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Modelling And Solving Course Scheduling Problems (Case Study: Mathematics Study Program, Institut Teknologi Sumatera)

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Abstract
Every educational institution has a standard process for scheduling courses. In scheduling, there are a lot of constraints that must be fulfilled, including hard and soft constraints. Hard constraints are constraints that must be met and cannot be disregarded; a lecturer, for instance, is limited to teaching one course in one room at a time. Soft constraints, on the other hand, are a type of restriction that can be broken, but breaks are minimized to the greatest extent possible. The aim of this research is to produce an optimal lecture schedule and to provide alternative solutions. The case study taken is the even semester at Institut Teknologi Sumatera (ITERA) Mathematics Study Program. The problem is modelled using Goal Programming and solved using LINGO. The result shows that the scheduling can fulfill every requirement.
Keywords: *scheduling, hard constraint, soft constraint, goal programming*

1. INTRODUCTION

Scheduling is one of the important aspects of a study program of a university. Class scheduling is a routine activity at the beginning of the semester that must be carried out by each study program. In making class schedules, various problems were encountered, such as limited space, the number of rooms that can be used to organize lectures, limited space capacity, limited teaching hours for lecturers, and others [1]. The more courses will be scheduled, the more difficult the problem is faced. In designing a schedule for classes offered on a study program, there are constraints that must be fulfilled and cannot be violated, and those constraints are called hard constraints; for example, a course at time t1 given by lecturer A in room R1, then lecturer A cannot teach at time t1 for other courses and room R1 cannot be used by other lectures at time t1, and so on. In addition to hard constraints, there are some soft constraints [2]. These types of constraints may not be fulfilled. However, these violations should be made at the minimum as possible. Time preference for lectures is one example of these constraints.

Some researchers have investigated the class scheduling problems, such as Suhartono who used Genetics Algorithms to optimize the computer laboratory in AMIK JTC Semarang [3], and Ruhiyat et al, who used Goal Programming to minimize the overlapping schedules programs FMIPA IPB [4].

In the Mathematic Study Program of Institut Teknologi Sumatera, the class scheduling process is still done manually, and frequently the violation of hard constraints occur, and usually the violations are fixed after a series of revisions made to the schedule. In this research we developed a mathematical model for that problem using goal programming and then solved the problem using LINGO.

2. THE METHOD

Scheduling is ordering or sequencing items in a way that best achieves a set of goals while adhering to a set of constraints, or allocation of resources to objects being put in space-time, subject to limitations [5]. In scheduling, the following are some of the difficult constraints:

- A lecturer can not teach more than one course/class at the same time.
- A course for students at the same level and the same major cannot be scheduled at the same time.
- A classroom for a certain time can only be used for one class, and cannot use the same room for more than one class.
- The capacity of the classroom must be able to cover the number of students.
- Some classes/courses need a specific room, for example, a computer laboratory.

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The soft constraints are 'preferable' constraints which may be violated. Some constraints below are some of the soft constraints for class sheduling

- Lecturers' preference to teach at a specific time, specific day
- The class, which has 4 credit units, may be split into 2 times; each consists of 2 credits
- It is better for every lecturer to have a day off during a weekday so that he has a 'free" day so that he can manage it to improve the quality of teaching materials or other academic activity on campus.

In reality, it is hard to satisfy all soft constraints. The quality feasible schedule is a schedule that not only satisfies hard constraints, but also soft constraints. However, it is acceptable if some soft constraints are violated, as long as the violations should be made at as minimum as possible.

In order to have a solution that can handle those two kinds of constraints, goal programming can be used. Goal programming is one method that can be used to solve a multi-objective linear programming. The procedure for modelling a problem using goal programming is as follow [6]:

a. Determine decision variable. Determining decision variables is the most important step. The more precise the decision variable is, the more accurate the model.
b. Determine the constraints.
c. Determine the priority
d. Determine the weight
e. Determine the objective
f. Non negativity

The multi-objective linear programming can be defined as follows:

Min $z_1(x) = c_1x$

Min $z_2(x) = c_2x$

Min $z_k(x) = c_kx$

Subject to: $Ax \leq b,$

$x \geq 0$

Goal programming method can be used to solve the multi-objective linear programming. In order to use goal programming, the problem must be transformed to a goal programming model, and then define what the goal is, and also add the deviation variables to the goal. In the next section we will discuss how we model the class scheduling using goal programing and then solve the model using LINGO 18.0.

3. RESULTS AND DISCUSSION

In this section we will discuss how to formulate the class scheduling using an integer programing model, put it into goal programming model, and then solve it. The data used is data on the even semester 2020-2021 in the mathematics study program at Institut Teknologi Sumatera (ITERA). The data consists of data lecturers, parallel classes, courses, rooms, days, and time periods of courses.

1. Courses.
   The courses given in the mathematics study program at ITERA consist of compulsory and elective courses. The compulsory courses must be taken by students, while elective courses are not. The credits for each course are 3 Semester Credit Units (SCU). The time for giving the lecturer is 50 minutes for each SCU. Most of the courses given are assigned to be taught by lecturers from ITERA itself. However, some courses are assigned to be taught by lecturers from other institutions.
2. Days and time periods.
   The days for giving lectures in ITERA are from Monday through Friday. For the time period, it starts from 7.00 a.m until 15.30 p.m, thus one day only consists of three time periods: 07.00 – 09.30, 10.00 -12.30, 13.00 – 15.30.There are thirty minutes between the two time periods. Note that on Friday, there are only two time periods to give time for students and lectures to follow Jum'ah prayer. We use index j for days.
3. There are 15 lectures in Mathematics Study Program of ITERA, including 3 lecturers from other institutions. The following table shows the lecturer and the course assigned.

Table 1. Courses name and their types

Indeks i	Course name	Type of course	Time (minutes)	Semester
1	Geometry	Compulsory courses	150	4
2	Discrete Mathematics		150	4
3	Introductory Diferensial Equation		150	4
4	Algebraic Structure I		150	4
5	Complex Function	Elective courses	150	6
6	Time Series Analysis		150	6
7	Finance Mathematics		150	6
8	Advanced Optimization		100	6
9	Introductory Stochastic Process		150	6
10	Dynamical System		150	6
11	Analysis I		150	6
12	Matrix Theory		150	6
13	Capita Selecta of Statistics		150	8
14	Capita Selecta of Computation		150	8
15	Capita Selecta of Algebra		150	8
16	Capita Selecta of Applied Mathematics		150	8

Table 2. The lecturers and the course taught

Index (m)	Lecturer	The course
1	Prof. Leo H Wiryanto, M.S.	Introductory Diferensial Equation
2	Triyana Muliawati, M.Si	Introductory Stochastic Process Capita Selecta of Statistics
3	Dr. Sri Efrinita Irwan, M.Si	Algebraic Structure I Matrix Theory Capita Selecta of Algebra
4	Eristia Arfi, S.Si., M.Si.	Complex Function Introductory Diferensial Equation.
5	Dear Michiko Mutiara Noor,S.Si., M.Si.	Capita Selecta of Applied Mathematics Dynamical System
6	Mira Mustika, S.Si., M.Sc.	Geometry Advanced Optimization Discrete Mathematics
7	Dr. Rifky Fauzi	Analysis 1 Capita Selecta of Computation
8	Lutfi Mardianto, M.Si.	Finance Mathematics Complex Function
9	Dani Al Mahkya, S.Si., M.Si.	Time Series Analysis
10	Aswan Anggun Pribadi, M.Si.	Geometry Discrete Mathematics
11	Tiara Shofi Edriani, M,Si	Finance Mathematics Time Series Analysis.
12	Nela Rizka, S.Pd., M.Si	Algebraic Structure I Complex Function
13	Bonno Andri Wibowo, S.Si.,M.Si.	Introductory Stochastic Process
14	Achmad Suryadi Nasution, S.Si,M.Si.	Advanced Optimization Discrete Mathematics
15	Gusrian Putra, S.Si., M.Si.	Geometry Complex Function

4. Rooms

   There are only three rooms available for class/lectures as shown in the following table:

Table 3. The rooms available for lectures

Indeks (n)	Room
1	Room F108
2	Room F109
3	Room F110

5. Parallel classes
   For even semester of 2020-2021 there are some parallel classes, depending on the number of students and the number of lecturers who can teach the courses. The parallel classes are: 4 parallel classes for Complex Function; 3 parallel classes for Geometry and Discrete Mathematics; 2 parallel courses for Introduction to Differential Equation, Algebraic Structure, Time Series Analysis, Finance Mathematics, Advanced Optimization, and Introduction to Stochastic Process; and no parallel class for Dynamical System, Analysis I, Matrix Theory, Capita Selecta Statistics, Capita Selecta Computation, Capita Selecta Algebra, and Capita Selecta Applied Mathematics.

By using this information, we model the class scheduling for the Mathematics Study Program in ITERA as follows:

i) Index

i : course index, i= 1,2,3,…,16.
j : day index, j= 1,2,…,5.
k : parallel class index, k =1,2,…,4.
l : time period index, l= 1,2,3.
m : lecturer index, m= 1,2,3,…,15.
n : room index, n = 1,2,3.

ii) Parameters

$$t_i = \begin{cases} 1, & \text{if } i \text{ is index for compulsory course} \\ 2, & \text{if } i \text{ is index for elective course} \end{cases}$$

$$s_i = \begin{cases} 4, & \text{if } s_i \text{ is the fourth semester student} \\ 6, & \text{if } s_i \text{ is the sixth semester student} \\ 8, & \text{if } s_i \text{ is the eighth semester student} \end{cases}$$

iii) Sets

A = set of courses taught at even semester at Mathematics Study Program, ITERA.
B = set of the days where the courses taught.
C = set of parallel classes with four classes
D = set the time periods
E = set of lecturers
F = set of rooms for teaching activities.
G = set of compulsory courses
T_1= set of courses for fourth semester students.
T_2= set of courses for sixth semester students.
T_3= set of courses for eighth semester students.
Q = set of parallel classes with three classes
R = set of parallel classes with two classes
S = set of nonparallel classes
AE_m = set pf courses taught by lecturer m.
Note that $G \subset A$, $T_1 \subset A$, $T_2 \subset A$, $T_3 \subset A$

iv) Decision variable:

$$x_{i,j,k,l,m,n} = \begin{cases} 1, & \text{if course } i \text{ is scheduled for day } j \text{ for class } k \text{ on time period } l, \text{taught by lecturer } m \text{ in room } n \\ 0, & \text{for others} \end{cases}$$

v) Deviation Variable

$d^{+}_{1,m,j}$ = the value that holds the deviation that is above the target at the 1st goal for lecturer m teaching on day j.
$d^{-}_{1,m,j}$ = the value that holds the deviation that is below the target at the 1st goal for lecturer m teaching on day j.
$d^{+}_{2,m,j}$ = the value that holds the deviation that is above the target at the 2nd goal for lecturer m teaching on day j not on sequential time period.
$d^{-}_{2,m,j}$ = the value that holds the deviation that is below the target at the 2nd goal for lecturer m teaching on day j not on sequential time period.
$d^{+}_{3,m,j}$ = the value that holds the deviation that is above the target at the 3rd goal for every course for fourth semester at day j.
$d^{-}_{3,m,j}$ = the value that holds the deviation that is below the target at the 3rd goal for every course for fourth semester at day j.
$d^{+}_{4,m,j}$ = the value that holds the deviation that is above the target at the 4th goal for every course for sixth semester at day j.
$d^{-}_{4,m,j}$ = the value that holds the deviation that is below the target at the 4th goal for every course for sixth semester at day j.
$d^{+}_{5,m,j}$ = the value that holds the deviation that is above the target at the 5th goal for every course for eighth semester at day j.
$d^{+}_{5,m,j}$ = the value that holds the deviation that is below the target at the 5th goal for every course for eighth semester at day j.

vi) Set of Constraints

a. Hard Constraints

The hard constraints are constraints that must be fulfilled and cannot be violated which are:

1. The number of scheduled courses for a week is 29
   $\sum_{i\in A}\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{m\in D}\sum_{n\in F} x_{i,j,k,l,m,n} = 29$
   $i\in A \;\; j\in B \;\; k\in C \;\; l\in D \;\; m\in E \;\; n\in F$
2. The compulsory course cannot be scheduled at the same time period on the same day.
   $\forall j \in B, l \in D,\ \sum_{i\in G}\sum_{k\in C}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 1$, where G $=\{i \mid s_i=4$ and $s_i=6$, $t_{i=1}\}$
3. **3.** All courses for fourth, sixth, and eighth semester cannot be scheduled at the same day and the same time period
   a. For fourth semester students
   $\forall j \in B, l \in D,\ \sum_{i\in T_1}\sum_{k\in C}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 1$, where $T_1 = \{i \mid s_i=4$, $t_{i=1}\}$
   b. For sixth semester students
   $\forall j \in B, l \in D,\ \sum_{i\in T_2}\sum_{k\in C}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 1$, where $T_2 = \{i \mid s_i=6$, $t_{i\ge1}\}$
   c. For eighth semester students
   $\forall j \in B, l \in D,\ \sum_{i\in T_3}\sum_{k\in C}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 1$, where $T_3 = \{i \mid s_i=8$, $t_{i=2}\}$
4. **4.** Every course is scheduled exactly on one day, one room and one time period
   $\forall i \in A, k \in C,\ \sum_{j\in B}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 1$
5. **5.** Every room in every time period only can be used by one course
   $\forall j \in B, l \in D,\ n \in F,\ \sum_{i\in A}\sum_{k\in C}\sum_{m\in E} x_{i,j,k,l,m,n} \le 1$
6. **6.** Every lecture only can teach one course at a certain room, certain day, and a certain time period
   $\forall j \in B, l \in D,\ m \in E,\ \sum_{i\in A}\sum_{k\in C}\sum_{n\in F} x_{i,j,k,l,m,n} \le 1$
7. **7.** There are three lectures from other institution who only can teach on a certain day and certain time
   - Introductory Differential Equation only can be held twice on Tuesday, from 07.00 a.m until 15.30 p.m
     $\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{3,2,k,l,m,n} = 2$
   - Geometry only can be held on Monday or Friday, three times, from 07.00 a.m until 15.30 p.m
     $\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{1,1,k,l,m,n} + x_{1,5,k,l,m,n} = 3$
   - Analysis I only can be held once a week, on Monday or Friday, from 07.00 a.m until 15.30 p.m
     $\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{11,1,k,l,m,n} + x_{11,5,k,l,m,n} = 1$
8. **8.** There are no classes on Friday from 10.00 am to 12.30 pm, because that

time period is used for Jum'ah prayer.

- $\sum_{i\in A}\sum_{k\in C}\sum_{m\in E}\sum_{n\in F} x_{i,5,k,2,m,n} = 0$

9. Every lecturer teaches courses accordance to his expertise

- For m =1 and $\forall i \in AE_1$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F} x_{3,j,k,l,1,n} = 1$; $AE_1 = \{3\}$

- For m =2 and $\forall i \in AE_2$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{9,j,k,l,2,n} + x_{13,j,k,l,2,n}) = 2$; $AE_2 = \{9, 13\}$

- For m =3 and $\forall i \in AE_3$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{4,j,k,l,3,n} + x_{12,j,k,l,3,n} + x_{15,j,k,l,3,n}) = 3$; $AE_3 = \{4, 12, 15\}$

- For m =4 and $\forall i \in AE_4$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{3,j,k,l,4,n} + x_{5,j,k,l,4,n}) = 2$; $AE_4 = \{3,5\}$

- For m =5 and $\forall i \in AE_5$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{10,j,k,l,5,n} + x_{16,j,k,l,5,n}) = 2$, $AE_5 = \{10,16\}$

- For m =6 and $\forall i \in AE_6$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{1,j,k,l,6,n} + x_{2,j,k,l,6,n} + x_{8,j,k,l,6,n}) = 3$, $AE_6 = \{1, 2, 8\}$

- For m =7 and $\forall i \in AE_7$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{11,j,k,l,7,n} + x_{14,j,k,l,7,n}) = 2$, $AE_7 = \{11,14\}$

- For m =8 and $\forall i \in AE_8$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{5,j,k,l,8,n} + x_{7,j,k,l,8,n}) = 2$, $AE_8 = \{5,7\}$

- For m =9 and $\forall i \in AE_9$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F} x_{6,j,k,l,9,n} = 1$, $AE_9 = \{6\}$

- For m =10 and $\forall i \in AE_{10}$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{1,j,k,l,10,n} + x_{2,j,k,l,10,n}) = 2$, $AE_{10} = \{1,2\}$

- For m =11 and $\forall i \in AE_{11}$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{7,j,k,l,11,n} + x_{6,j,k,l,11,n}) = 2$, $AE_{11} = \{7,6\}$

- For m =12 and $\forall i \in AE_{12}$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{4,j,k,l,12,n} + x_{5,j,k,l,12,n}) = 2$, $AE_{12} = \{4,5\}$

- For m =13 and $\forall i \in AE_{13}$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F} x_{9,j,k,l,13,n} = 1$, $AE_{13} = \{9\}$

- For m =14 and $\forall i \in AE_{14}$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{2,j,k,l,14,n} + x_{8,j,k,l,12,n}) = 2$, $AE_{12} = \{2, 8\}$

- For m =15 and $\forall i \in AE_{15}$

$\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F}(x_{1,j,k,l,15,n} + x_{5,j,k,l,15,n}) = 2$, $AE_{12} = \{1, 5\}$

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10. The parallel classes match with the number scheduled lecturers

- The parallel classes with four classes

For $i = 5$, $\sum_{j\in B}\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{5,j,k,l,m,n} = 4$

- The parallel classes with three classes

For $\forall\ i \in Q$, $\sum_{j\in B}\sum_{k=1}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} = 3$

- The parallel classes with two classes

For $\forall\ i \in R$, $\sum_{j\in B}\sum_{k=1}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} = 2$

- Non parallel classes

For $\forall\ i \in S$, $\sum_{j\in B}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,1,l,m,n} = 1$

b. Soft Constraints

1. Every lecturer only teaches maximum two courses at the same day.

$\forall\ j \in B, m \in E,$, $\sum_{i\in A}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F} x_{i,j,k,l,m,n} \le 2$

2. A lecturer is not teaching for sequential time period in one day

$\forall j \in B, m \in E,$ $\sum_{i\in A}\sum_{k\in C}\sum_{n\in F} x_{i,j,k,1,m,n} + 2x_{i,j,k,2,m,n} + x_{i,j,k,3,m,n} \le 2$

3. The number of courses taught for fourth semester students at most 2.

$\forall j \in B,$ $\sum_{i\in T_1}\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 2$, $T_1 = \{i \mid s_i=4 , t_{i=1}\}$

4. The number of courses taught for sixth semester students at most 2.

$\forall j \in B,\ \sum_{i\in T_2}\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 2$, $T_2 = \{i \mid s_i = 6, t_i \ge 1\}$

5. The number of courses taught for eighth semester students at most 2.
   $\forall j \in B,\ \sum_{i\in T_3}\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} \le 2$, $T_2 = \{i \mid s_i = 8, t_i = 2\}$

In order to minimize the violation on soft constraint, we add positive and negative deviations on soft constraints so that the soft constraints will be as follow:

$\forall j \in B, m \in E,\ ,\ \sum_{i\in A}\sum_{k\in C}\sum_{l\in D}\sum_{n\in F} x_{i,j,k,l,m,n} + d^-_{1,j,m} - d^+_{1,j,m} = 2$

$\forall j \in B, m \in E,\ \ \sum_{i\in A}\sum_{k\in C}\sum_{n\in F} x_{i,j,k,1,m,n} + 2x_{i,j,k,2,m,n} + x_{i,j,k,3,m,n} + d^-_{2,j,m} - d^+_{2,j,m} = 2$

$\forall j \in B,\ \sum_{i\in T_1}\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} + d^-_{3,j} - d^+_{3,j} = 2$

$\forall j \in B,\ \sum_{i\in T_2}\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} + d^-_{4,j} - d^+_{4,j} = 2$

$\forall j \in B,\ \sum_{i\in T_3}\sum_{k\in C}\sum_{l\in D}\sum_{m\in E}\sum_{n\in F} x_{i,j,k,l,m,n} + d^-_{5,j} - d^+_{5,j} = 2$

vii) Non negativity

$x_{i,j,k,l,m,n} \ge 0$

$d^+_{1,j,m} \ge 0,\ d^-_{1,j,m} \ge 0,\ d^+_{2,j,m} \ge 0,\ d^-_{2,j,m} \ge 0,\ d^+_{3,j} \ge 0,\ d^-_{3,j} \ge 0,\ d^+_{4,j} \ge 0,\ d^-_{4,j} \ge 0,\ d^+_{5,j} \ge 0,\ d^-_{5,j} \ge 0$

viii) Objective function.

In this scheduling model the goal is to minimize the deviations on the soft constraints. Thus, the objective function is:

$$\min Z = w_1\left(\sum_j\sum_m d^+_{1,j,m}\right) + w_2\left(\sum_j\sum_m d^+_{2,j,m}\right) + w_3\left(\sum_j d^+_{3,j}\right) + w_4\left(\sum_j d^+_{4,j}\right) + w_5\left(\sum_j d^+_{5,j}\right)$$

In this study we use two weighted methods which are:

a. Same weight, no priority. The objective function is:

$$\min Z = \left(\sum_j\sum_m d^+_{1,j,m}\right) + \left(\sum_j\sum_m d^+_{2,j,m}\right) + \left(\sum_j d^+_{3,j}\right) + \left(\sum_j d^+_{4,j}\right) + \left(\sum_j d^+_{5,j}\right)$$

b. Weighted, with $w_1 = 60$, $w_2=40$, $w_3=10$, $w_4=20$, $w_5=10$. The objective function is:

$$\min Z = 60\left(\sum_j\sum_m d^+_{1,j,m}\right) + 40\left(\sum_j\sum_m d^+_{2,j,m}\right) + 10\left(\sum_j d^+_{3,j}\right) + 20\left(\sum_j d^+_{4,j}\right) + 10\left(\sum_j d^+_{5,j}\right)$$

By Solving model (a), the same weight priority, using LINGO 18.0 we get the solution is 5 with $d^+_{1,j,m} = 0$, $d^+_{2,j,m} = 0$, $d^+_{3,j} = 0$, , $d^+_{4,j} = 5$, and $d^+_{5,j} = 0$. Moreover, there are 29 variables whose value 1.

$x_{1,1,2,3,15,3}$ = the first course (Geometry) is scheduled on the first day (Monday) for parallel class 2 (B) on time period 3 (13.00 – 15.30) taught by lecturer 15 (Gusrian Putra, S.Si , M.Si) in room 3 (room F110).

The other variables with value 1 are: $x_{1,1,3,1,6,1}$, $x_{1,5,1,3,10,1}$, $x_{2,3,3,2,10,2}$, $x_{2,4,1,2,6,3}$, $x_{2,5,2,1,14,1}$, $x_{3,2,1,1,1,2}$, $x_{3,2,2,3,4,2}$, $x_{4,3,1,1,3,3}$, $x_{4,4,2,3,12,2}$, $x_{5,1,4,2,4,1}$, $x_{5,2,1,2,12,3}$, $x_{5,3,3,3,15,2}$, $x_{5,4,2,1,8,3}$, $x_{6,1,2,3,11,2}$, $x_{6,2,1,2,9,2}$, $x_{7,2,1,1,11,3}$, $x_{7,4,2,3,8,3}$, $x_{8,3,1,3,14,3}$, $x_{8,3,2,2,6,3}$, $x_{9,1,2,2,2,2}$, $x_{9,5,1,1,13,3}$, $x_{10,2,1,3,5,1}$, $x_{11,5,1,3,7,3}$, $x_{12,1,1,1,3,3}$, $x_{13,3,1,2,2,1}$, $x_{14,4,1,3,7,1}$, $x_{15,5,1,3,3,2}$ and $x_{16,4,1,2,5,1}$.

Therefore, using that result we can construct the following table:

Table. 4. The schedule obtained by using the same weight (no priority)

Day	**Time period**	**Course**	**Class**	**Room**	**Lecturer**
Monday	07.00 -09.30	Geometry	C	F108	Mira Mustika, S.Si., M.Sc.
		Matrix Theory	A	F110	Dr. Sri Efrinita Irwan, M.Si
	10.00-12.30	Complex Function	D	F108	Eristia Arfi, S.Si., M.Si.
		Introduction to Stochastic Process	B	F109	Triyana Muliawati, M.Si
	13.00-15.30	Geometry	B	F110	Gusrian Putra, S.Si., M.Si.
		Time Series Analysis	B	F109	Tiara Shofi Edriani, M,Si

Tuesday	07.00 -09.30	Introduction to Differential Equation	A	F109	Prof. Leo H Wiryanto, M.S.
		Finance Mathematics	A	F110	Tiara Shofi Edriani, M,Si
	10.00-12.30	Complex Function	A	F110	Nela Rizka, S.Pd., M.Si
		Analisis Deret Waktu	A	F109	Dani Al Mahkya, S.Si., M.Si
	13.00-15.30	Introduction to Differential Equation	B	F109	Eristia Arfi, S.Si., M.Si.
		Dynamical System	-	F108	Bonno Andri W, S.Si., M.Si.
Wednesday	07.00 -09.30	Algebraic Structure	A	F110	Dr. Sri Efrinita Irwan, M.Si
	10.00-12.30	Discrete Mathematics	C	F109	Aswan Anggun Pribadi, M.Si.
		Capita Selecta Statistics	-	F108	Triyana Muliawati, M.Si
		Advanced Optimization	B	F110	Mira Mustika, S.Si., M.Sc.
	13.00-15.30	Advanced Optimization	A	F110	Achmad Suryadi N.,S.Si, M.Si.
		Complex Function	C	F109	Gusrian Putra, S.Si., M.Si.
Thursday	07.00 -09.30	Complex Function	B	F110	Lutfi Mardianto, M.Si.
	10.00-12.30	Discrete Mathematics	A	F110	Mira Mustika, S.Si., M.Sc.
		Capita Selecta Applied Mathematics	-	F108	Dear Michiko Mutiara Noor, S.Si., M.Si.
		Algebraic Structure	A	F109	Nela Rizka, S.Pd., M.Si
	13.00-15.30	Finance Mathematics	B	F110	Lutfi Mardianto, M.Si.
		Capita Selecta Computation	-	F109	Dr. Rifky Fauzi
Friday	07.00 -09.30	Introduction to Stochastic Process	A	F110	Bonno Andri W, S.Si., M.Si.
		Discrete Mathematics	B	F108	Achmad Suryadi N., S.Si, M.Si.
		Geometry	A	F108	Aswan Anggun Pribadi, M.Si.
	13.00-15.30	Analysis 1	-	F110	Dr. Rifky Fauzi
		Capita Selecta Algebra	-	F109	Dr. Sri Efrinita Irwan, M.Si

From Table 4 we can see that by using no priority (all weights are the same), the schedule satisfies all hard constrained. However, for the soft constraints not all are satisfied, as shown in Table 5. From that table it shows that the first, second, third and fifth goals are satisfied, which means that all lecturers teach no more than two courses a day, no lecturers teach on a two consecutive time periods. The same results for the courses for fourth semester and eighth semester students where there are no more than two courses taught for fourth semester students and also for eighth semester students. For sixth semester students, because the courses are more than fourth semester and eighth semester lecture, then the preference to teach no more than two classes a day is not satisfied which can be seen on Monday.

Variabel deviasi	Information	Value
$\sum_j \sum_m d_{1,j,m}^+$	the value that holds the deviation that is above the target at the first goal	0
$\sum_j \sum_m d_{2,j,m}^+$	the value that holds the deviation that is above the target at the second goal	0
$\sum_j d_{3,j}^+$	the value that holds the deviation that is above the target at the third goal	0
$\sum_j d_{4,j}^+$	the value that holds the deviation that is above the target at the fourth goal	5
$\sum_j d_{5,j}^+$	the value that holds the deviation that is above the target at the fifth goal	0

Table 5. The value of deviation

By Solving model (b), using LINGO 18.0 with w_1 = 60, w_2=40, w_3=10, w_4=20, w_5=10., we get the following 29 variables whose value 1:

$x_{1,1,1,3,10,3}$, $x_{1,1,3,2,6,1}$, $x_{1,5,2,3,15,1}$, $x_{2,3,1,2,6,3}$, $x_{2,4,3,3,14,3}$, $x_{2,5,2,1,10,3}$, $x_{3,2,1,1,4,1}$, $x_{3,2,2,2,1,1}$, $x_{4,3,1,3,12,3}$, $x_{4,4,2,1,3,1}$, $x_{5,1,2,1,15,2}$, $x_{5,2,3,3,4,1}$, $x_{5,3,4,1,12,2}$, $x_{5,4,1,2,8,1}$, $x_{6,2,2\ 3,9,3}$, $x_{6,5,1,1,11,2}$,

$x_{7,1,22,11,2}$, $x_{7,3,1,3,8,2}$, $x_{8,4,1,2,6,2}$ $x_{8,5,2,3,14,3}$, $x_{9,2,2,1,2,2}$, $x_{9,3,1,2,13,2}$, $x_{10,2,1,2,5,3}$, $x_{11,1,1,1,7,1}$, $x_{12,4,1,3,3,2}$, $x_{13,5,1,1,2,1}$, $x_{14,4,1,3,7,1}$, $x_{15,2,1,3,3,2}$, $x_{16,3,1,3,5,1}$

By using this result we get the following table:

Table. 6. The schedule obtained by using different weight (w_1 = 60, w_2=40, w_3=10, w_4=20, w_5=10)

Day	Time period	Course	Class	Room	Lecturer
Monday	07.00 -09.30	Complex Function	B	F109	Gusrian Putra, S.Si., M.Si.
		Analysis 1	-	F108	Dr. Rifky Fauzi
		Geometry	C	F108	Mira Mustika, S.Si., M.Sc.
		Finance Mathematics	B	F110	Tiara Shofi Edriani, M,Si
	13.00-15.30	Geometry	A	F110	Aswan Anggun Pribadi, M.Si.
Tuesday	07.00 -09.30	Introduction to Differential Equation	A	F108	Eristia Arfi, S.Si., M.Si.
		Introduction to Stochastic Process	B	F109	Triyana Muliawati, M.Si
	10.00-12.30	Dynamical System	-	F110	Dear Michiko Mutiara Noor, S.Si., M.Si.
		Introduction to Differential Equation	B	F108	Prof. Leo H Wiryanto, M.S.
		Complex Function	C	F108	Eristia Arfi, S.Si., M.Si.
	13.00-15.30	Time Series Analysis	B	F110	Dani Al Mahkya, S.Si., M.Si
		Capita Selecta Algebra	-	F109	Dr. Sri Efrinita Irwan, M.Si
Wednesday	07.00 -09.30	Complex Function	D	F109	Nela Rizka, S.Pd., M.Si
	10.00-12.30	Introduction to Stochastic Process	A	F109	Bonno Andri W, S.Si., M.Si.
		Discrete Mathematics	A	F110	Mira Mustika, S.Si., M.Sc.
		Algebraic Structure	A	F110	Nela Rizka, S.Pd., M.Si
	13.00-15.30	Finance Mathematics	A	F109	Lutfi Mardianto, M.Si.
		Capita Selecta Applied Mathematics	-	F108	Dear Michiko Mutiara Noor, S.Si., M.Si.
Thursday	07.00 -09.30	Algebraic Structure	B	F108	Dr. Sri Efrinita Irwan, M.Si
	10.00-12.30	Complex Function	A	F108	Lutfi Mardianto, M.Si.
		Advanced Optimization	A	F109	Mira Mustika, S.Si., M.Sc.
		Discrete Mathematics	C	F110	Achmad Suryadi N, S.Si, M.Si.
	13.00-15.30	Matrix Theory	-	F109	Dr. Sri Efrinita Irwan, M.Si
		Capita Selecta Computation	-	F108	Dr. Rifky Fauzi
Friday		Time Series Analysis	A	F109	Tiara Shofi Edriani, M,Si
	07.00 -09.30	Discrete Mathematics	B	F110	Aswan Anggun Pribadi, M.Si.
		Capita Selecta Statistics	-	F108	Triyana Muliawati, M.Si
	13.00-15.30	Geometry	B	F108	Gusrian Putra, S.Si., M.Si.
		Advanced Optimization	B	F110	Eristia Arfi, S.Si., M.Si.

The result for different weight also produces the schedule which satisfies hard constraints. However, one soft constraint is not satisfied. This result is similar with the model with no priority, where fourth goal has deviation value 5 as shown in Table 5.

4. CONCLUSION

From the results and discussion above we can conclude that the goal programming can be used to solve the class scheduling problems. Based on the data of even semester 2020-2021 in Mathematics study Program ITERA, for two models designed, both produce a schedule which satisfy hard constraints, and both models also violate the soft constraints with same value of deviation on the fourth goal. This mean that the sixth semester student must have more than two courses in a day.

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