part model are much more efficient due to the significant reduction in the number of binary and binary variables and as a result a significant reduction in the answer search space.

The schedule of one semester of university courses was formulated using two models, taking into account the number of courses, professors, departments, and classrooms, and the overall optimal answer was reached. Considering the computational time of the model, it can be concluded that the model has acceptable computational efficiency. The quality of the current manually created timeline is good and requires a lot of time to prepare with more data. In addition, if a professor changes his / her lessons or time priorities (preferences and rhythm), it will take a long time to restructure the problem data. This is the case with the two-part model, the quality of the answer of the two-part model is more desirable and is optimally universal. Also in the case of the two-part model, by changing the data, it is possible to solve the problem again in a short time. Given that the time to solve scheduling problems depends on various parameters, the use of different data and quality sensitivity analysis of the answers obtained for future research in the performance of the first two models is proposed. Considering that the schedule of courses in each educational institution is different according to the laws and regulations of that institution and the structure and regulations of higher education in each country, many issues can be defined and presented with new features. In order to develop the models presented in this research, by violating the assumptions and parameters or adding new assumptions and parameters, it can be designed as well as removing and adding hard and soft constraints, a new model can be adapted to the conditions of the institution and the educational system under study.

Timing is generally a problem with four parameters of time, activity, resources and a set of constraints that are done with the aim of allocating resources and time to activities and observing the constraints, demands and requirements of the problem. The issue of scheduling has many applications. Examples include scheduling of sports competitions, exams, classes, work shifts, flights and projects, the movement of trains in rail and transport fleets, the movement of buses, and so on. Appeared. For future research, it is suggested to use the problem and scheduling method for the mentioned systems and formulate them according to the fact that each fleet and each scheduling system has its own limitations, rules, requirements and characteristics. Integer method used for formulation and modeling.

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