Resources's Optimisation in Pedagogical Activities Scheduling

Boureima KOUSSOUBE[1], Moustapha BIKIENGA[2] and Telesphore TIENDREBEOGO[3]
{koussoubeboureima@hotmail.com[1], bmoustaph@yahoo.fr[2], tetiendreb@gmail.com[3]}

University Nazi BONI, Bobo Dioulasso, BURKINA FASO [1]
University Norbert ZONGO, Koudougou, BURKINA FASO [2]
University Nazi BONI, Bobo Dioulasso, BURKINA FASO [3]

Abstract. The scheduling of pedagogical activities is a process that assigns a number of pedagogical activities to a limited set of resources and time slots, in accordance with a set of constraints. It is a complex and delicate task because it involves several educational activities and few resources, but also several constraints, some of which are contradictory, which must be satisfied as best as possible. Given the complexity of the problem, the use of computer tools becomes indispensable. The implementation of a tool most often requires the use of a mathematical model. This article proposes a binary model that allows to schedule pedagogical activities and optimize the use of resources (teachers and rooms) in a context of lack of resources and their availability. The resources's optimization was possible by minimizing the difference between the availability sum of each resource and the courses sum in which the resource is involved

Keywords: Timetabling, Scheduling, Pedagogical activities, Mathematical model.

1 Introduction

The scheduling of pedagogical activities is a responsive problem because it has a direct impact on the level of students. It involves assigning a number of pedagogical activities to a limited set of time slots and resources, in accordance with a set of constraints according to the definition given in [1] [2] and [3].This is a problem with several constraints but also with several pedagogical activities to schedule. Faced with all these constraints, need to get help from the computer becomes a necessity in order to find a better compromise. So that the universities do not have the same constraints, the same rules and the same objectives so the portable software are unworkable. Each university formulates its own problem and develops its own solution. In order to design solutions that can be used in several institutes but also to compare and test different solutions, the scientific community through the second International Timetabling Competition (ITC-2007) has defined two possible formulations of the problem. Each institute is therefore called upon to translate its problem into one of the standard formulations. One of the standard formulations is the formulation based on the curriculum [4] which considers to program groups of students in order to minimize conflicts. The second based on post-enrolment [5] which consists to programm each student enrolled in a number of modules. In this paper, our case study is carried out in the context of the Joseph Ki-Zerbo University more precisely at the Unit of Formation and Research in Exact and Applied Sciences(UFR-EAS). The UFR-EAS is composed of four major fields: chemistry,

JRI 2021, November 11-13, Bobo-Dioulasso, Burkina Faso

DOI 10.4108/eai.11-11-2021.2317971

computer science, mathematics and physics. The administration must schedule the various pedagogical activities in a context of lack of resources (rooms and teachers) but also their availability. The activities considered in our article are courses, laboratory work and tutorials. The timetabling developed must respect a certain number of constraints. The timetabling is done manually and this is not without consequences. However, there is considerable difficulty in the execution of the schedules because it does not take enough account of the various constraints. It is therefore necessary to propose a mathematical model that will minimize the violation of these constraints. For the formulation of our problem we will consider the formulation based on the curriculum. The proposed model aims to maximize the use of resources while avoiding conflicts. First we present the differents classifications, second we will present the problem of course based on the curriculum. Then we present our model. In a fourth we present our implementation before concluding by giving the results achieved and our perspectives.

2 Timetabling problem

This section will address a classification of constraints and a different classification of timetablings in the academic field.

2.1 Constraints

The constraints are generally related to the availability of teachers, rooms, capacity and type of room. The preferences of teachers and students must also be taken into account and must therefore be translated into constraints. All this leads to constraints that are contrive. The plans elaborated must present a better compromi between these different. The work of A. Schaerf [2] made it possible to distinguish two classes of constraints. First class is the hard constraints: these constraints cannot be violated under any circumstances. A timetabling that satisfies all the hard constraints is said to be achievable. Second, we have soft constraints: these constraints embody wishes and are not absolutely critical. As far as possible, a timetabling must minimize the violation of these constraints.

2.2 Literature review

The problem of pedagogical activities scheduling is a problem that varies from one university to another. To solve it, each university has its own rules and criteria that it is required to follow. Each one therefore proposes according to the objectives. We will review some models that are close to our context.

In [6] the authors proposed a mathematical model for scheduling second semester courses in an Iranian university. The proposed mathematical model maximizes the preferences of the teachers to teach the day and the time slot of their choice. Another model to maximize the number of students in the classrooms for courses was proposed in [7]

In [8] the authors proposed a mathematical model for scheduling exams. In this model, they defined an objective function to minimize the distance between rooms for consecutive sessions for each student. Another objective function was defined to maximize the number of students in the exam rooms.

In [9] a model for managing teacher competencies has been proposed. Each teacher has competences. The model makes it possible to manage the situations of unavailability and lack of teachers for a given subject. It aims at defining the nature and the number of external competences that the institution will need.

2.3 Different academic timetabling

In the academic field, we meet different classifications of the timetabling but the one proposed by A. Schaerf [2] seems to us better and popular. He proposed three classes, we have the:

i. **school timetabling:** we have the weekly programming of the different courses for all classes of an institution, the courses have to be programming weekly and avoiding that a teacher is programmed in two classes during the same period and vice versa;
ii. **university course timetabling:** we have the programming of a set of courses, avoiding or minimizing overlaps of courses with common students;
iii. **exams timetabling:** we have the programming of a set of exams, avoiding the overlap of the exams having students in common and distributing the exams for the students as much as possible.

As with other timetablings, the implementation of university course timetablings varies depending on the institutions [10]. The problem belongs to the class of NP-complete problems, that is, we do not know an exact method to solve it in a reasonable time (polynomial) [11] [5] [4] [12] [13] [14]. The problem has a large number of courses as well as constraints, so it is a large problem [15]. This problem has therefore attracted the attention of the scientific community through the second edition of the international timetabling competition, which brought together four major research groups. During this competition, the problem of course timetabling was classified into two major classes: the problem of curriculum-based courses and the problem of courses based on post-enrolment. A formulation of each problem has been drawn up within the framework of the competition but also these formulations will have to be standard formulations for the institutes in order to be able to compare the different solutions. These formulations should lead to solutions that incorporate the most constraint. Section 3 will be an opportunity for us to address one of its curriculum-based problems.

3 Problem with curriculum-based courses

The problem of curriculum-based scheduling is to schedule a week of course sessions in a given number of rooms and periods, where conflicts between courses are defined by the University. The problem [4] although it is slightly simplified compared to the real problem allows to maintain a certain level of generality. It is a formulation standard for several cases [16] [17] [18].

3.1 Description of problem

The curriculum-based scheduling problem consists of the following entities:

- **Days, time slots and periods**. A number of teaching days are given in the week. Each day is divided into a fixed number of time slots, which is equal for every day. A period is a pair composed of one day and one hour.
- **Courses and teachers**. Each course includes a fixed number of sessions to be scheduled at separate periods, is attended by a given number of students and is taught by a teacher.
- **Room**. Each room has a capacity and is expressed in the number of seats available. All rooms are suitable for all course.
- **Curriculum**. A curriculum is a set of courses such that any pair of class in the group is taught to students in common. Based on this set of courses, we have conflicts between the courses and other constraints.

The solution to the problem is an assignment of a period (day and time) and of a room to all the sessions of each course while respecting a certain number of constraints.

3.2 Hard Constraints

The hard constraints are four and are common to all the problems encountered in the literature. We have:

- all sessions of a course must be scheduled and assigned to periods;
- two sessions cannot take place in the same room during the same period;
- classes taught by the same teacher must be scheduled at different times;
- if a teacher is not available to teach a course at a given time, no session of that course can be scheduled at that time;

These different constraints do not reflect the availability of the rooms when we know that the rooms are generally shared. The availability of the room will be taken into account in our model.

3.3 Soft constraints

The constraints considered are four. Some will be used as hard constraints in our model:

1. for each course session the room must be able to accommodate all students taking this course. This constraint is seen in our case as a hard constraint;
2. the course sessions must be well distributed in a minimum of day;
3. course sessions belonging to a curriculum must be scheduled for consecutive periods;
4. all sessions of a course must be scheduled in the same room. In our model the sessions of a course can be programmed in rooms of the same category.

3.4 Other variants of the problem

Without being taken into account during the contest in track 3 [4], a certain number of constraints were underlined in track 2 [19] in order to improve the timetablings. These constraints concern:

- intersite travel time;

- the lunch break offer;
- the disposition of the courses;
- courses without rooms;
- availability of rooms;
- room hierarchies;
- the filling rooms;
- free days;
- teachers' preferences.

Solving the problem is possible through the use of mathematical tools but also powerful algorithms. In 2013, V. Cacchiani and al [20] as proposing a two-part modelling based on Integer Linear Programs (Ilps). In 2015 Andrea Bettimelli and al [21] conducted a study on this problem while shedding light on the different mathematical models, exact and heuristic methods as well as the different data instances.

4 Overview of our model

4.1 Context

The problem of the scheduling of pedagogical activities in universities has similarities but also points that are specific to each university and also to each UFR(Unit´ e de Formation et de recherche). One of the peculiarities of our problem is that we have to take into account in addition to masterly courses but also practical work and tutorials. Indeed at the UFR-SEA(Sciences Exacte et Appliqu´ ee) we have promotions of four major fields namely computer science, physics, chemistry and mathematics. For the first year students, they all have to follow the same modules and at the end of some modules, groups are formed to perform the practical work and the tutorials. For students in the second year each student must register in a stream. Some modules are common to all or some sectors. On the other hand, other courses are specific to the students. Only one course session is organized for the common modules. Each student must be able to complete all sessions related to these course. The groups are formed according to the course or the number of students. For example if we have 80 students in physics then we can have two groups of 40 students and if in computer science we have 30 students then we will have another 30 students. From the third year, there are more common modules, the courses(masterly courses, practical work and tutorials) are followed by the students. The goal is to avoid conflicts that prevent a student or teacher from being programmed more than once during a time slot. But also to allow optimal use of resources. This section allowed us to extract all the information about our problem. Now we will pass the identification of the different constraints and a mathematical representation of them.

4.2 Quality of timetabling

The ideal would be to have workable timetabling but this is impossible in practice. However, a good timetabling must present a better compromise between the different actors. Two criteria were defined to assess the quality of a timetabling during the second international timetabling competition [5] [4]. The first criterion concerns the validity of the timetabling. It is clear that in a timetabling we will have some courses that will violate a certain number of constraints so these courses will not be scheduled. These unscheduled courses will allow to calculate a measure of distance of feasibility . This is calculated by identifying the number of students who must attend each of the non-scheduled courses and then making the sum of these values. So, if, for example, we have a solution with four courses that are not programming, and the number of students attending each of them is 10, 8, 3 and 5, then the feasibility distance is simply (10 + 8 + 3 + 5) = 26. For two given solutions, the solution with the most remote feasibility is then considered better. However, if the two solutions are equal under the first criterion then the second criterion comes into play. This consists of examining the number of breaches of soft constraints in each of the solutions by following the following steps:

- count the number of occurrences of a student with only one course on one day;
- count the number of occurrences of a student with more than two consecutive courses;
- count the number of occurrences of a student having a course in the last time slot of the day.

These three steps will determine the soft cost, which is simply the total of these three values. The best solution is the one that has the most Soft Cost.

4.3 Modelling

4.3.1 Sets

- A = {1, ..., i, ..., NM} : set of modules;
- B = {1, ..., g, ..., NG} : set of groups;
- C = {1, ..., k, ..., NC} : set of time slots;
- D = {1, ..., t, ..., NE} : set of teachers;
- E = {1, ..., j, ..., NS} : set of rooms;
- F = {1, ..., jr, ..., NJ} : set of days;

4.3.2 Parameters and variables

• nsmaxig: the maximum daily number of sessions in the i module for the g group
• nsminig: the number of sessions of minimum daily sessions in the i module given to the g group;

- g $jmax_g$: the maximum number of sessions of a group g per day;
- g $jmin_g$: the minimum number of sessions in a g group per day;
- $gsmax_g$: the maximum number of sessions of a g group per week;
- $gsmin_g$: the minimum number of sessions of a g group per week;
- e $jmax_t$: the maximum number of sessions of a teacher t per day;
- e $jmin_t$: the minimum number of sessions of a teacher t per day;
- $esmax_t$: the maximum number of sessions a teacher t can take per week;
- $esmin_t$: the minimum number of sessions per week for a teacher t;
- $DISPOe_{tk}$: availability of the teacher t during a time slot k. $DISPOe_{tk}$ = 1 if the teacher t is available during the k time slot otherwise 0.
- $DISPOs_{jk}$: room availability d during a time slot k. $DISPOs_{jk}$ = 1 if the room j is available during the time slot k otherwise 0.

- $COURS_{tgi}$: it will clarify whether a t teacher is to provide a i module to the g group $COURS_{tgi} = 1$ if the t teacher dispenses the g group with the i module.
- $CONFLIT_{gg'}$: it is clarify whether a group is whether the groups that can be programmed during the same sessions. $CONFLIT_{gg'} = 1$ if two groups g and g′ can be programmed in the same time slot otherwise 0.
- $BONNESALLE_{ij}$: it will specify whether a room is suitable for teaching a given module. $BONNESALLE_{i\,j} = 1$ if the i module is available in the j room
- X_{ijg}^{kt} : it represents the output variable, it will specify for each scheduled session the module, the room, the group, the teacher and the time slot. $X_{ijg}^{kt} = 1$ if a g group has a i module during a k time slot by a t teacher in the j room otherwise 0.

4.3.2 Timetabling Structure

The table 1 represents all the courses that must take place in the n rooms during the 33 times slots from Monday to Saturday. The elements of the table are represented by the triplet (teacher, module, group).

	Monday						Tuesday						...	Saturday		
Room	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	...	C31	C32	C33
S1	..	..	..	..	..	..	..	..	..	..	..	..	...	..	..	..
S2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
S3	..	..	..	..	..	..	..	..	..	..	..	..	...	..	..	..
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sn	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table 1: structure of a timetabling

4.3.3 Hard constraints

- The modules are taught in a classroom and to a group of students. For each given module it is necessary to take into account the number of students who will take part and the teaching material. In short it is necessary that the module taught is adequate to the room. ∀ k = 1, ..., 33 , i ∈ NM and j ∈ NS:

$$\sum_{g=1}^{NG}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq \text{BONNESALLE}_{i\,j} \qquad (1)$$

$BONNESALLE_{ij}$ precise whether a module is suitable for a room or not. $\sum_{g=1}^{NG}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq \text{BONNESALLE}_{ij}$ is the sum of sessions involving all teachers and all groups in a given time slot for a given module and in a given room, and must not be less than the value of $BONNESALLE_{ij}$.

- A room cannot accommodate more than one course during a time slot k. ∀ k = 1, ..., 33 and for any room j ∈ NS we have:

$$\sum_{i=1}^{NM}\sum_{g=1}^{NG}\sum_{t=1}^{NE} X_{ijg}^{kt} \ \leq\ 1 \qquad (2)$$

$\sum_{i=1}^{NM}\sum_{g=1}^{NG}\sum_{t=1}^{NE} X_{ijg}^{kt}$ represents the sum of the sessions for all the modules, groups and teachers that must take place in a given room and at the same time. This sum must be less than or equal to one, otherwise we will have more than one course in a same room and a same time slot.

- For each course programmed in a room and at a time slot it will be necessary to verify if this room is available during this time. ∀ k = 1, ..., 33 and j ∈ NS we have :

$$\sum_{i=1}^{NM}\sum_{g=1}^{NG}\sum_{t=1}^{NE} X_{ijg}^{kt} \ \leq\ DISPO_{ij} \qquad (3)$$

$\sum_{i=1}^{NM}\sum_{g=1}^{NG}\sum_{t=1}^{NE} X_{ijg}^{kt}$ represents the sum of all sessions involving all teachers, modules and groups that must be held in a given room and at the same time slot. This sum must be less than the value of $DISPO_{jk}$.

- For all course sessions, we must be sure that it is the right teacher who delivers the module that it is supposed to deliver to the right group. ∀ k = 1, ... 33 and j ∈ NS we have :

$$X_{ijg}^{kt} \leq COURS_{igt} \qquad (4)$$

- A group cannot be programmed more than once during the same time slot k. ∀ k = 1, ... 33 and for each group g ∈ NG we have :

$$\sum_{i=1}^{NM}\sum_{j=1}^{NS_K}\sum_{t=1}^{NE_k} X_{ijg}^{kt} \leq 1 \qquad (5)$$

$\sum_{i=1}^{NM}\sum_{j=1}^{NS_K}\sum_{t=1}^{NE_k} X_{ijg}^{kt}$ represents the sum of the sessions of a group for a given time slot.

- Two conflicting g and g′ groups cannot be programmed in the same time slot. If we have, for example, five groups that are in conflict, then only one of those five groups can have a given time slot. ∀ k = 1, ... 33 and ∀ (g) ∈ NG we have:

$$\sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{g'=0}^{NG'}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq \sum_{g'=0}^{NG'} CONFLIT_{gg'} \qquad (6)$$

$\sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{g'=0}^{NG'}\sum_{t=1}^{NE} X_{ijg}^{kt}$ represents the sum of the sessions of all teachers in all rooms for all modules and of all groups in conflict with group g.

$\sum_{g'=0}^{NG'} CONFLIT_{gg'}$ represents the sum of the elements of line g in the matrix $CONFLIT_{gg'}$

- Maximum number of sessions for each group for one day must be respected. ∀ jr=1, 2, 3, 4, 5 and ∀ g ∈ NG, we have :

$$\sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{k=(jr-1)*6+1}^{jr*6}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq gjmax_g^{jr} \qquad (7)$$

and

$$\sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{k=(jr-1)*6+1}^{jr*6}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq gjmin_g^{jr} \qquad (8)$$

for Saturday jr= 6, we will have:

$$\sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{k=31}^{33}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq gjmax_g^{6} \qquad (9)$$

$\sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{k=(jr-1)*6+1}^{jr*6}\sum_{t=1}^{NE} X_{ijg}^{kt}$ represents the sum of the course sessions for each group for one day. We therefore limited this sum to $gjmax_g^{jr}$ and $gjmin_g^{jr}$

- The maximum number of daily sessions to be taken by each group for each module must be respected. ∀ jr=1, 2, 3, 4, 5, ∀ g ∈ NG and i ∈ NM, we have :

$$\sum_{j=1}^{NS}\sum_{k=(jr-1)*6+1}^{jr*6}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq\ nsmax_{ig} \qquad (10)$$

and

$$\sum_{j=1}^{NS}\sum_{k=(jr-1)*6+1}^{jr*6}\sum_{t=1}^{NE} X_{ijg}^{kt} \geq\ nsmin_{ig} \qquad (11)$$

for Saturday jr= 6, we will have:

$$\sum_{j=1}^{NS}\sum_{k=31}^{33}\sum_{t=1}^{NE} X_{ijg}^{kt} \leq nsmax_g^{6} \qquad (12)$$

$\sum_{j=1}^{NS} \sum_{k=(jr-1)*6+1}^{jr*6} \sum_{t=1}^{NE} X_{ijg}^{kt}$ represents the sum of the maximum daily sessions that each group must participate in for each given module. This amount was limited to nsmaxig and nsminig

- Each teacher programmed for each time slot must be available. ∀ k=1, ..., 33 and ∀ t ∈ NE, we have :

$$\sum_{i=1}^{NM} \sum_{g=1}^{NG} \sum_{j=1}^{NS} X_{ijg}^{kt} \leq DISPOe_{tk} \tag{13}$$

$\sum_{i=1}^{NM} \sum_{g=1}^{NG} \sum_{j=1}^{NS} X_{ijg}^{kt}$ represents the sum of the sessions that a teacher must teach during a given time slot. This sum must be less than the value of $DISPOe_{tk}$

- The daily load of a teacher must be respected. ∀ jr=1, 2, 3, 4, 5 and ∀ t ∈ NE, we have :

$$\sum_{i=1}^{NM} \sum_{j=1}^{NS} \sum_{g=1}^{NG} \sum_{k=(jr-1)*6+1}^{jr*6} X_{ijg}^{kt} \leq ejmax_t \tag{14}$$

and

$$\sum_{i=1}^{NM} \sum_{j=1}^{NS} \sum_{g=1}^{NG} \sum_{k=(jr-1)*6+1}^{jr*6} X_{ijg}^{kt} \geq ejmin_t \tag{15}$$

$\sum_{i=1}^{NM} \sum_{j=1}^{NS} \sum_{g=1}^{NG} \sum_{k=(jr-1)*6+1}^{jr*6} X_{ijg}^{kt}$ represents the sum of a teacher's sessions for a given day.

- The weekly load of a teacher must be respected. ∀ t ∈ NE, we have :

$$\sum_{i=1}^{NM} \sum_{j=1}^{NS} \sum_{g=1}^{NG} \sum_{k=1}^{33} X_{ijg}^{kt} \leq esmax_i \tag{16}$$

and

$$\sum_{i=1}^{NM} \sum_{j=1}^{NS} \sum_{g=1}^{NG} \sum_{k=1}^{33} X_{ijg}^{kt} \geq esmin_i \tag{17}$$

$\sum_{i=1}^{NM} \sum_{j=1}^{NS} \sum_{g=1}^{NG} \sum_{k=1}^{33} X_{ijg}^{kt}$ represents the sum of a teacher's session for a given week.

After modelling the constraints that determine the feasibility of the planning, we will move on to modelling those that will determine the quality of the planning.

4.3.4 Soft constraints

The various soft constraints are represented by the objective functions. In our case these different functions aim to maximize the use of resources. '

- If a teacher is available, he will have to be programmed to the maximum. To do this we will minimize the gap between the sum of the sessions where it is involved and the sum of the slots to which it is available. ∀ t ∈ NE we have :

$$f_1 = Min(\sum_{k=1}^{33} DISPOe_{tk} - \sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{g=1}^{NG}\sum_{k=1}^{33} X_{ijg}^{kt}) \qquad (18)$$

$\sum_{k=1}^{33} DISPOe_{tk}$ represents the sum of a teacher's availabilities

$\sum_{i=1}^{NM}\sum_{j=1}^{NS}\sum_{g=1}^{NG}\sum_{k=1}^{33} X_{ijg}^{kt}$ represents the sum of a teacher's sessions for a week.

- If a room is made available to the UFR, it will need to be occupied to the maximum. To do this we will minimize the gap between the sum of the sessions where it is involved and the sum of its availability. For any room of any category, we have:

$$f_2 = Min(\sum_{k=1}^{33} DISPOs_{tk} - \sum_{i=1}^{NM}\sum_{t=1}^{NE}\sum_{g=1}^{NG}\sum_{k=1}^{33} X_{ijg}^{kt}) \qquad (19)$$

$\sum_{k=1}^{33} DISPOs_{tk}$ represents the sum of the availabilities of a room for a given week.
$\sum_{i=1}^{NM}\sum_{t=1}^{NE}\sum_{g=1}^{NG}\sum_{k=1}^{33} X_{ijg}^{kt}$ represents the sum of the sessions in a room during one week.
So we have an optimization problem with two objective functions to minimize.

5 Implementation

The test was performed on a 4 GB RAM machine and a 64-bit operating system. The GAMS software was used to implement the model. GAMS integrates 15 mathematical models including RMIP (Relaxed Mixed integer programming) that we use because of some binary variables. We therefore considered 2 modules (i1 and i2), 2 groups (g1 and g2), 3 time slots (k1, k2 and k3), 2 teachers (t1 and t2) and 2 rooms (j1 and j2) in order to better visualize the output variables. The t2 teacher is not available during the k3 slot and the j1 room is not available during the k2 slot. With his data the number of equation was 151, 49 variables and 48 discrete variables and the time of exucution was 0.078 seconds.

---- VAR X

	LOWER	LEVEL	UPPER	MARGINAL
i1.j1.g1.k1.t1	.	1.000	1.000	.
i1.j1.g1.k1.t2	.	.	1.000	.
i1.j1.g1.k2.t1	.	1.000	1.000	.
i1.j1.g1.k2.t2	.	.	1.000	.
i1.j1.g1.k3.t1	.	1.000	1.000	.
i1.j1.g1.k3.t2	.	.	1.000	.
i1.j1.g2.k1.t1	.	.	1.000	.
i1.j1.g2.k1.t2	.	.	1.000	EPS
i1.j1.g2.k2.t1	.	.	1.000	.
i1.j1.g2.k2.t2	.	.	1.000	EPS
i1.j1.g2.k3.t1	.	.	1.000	.
i1.j1.g2.k3.t2	.	.	1.000	EPS
i1.j2.g1.k1.t1	.	.	1.000	EPS
i1.j2.g1.k1.t2	.	.	1.000	EPS
i1.j2.g1.k2.t1	.	.	1.000	.
i1.j2.g1.k2.t2	.	.	1.000	EPS
i1.j2.g1.k3.t1	.	.	1.000	EPS
i1.j2.g1.k3.t2	.	.	1.000	EPS
i1.j2.g2.k1.t1	.	.	1.000	EPS
i1.j2.g2.k1.t2	.	.	1.000	EPS
i1.j2.g2.k2.t1	.	.	1.000	EPS
i1.j2.g2.k2.t2	.	.	1.000	EPS
i1.j2.g2.k3.t1	.	.	1.000	EPS
i1.j2.g2.k3.t2	.	.	1.000	EPS
i2.j1.g1.k1.t1	.	.	1.000	.
i2.j1.g1.k1.t2	.	.	1.000	.
i2.j1.g1.k2.t1	.	.	1.000	1.000
i2.j1.g1.k2.t2	.	.	1.000	1.000
i2.j1.g1.k3.t1	.	.	1.000	.
i2.j1.g1.k3.t2	.	.	1.000	.
i2.j1.g2.k1.t1	.	.	1.000	EPS
i2.j1.g2.k1.t2	.	.	1.000	EPS
i2.j1.g2.k2.t1	.	.	1.000	1.000
i2.j1.g2.k2.t2	.	.	1.000	1.000
i2.j1.g2.k3.t1	.	.	1.000	EPS
i2.j1.g2.k3.t2	.	.	1.000	.
i2.j2.g1.k1.t1	.	.	1.000	EPS
i2.j2.g1.k1.t2	.	.	1.000	EPS
i2.j2.g1.k2.t1	.	.	1.000	EPS
i2.j2.g1.k2.t2	.	.	1.000	.
i2.j2.g1.k3.t1	.	.	1.000	EPS
i2.j2.g1.k3.t2	.	.	1.000	EPS
i2.j2.g2.k1.t1	.	.	1.000	EPS
i2.j2.g2.k1.t2	.	1.000	1.000	.
i2.j2.g2.k2.t1	.	.	1.000	.
i2.j2.g2.k2.t2	.	1.000	1.000	.
i2.j2.g2.k3.t1	.	.	1.000	EPS
i2.j2.g2.k3.t2	.	1.000	1.000	EPS

Fig. 1. The values of variable X

The output variables are in Figure 1. Through this figure, 6 sessions (X(i1, j1,g1,k1,t1), X(i1, j1,g1,k2,t1), X(i1, j1,g1,k3,t1), X(i2, j2,g2,k1,t2), X(i2, j2,g2,k2,t2) and X(i2, j2,g2,k3,t2)) are worth 1 those that imply that these course sessions have been scheduled. Of these 6 classes only two violated a constraint.

6 Conclusion

The quality of the teaching is very important for the direction of the UFR-SEA. Empirical timetablings do not satisfy students, teachers or administration. A good solution for one establishment is not the case for another. Each institution must therefore develop its own solution in order to better integrate its constraints and objectives. In this article, the problem is seen as a problem with curriculum-based courses. Formulating our problem into a problem of curriculum-based courses allows to better represent our contraines. The proposed model is based on binary variables, parameters, sets and mathematical equations. The problem of lack of resources and their availability was solved by the course by minimizing the gap between the sum of the availabilities of each resource and the sum of the courses where the resource is involved. Verification of the model was done on very small data and on a certain number of constraints. This implementation made it possible to appreciate the satisfaction of its constraints and one of the most important parts which is the optimization of the rooms. A significant amount of work remains to be done. First define another objective function that will minimize off-peak hours in the schedule. Then the extension of your work with more data and constraints. The exploration of algorithms and techniques of constraint programming and the use of better solvers will allow us to improve our model.

References

[1] **Book:** Marmier F. Contribution ` a l'ordonnancement des activités de maintenance sous contrainte de comp´ etence: une approche dynamique, proactive et multi-crit` ere. Phd thesis, université de franche-comt´ e ed.; 2007.

[2] **Journal article**: Schaerf A. A survey of automated timetabling. Artificial intelligence review. 1999;vol. 13(no. 2):pp. 87–127.

[3] **Conference proceedings paper:** R Qu BMLTM E K Burke, Lee SY. A survey of search methodologies and automated system development for examination timetabling. Journal of scheduling. 2009;vol. 12(no. 1):p. 55–89.

[4] **Journal article:** Luca Di Gaspero BM, Schaerf A. The second international timetabling competition (ITC2007): Curriculum-based course timetabling (track 3). 2007.

[5] **Journal article:** Lewis R, Paechter B, McCollum B. Post-enrolment based course timetabling: A description of the problem model used for track two of the second international timetabling competition. 2007.

[6] **Journal article:** Jamili A, Hamid M, Gharoun H, Khoshnoudi R. Developing a comprehensive and multiobjective mathematical model for university course timetabling problem: a real case study. In: Conference: proceedings of the international conference on industrial engineering and operations management, Paris, France; 2018. p. 2108.

[7] **Journal article:** Lemos A, Melo FS, Monteiro PT, Lynce I. Room usage optimization in timetabling: A case study at Universidade de Lisboa. Operations Research Perspectives. 2019;6:100092.

[8] **Journal article:** Ergul Z, Kamisli Ozturk Z. A new mathematical model for multisession exams-building assignment. Acta Physica Polonica A. 2017;132(3):1207-10.

[9] **Conference proceedings paper:** Wikarek J. Lecturers' competences configuration model for the timetabling problem. In: 2018 Federated Conference on Computer Science and Information Systems (FedCSIS). IEEE; 2018. p. 441-4**.**
[10] **Journal article:** Burke EK, Petrovic S. Recent Research Directions in Automated Timetabling. European Journal of Operational Research - EJOR. 2002.
[11] **Journal article:** Burke E, Jackson K, Kingston JH, Weare R. Automated university timetabling: The state of the art. The computer journal. 1997.
[12] **Journal article:** Edmund K Burke HRE. Practice and Theory of Automated Timetabling VI. 2006.
[13] **Journal article:** Alexandre Lemos PTMIL Francisco S Melo. Room usage optimization in timetabling: A case study at Universidade de Lisboa. 2018.
[14] **Journal article:** Tellaeche JAMAS. Development of a tool for university timetabling using an integrated spreadsheet. 2016.
[15] **Conference proceedings paper:** Burke EK, Newall JP. A multistage evolutionary algorithm for the timetable problem. IEEE transactions on evolutionary computation. 1999;vol. 3(no. 1):63–74.
[16] **Journal article:** Schaerf ABDCDG. Benchmarking Curriculum-Based Course Timetabling: Formulations, Data Formats, Instances, Validation, Visualization, and Results.
[17] **Journal article:** Nieuwenhuis RAA. Curriculum-based Course Timetabling with SAT and MaxSAT. 2007.
[18] **Journal article:** Lubbecke GLE. Curriculum based course timetabling: new solutions to Udine benchmark instances. 2010**.**
[19] **Journal article:** Rhydian Lewis BP, McCollum B. Post Enrolment based Course Timetabling: A Description of the Problem Model used for Track Two of the Second International Timetabling Competition. August 2007.
[20] **Journal article:** V Cacchiani RRPT A Caprara. A new lower bound for curriculum-based course timetabling. 2013.
[21] **Journal article:** Toth ABCR. An overview of curriculum-based course timetabling. 19 March 2015.