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AN INTEGER LINEAR PROGRAMMING APPROACH TO A UNIVERSITY COURSE TIMETABLING PROBLEM

Asma Adlina Ariffin[1], Syalina Sulaiman[2] and Nurul Liyana Abdul Aziz[3*]

Faculty of Computer and Mathematical Sciences (FSKM), UiTM Cawangan Negeri Sembilan, Kampus Seremban, Persiaran Seremban Tiga/1, Seremban 3, 70300 Seremban, Negeri Sembilan

[1]2018276616@student.uitm.edu.my, [2]2019415696@student.uitm.edu.my, [3*]liyana511@uitm.edu.my

(indicates the corresponding author)*

ABSTRACT

In this study, the problem of university course timetabling in a Mathematics Department in Faculty of Computer and Mathematical Sciences of UiTM Seremban was addressed. Integer Linear Programming (ILP) was used to solve the problem of allocating lecturers, student groups, and class meetings to defined timeslots, typically a week, while satisfying a variety of problem-specific constraints. University Course Timetabling Problem (UCTP) is tough to address due to the scale of the challenges and various severe hard and soft constraints. The timetabling process must be done for each semester often, which is an exhausting and time-consuming task. The allocation of events in timeslots and class meetings is performed by the UCTP process using the list of hard and soft limitations supplied in one semester, so that no conflict is generated in such allocations. In the UCTP, the hard constraints should not be breached under any conditions; the soft constraints, likewise, should not be violated as much as possible. Over the years, numerous approaches have been offered to address UCTP. The purpose of the study is to model the UCTP as an ILP problem; likewise, the model will then be solved using the Excel Solver.

Keywords*: Constaint, Integer Linear Programming, University Course Timetabling Problem.*

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1. Introduction

1.1 Background of Study

Timetabling is described as the work of allocating a series of activities (exams, courses, sports events, surgeries) and resources (exam proctors, instructors, athletes, sports officials, nurses, medical doctors) to space (exam halls, classrooms, sporting grounds, operating theatres) and time. It is a common issue in operations research and is used in various industries, including education in academic institutions such as schools, colleges, and universities (Chen et al., 2021). Several academicians are interested in solving this combinatorial optimization challenge. Hence, this study focuses on the University Course Timetabling Problem (UCTP).

Moreover, the standard definition of the UCTP was created by Ben Paechter and accepted by PATAT in 2002. It consists of a set of courses scheduled in 45-timeslots (5 days of 9 hours each), a group of rooms in which courses can take place, a group of students who attend the courses, and a set of features satisfied by rooms required by courses. Each student follows several courses, and each room has a maximum capacity. A solution is achieved when all courses have been assigned a timeslot and room (Berggren and Nielsen, 2018).

Several studies have been carried out on UCTP. In considering previous studies, Carter and Laporte (1998) divided this problem into five categories as follows:

- Course timetable: comprises the timetabling of existing courses in the curriculum of the university or colleges, according to the classrooms and lecturers' access.
- Lecturers' course timetabling: an intervention of the lecturers' programme is surveyed concerning the allocation of classrooms and courses.
- Student timetabling: the capacity of courses for each period is determined to select the duration.
- Assignment of lecturers: the lecturers are assigned to courses based on the relative timetable.
- Allocation of classrooms: the classrooms are allotted to the measures taken in the programme.

Regarding the five classes under consideration above, one or more plans are usually determined based on university course timetabling. Generally speaking, when the number of courses, classes, and lecturers is increased in UCTP, it becomes an NP-Hard problem. Solving this requires heuristic and metaheuristic algorithms (such as simulated annealing, genetic algorithms, or tabu search) (Carter and Laporte, 1998; Domenech and Lusa, 2015).

UCTP is regarded as one of the most intriguing difficulties confronting colleges. Yet some schedulers continue to design timetables manually using simple office software such as spreadsheets. Given the numerous constraints that must be met, this is a tremendously challenging task. Automating timetabling issues is a task that saves institutions a lot of effort and time and delivers ideal solutions by increasing the quality of education and services. The educational timetabling problem has been framed and solved using different analytic or heuristic techniques. However, applying the same solution to a problem is difficult because each institution has unique qualities and limitations (Arratia-Martinez et al., 2021).

Typically, institutions create the course timetable manually, which requires a significant amount of time and human resources each year. However, it may not be the best option, even if a realistic timeline is discovered. Nowadays, advances in the numerical sector, namely in operational research and artificial intelligence, have enabled cutting-edge tools for proposing optimal solutions to timetabling problems (Dive and Edouard, 2020). Based on that literature, this study aims to model the university course timetabling problem as an integer linear programming problem. The integer linear programming model will then be solved by using the Excel Solver. In addition, this study employs the model developed to solve UCTP in Malaysian university.

1.2 Problem Statement

In university, there are many issues regarding the conflict in timetable arrangement. All the conflicts should be effectively managed in order to create the optimal timetable. Lecturers, students' capacity, course, class size, and sometimes the number of courses in a day can all be sources of conflict. This study considered a UCTP in Mathematics Department, Faculty of Computer and Mathematical Sciences, UiTM Seremban for semester March to July 2022. An appropriate university course timetable has to consider several rules to avoid any issues. First of all, students, lecturers, and the class meeting are the three essential components of any course timetable. Criteria are connected with every element. The first means that a student group can only be allocated to one class meeting at a time. The second implies that if a lecturer gives more than one course, they should not overlap.

1.3 Objectives of Study

1. To model the university course timetabling problem as an integer linear programming problem.
2. To solve the integer linear programming model using Excel Solver.
3. To employ the model developed to solve university course timetabling problem in UiTM Seremban.

1.4 Scope and Limitation

This study focuses on modelling UCTP as an Integer Linear Programming (ILP) model. This ILP model will be employed to solve UCTP in a Malaysian university. The proposed mathematical model will aid in the department's current approach, in which a timetable is created to distribute course-lecturer timeslots, assisting in this difficult work and assuming a prior knowledge of the lecturers' availability. Moreover, the integer linear programming model will be solved using Excel Solver.

1.5 Significant of Study

This study provides the integer linear programming model for timetabling disciplinary courses for a Malaysian university. The use of this mathematical model is to create a timetable that helps to achieve the goal of meeting all requirements, at least for the study programme and the timeslots allotted for it. The models also allowed for the provision of information about potential lecturers (due to the fact that the current staff is unable to cover all of the available courses or sections). The classroom assignment is not carried out because of online distance learning. The timetable's section arrangement makes it simple for students to choose other basic courses to prevent conflicts. Despite the fact that it is a model with unique institution criteria, many limits may be useful in other scenarios of study. The timetable' s section arrangement also makes it easier for the lecturer to arrange their timetable. Moreover, understand that expanding the timetable construction for more than one department, or even the entire university, will necessitate taking into account varied timeslots and a variety of additional criteria.

2. Methodology

2.1 Definition of the Problem

The university course timetabling problem (UCTP) entails allocating a restricted number of timeslots to courses taken by a group of students taught by a specific lecturer. The task is carried out in such a way that no conflicts arise between students, and lecturers, while meeting a variety of constraints. The limits include university-imposed norms and policies, as well as lecturers and student preferences for the number of courses to be assigned to specific timeslots. Constructing a timetable is time-consuming, but producing a high-quality timetable is not. The task of creating a timetable is considerably more difficult. A high-quality timetable is one that can accommodate the user's preferences while taking into account all resource availability and conflict.

2.2 Construction of the Model

In this section an integer linear programming model is constructed for the university course timetabling problem. The following notation is needed to describe the model.

M = Set of class meetings

L =Set of lecturers

G= Set of student groups

T =Set of timeslots

M_{lec} =Class meetings that are taught by lecturer *lec*, $\forall lec \in L$

M_g =Class meetings that have the same group of students *g*, $\forall g \in G$

T_{break} =Timeslot for prayer and lunch break

T_{lec}=Timeslot for lecturer *lec*, $\forall lec \in L$ is not available

$P_{m,t,}$ =Preference of having class meeting *m* in timeslot *t*

Decision Variable

$$X_{m,t} = \begin{cases} 1, \textit{if a class meeting m is assigned to timeslot t} \\ 0, \quad \textit{otherwise} \end{cases} \qquad \forall m \qquad \forall t$$

Objective Function

$$\text{Maximise } \sum_m \sum_t P_{m,t} X_{m,t}$$

This study aims to optimise the allocation of class meetings to timeslots. The value of $P_{m,t,}$ depends on the lecturer. All the lecturers present different levels of preferences for the timeslots. In our model, these parameters reflect the priority of allocating classes to the desired timeslots. Integer values between scales 1 (least preferable) and 5 (most preferable) are used randomly to determine these preferences.

Constraints

In general, these characteristics are rules established by the institution that must be followed by the scheduler. In the literature, there are three main guidelines that are often employed in university course timetabling models. Completeness, in which each aspect of a course or unit must be assigned to a slot, avoidance of resource conflict (lectures, students, and rooms), and availability are among them. The following are all of the features for this model:

a) All class meeting must be assigned to a timeslot

$$\sum_t \sum_m X_{m,t} = 1 \qquad \forall m \qquad (1)$$

b) Availability of lecturer

$$\sum_{t \epsilon T_{lec}} \sum_{m \epsilon M_{lec}} X_{m,t} = 0 \qquad \forall lec\ \epsilon L \qquad (2)$$

c) Availability of timeslot

$$\sum_{t \epsilon T_{break}} X_{m,t} = 0 \qquad \forall m \qquad (3)$$

d) A lecturer cannot teach more than one class meeting at a time

$$\sum_{m \epsilon M_{lec}} X_{m,t} \leq 1 \qquad \forall t \qquad \forall lec\ \epsilon L \qquad (4)$$

e) A student cannot attend more than one class meeting at a time

$$\sum_{m \epsilon M_g} X_{m,t} \leq 1 \qquad \forall t \qquad \forall g\ \epsilon G \qquad (5)$$

Using these notations and features, the model for the UCTP can be written as:

$$Maximise \sum_m \sum_t P_{m,t} X_{m,t}$$

Subject to:

Constraint (1)-(5)

And $X_{m,t} \epsilon \{0,1\} \qquad \forall m \qquad \forall t$

2.3 Solution of the Model

There are various software that can be used to solve ILP such as AIMMS, AMPL, APMonitor, CPLEX, Excel Solver, LINDO, and others. This study will be using Excel Solver.

2.4 Flow Chart of the Study

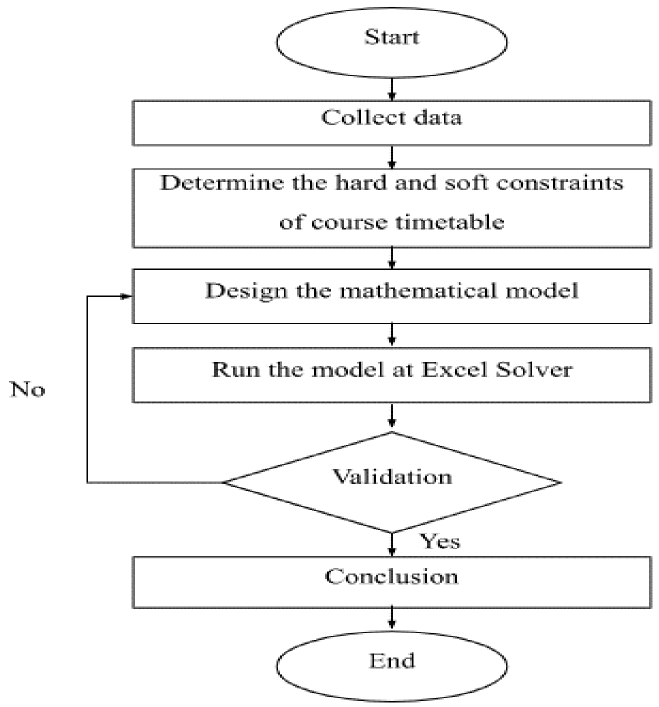

Figure 2.4 Flow chart of study

As illustrated in Figure 2.4, this study begins with obtaining data involving courses with lecturers who are in charge of it and also includes the group of students, which will be used as data input. Following that, soft limitations will be established, such as lecturers' time preferences, which will be taken into account when creating the timetable. The next step is to develop the integer linear programming model of the course timetable for this study and execute it using Excel Solver. If the results are satisfactory and there are no conflicts in the model, we may draw a conclusion about this model and conclude this study, but if not, we must redesign the integer linear programming model until it is suitable for usage.

2.5 Data Collection

This case is study taken from university course timetabling problem in Mathematics department in Faculty of Computer and Mathematical Sciences UiTM Seremban for semester March until July 2022. There are 28 different student groups led by 5 different lecturers for the course MAT491, which has a total of 27 different class meetings. Table 2.5.1 presents the class meeting for each lecturer and student group. For MAT 491, each group will be allocated 5 hours class meetings per week which will divided into three separate class meetings. The three class meetings consist of two 2-hour class meetings and one 1-hour class meeting. As can be seen in Table 2.5.1, each of the student group is expected to be present at a minimum of three of the weekly scheduled class meetings. Lecturer L1, L2 and L3 have three class meetings per week while L4 and L5 have nine class meetings per week.

Table 2.5.1: Class meetings for each lecturer and student group

Class Meeting	**Group**	**Lecturer**
M1, M2, M3	G1	L4
M1, M2, M3	G2	L4
M1, M2, M3	G3	L4
M1, M2, M3	G4	L4
M4, M5, M6	G5	L5
M7, M8, M9	G6	L3
M7, M8, M9	G7	L3
M7, M8, M9	G8	L3
M7, M8, M9	G9	L3
M7, M8, M9	G10	L3
M10, M11, M12	G11	L4
M10, M11, M12	G12	L4

M10, M11, M12	G13	L4
M10, M11, M12	G14	L4
M13, M14, M15	G15	L4
M13, M14, M15	G16	L4
M13, M14, M15	G17	L4
M13, M14, M15	G18	L4
M16, M17, M18	G19	L5
M16, M17, M18	G20	L5
M19, M20, M21	G21	L2
M22, M23, M24	G22	L5
M22, M23, M24	G23	L5
M22, M23, M24	G24	L5
M22, M23, M24	G25	L5
M25, M26, M27	G26	L1
M25, M26, M27	G27	L1
M25, M26, M27	G28	L1

Table 2.5.2 presents the 28 timeslots in a week. There are five working days and six timeslots on each of those days, with the exception of Friday, which only has four timeslots. The timeslots T4, T10, T16, T22 and T27 are not available for any class meeting since they are taken up by the lunch and prayer breaks that are allocated for both students and lecturers.

Table 2.5.2: The 28 timeslots in a week

<table>
<tr><th></th><th>8.00 -10.00</th><th>10.00 - 12.00</th><th>12.00 -13.00</th><th>13.00 -14.00</th><th>14.00 - 15.00</th><th>15.00 - 16.00</th><th>16.00 - 17.00</th><th>17.00 - 18.00</th></tr>
<tr><td>MON</td><td>T1</td><td>T2</td><td>T3</td><td>T4</td><td colspan="2">T5</td><td colspan="2">T6</td></tr>
<tr><td>TUE</td><td>T7</td><td>T8</td><td>T9</td><td>T10</td><td colspan="2">T11</td><td colspan="2">T12</td></tr>
<tr><td>WED</td><td>T13</td><td>T14</td><td>T15</td><td>T16</td><td colspan="2">T17</td><td colspan="2">T18</td></tr>
<tr><td>THU</td><td>T19</td><td>T20</td><td>T21</td><td>T22</td><td colspan="2">T23</td><td colspan="2">T24</td></tr>
<tr><td>FRI</td><td>T25</td><td>T26</td><td colspan="3">T27</td><td colspan="2">T28</td><td></td></tr>
</table>

Besides teachings, lecturers have many other commitments. Therefore, there are some timeslots that they are not available to attend the class meeting. Hence, the timeslots in which each lecturer is unavailable are generated randomly as in Table 2.5.3.

Table 2.5.3: Non-available timeslots for each lecturer

Lecturer	Non-Available Timeslots
L1	T1, T3 T6, T7, T12, T13, T18, T19, T24, T25, T28
L2	T1, T6, T7, T12, T13, T18, T19, T24, T25, T28
L3	T13, T14, T15, T17, T18, T19, T20, T21, T23, T24, T25, T26, T28

L4	T6, T8, T12, T18, T19, T20, T21, T23, T24, T28
L5	T6, T8, T12, T18, T19, T20, T21, T23, T24, T28

According to the information presented in Table 2.5.2, there are 19 2-hour timeslots which provided for only 2-hour class meetings and four 1-hour timeslots (T3, T9, T15, T21), for 1-hour class meeting within a week. The list of the timeslots for respective class meetings in this study are shown in Table 2.5.4.

Table 2.5.4: List of timeslots for respective class meetings

1-hour Class Meeting	**1-hour Timeslot**	**2-hour Class Meeting**	**2-hour Timeslot**
M1	T3	M2	T1
M4	T9	M3	T2
M7	T15	M5	T5
M10	T21	M6	T6
M13		M8	T7
M16		M9	T8
M19		M11	T11
M22		M12	T12
M23		M14	T13
		M15	T14
		M17	T17
		M18	T18
		M20	T19
		M21	T20
		M23	T23

		M24 M26 M27	T24 T25 T26 T28

3. Results and Discussions

3.1 Results and Discussions

For this problem, the ILP model for the course timetabling problem could be written as:

$$\text{Maximise} \sum_m \sum_t P_{m,t}, X_{m,t}$$

Subject to:

Constraint (1) – (5)

$$\text{and } X_{m\,t} \epsilon \{0,1\} \quad \forall m \; \forall t$$

The objective function of the model is to maximise the preferences of each lecturer. Based on the information gathered regarding the preferences of the lecturer, the majority of the classes were assigned during the lecturer's preferred timeslots, which were 5 and 4 (81.48% and 7.41%, respectively). Another 11.11% of all classes were assigned to timeslots for which the lecturers had indicated that they had "no preference." The conclusion that can be drawn from this is that the result that was achieved satisfies the preferences of each lecturer as well as the requirements of the model. Figure 3.1 shows the results for the lecturer preferences as percentages.

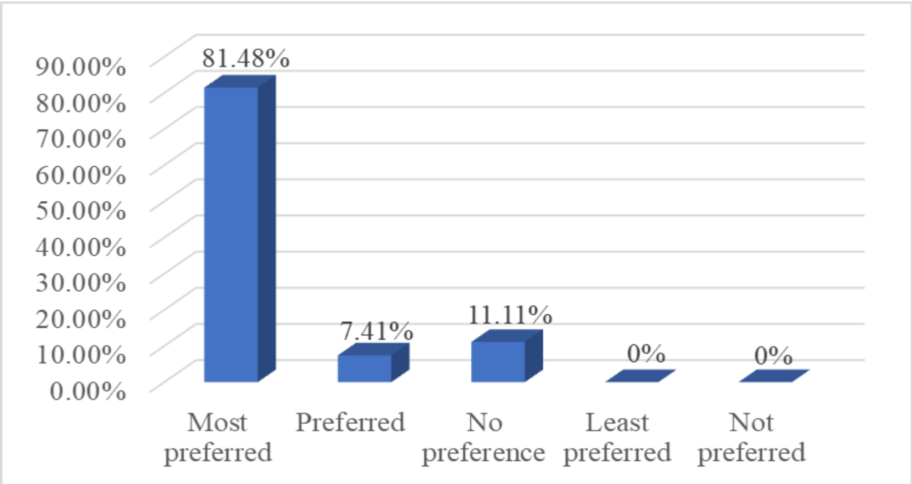

Figure 3.1: Overall percentage of timeslots matching lecturer preferences for model

The resulted timetable for the UCTP is presented in Table 3.1.

Based on Table 3.1, all 27 class meetings were assigned to specific timeslot with one lecturer for each class meeting. From Table 3.1, we can see that there are more than one class meetings for the same group and same lecturer assigned to the same day. For example, on Monday, M7 and M9 are assigned to T3 and T2, respectively. Both of these class meetings should be attended by L3 and student from G6, G7, G8, G9, and G10, which has a total of three consecutive hours class meeting on Monday. Since we only focus on five constraints, these class meeting are considered acceptable. There is no restriction for these kind of class meetings in our model.

Table 3.2: Table of class meetings and lecturers

	8.00-10.00	**10.00-12.00**	**12.00-13.00**	**13.00-14.00**	**14.00-15.00**	**15.00-16.00**	**16.00-17.00**	**17.00-18.00**
MON		M2 (L4), M9 (L3), M21(L2)	M7 (L3), M10(L4), M16(L5),		M27 (L1)			
TUE	M3 (L4)		M13(L4), M22(L5), M25 (L1)		M5 (L5), M26 (L1)		M8 (L3)	
WED	M15(L4) M23 (L5)	M17 (L5)	M1(L4), M4 (L5)		M12 (L4), M24 (L5)			
THU			M19 (L2)					

FRI	M14 (L4), M18 (L5)	M6 (L5), M11(L4) M20(L2)			

3.2 Model Verification

a) All class meeting must be assigned to a timeslot

Based on Table 3.2, we can see that all 27 class meetings are assigned to the respective timeslot. The result shows that this constraint is satisfied. There are 14 timeslots in which all the 27 class meetings have been assigned. There are fewer timeslots compared to the number of class meetings because there are different class meetings that have different lecturers and student groups that can be assigned to the same timeslots.

b) Availability of lecturer

Previously, Table 3.1.3 presents the non-available timeslots for each lecturer. For example, L4 and L5 will not be available at T6, T8, T12, T18, T19, T20, T21, T23, T24 and T28. From the resulted timetable in Table 3.2, it can be seen that, both of L4 and L5 are assigned to their available timeslots. There are none of them were assigned to T6, T8, T12, T18, T19, T20, T21, T23, T24 and T28.

c) Availability of timeslot

The availability of a timeslot for the class meeting to be assigned must also be considered. There are five timeslots which are not available and cannot be assigned to any of the class meetings. These are the timeslots for recess time, which is T4, T10, T16, T22, and T27. Table 3.2 shows that there is no class meeting assigned at T4, T10, T16, T22, and T27.

d) A lecturer cannot teach more than one class meeting at a time.

Table 3.2 shows that a lecturer only teaches one class meeting at a time. There is no timeslot that shows the lecturer teach more than one class meeting at the same time.

e) A student cannot attend more than one class meeting at a time

From Table 3.2, we can see that a student only attends one class meeting at a time. For example, M1, M2 and M3 that should be taken by G1, G2, G3 and G4 are assigned to different timeslots which are teach by the same lecturer. There is no condition where M1, M2 and M3 are overlapping.

As a conclusion, all five constraints in this study are satisfied. Besides, the objective function which is to maximise the preference of having class meeting *m* at timeslot *t* is equal to 127.

4. Conclusions and Recommendations

4.1 Conclusions

In conclusion, the study discussed an integer linear programming approach to a university course timetabling problem. Chapter 1 begins with an introduction to the background of the study, where it is about the timetabling that is being described generally. It then describes the specific study objectives, which consist of three: to model the university course timetabling problem as an integer linear programming problem, to solve the integer linear programming model using Excel Solver and to employ the model developed to solve UCTP in UiTM Seremban. Moreover, it contains the study’ s problem statement, scope and limitations, significance of the study, and definitions and terms.

Chapter 2 presents a background theory and a review of the literature that connects educational timetabling and the types of educational timetabling (which consists of three types: course timetabling, examination timetabling, and high school timetabling). In addition, it also contained the University Course Timetabling Problem (UCTP), which is the focus of the study, and several methods for solving the UCTP, including Genetic Algorithm (GA), Particle Swarm Optimization (PS), Simulated Annealing (SA), Graph Coloring, and Artificial Intelligence (AI). In the study, Integer Linear Programming (ILP) is the method that has been chosen. Chapter 2 then ended with a little bit of the conclusion literature review.

Chapter 3 provides the methodology and flow chart of the study. In this chapter, the ILP model for UCTP which consists of one objective function and five constraints are presented. Below are the constraints involved:

i. All classes must be assigned to a timeslot

ii. Availability of lecturer

iii. Availability of timeslot

iv. A lecturer cannot teach more than one class meeting at a time

v. A student cannot attend more than one class meeting at a time

Chapter 4 reports the results and discussion of this study. This study presents the UCTP in Mathematics Department, UiTM Seremban. There are 27 class meetings, 28 student groups, five lecturers and 23 available timeslots to be considered. Then it proceeds to describe the model verification where it discussed and concluded that all the constraints included in the study are satisfied.

Timetabling courses is an important activity in educational institutions; these must be assigned into appropriate timeslots for students, lecturers, and classroom meetings, reducing complaints. Even for big problems, university course timetabling problems (UCTP) can be solved with integer linear programming, even if the problem can be broken down into smaller, more manageable parts.

4.2 Recommendations

There are some suggestions for further research:

1. The fundamental issues in universities are the number, or perhaps hundreds, of class meetings that must be arranged within a finite number of resources. As a result, it is suggested that the difficulty be broken down into manageable parts.

2. To produce an accurate and better result, software with high performance may be utilised to calculate all constraints, whether minor, major, or unique data.

3. Future research may discuss how timetabling software is defined in this section as a collection of tools that work together in a digitized environment to improve timetabling systems.

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APPENDIX

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
1					G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	G22	G23	G24	G25	G26	G27	G28	L1	L2	L3	L4	L5
2	0	1	M1	T3	1	1	1	1																												1	
3	0	1	M1	T9	1	1	1	1																												1	
4	1	3	M1	T15	1	1	1	1																												1	
5	0	4	M2	T1	1	1	1	1																												1	
6	1	5	M2	T2	1	1	1	1																												1	
7	0	5	M2	T5	1	1	1	1																												1	
8	0	4	M2	T7	1	1	1	1																												1	
9	0	2	M2	T11	1	1	1	1																												1	
10	0	1	M2	T13	1	1	1	1																												1	
11	0	2	M2	T14	1	1	1	1																												1	
12	0	3	M2	T17	1	1	1	1																												1	
13	0	4	M2	T25	1	1	1	1																												1	
14	0	1	M2	T26	1	1	1	1																												1	
15	0	3	M3	T1	1	1	1	1																												1	
16	0	3	M3	T2	1	1	1	1																												1	
17	0	2	M3	T5	1	1	1	1																												1	
18	1	4	M3	T7	1	1	1	1																												1	
19	0	5	M3	T11	1	1	1	1																												1	
20	0	2	M3	T13	1	1	1	1																												1	
21	0	4	M3	T14	1	1	1	1																												1	
22	0	1	M3	T17	1	1	1	1																												1	
23	0	3	M3	T25	1	1	1	1																												1	
24	0	1	M3	T26	1	1	1	1																												1	
25	0	2	M4	T3					1																												1
26	0	4	M4	T9					1																												1
27	1	5	M4	T15					1																												1
28	0	3	M5	T1					1																												1
29	0	2	M5	T2					1																												1
30	0	1	M5	T5					1																												1
31	0	4	M5	T7					1																												1
32	1	5	M5	T11					1																												1
33	0	3	M5	T13					1																												1
34	0	1	M5	T14					1																												1
35	0	1	M5	T17					1																												1
36	0	3	M5	T25					1																												1
37	0	2	M5	T26					1																												1
38	0	1	M6	T1					1																												1
39	0	5	M6	T2					1																												1
40	0	3	M6	T5					1																												1
41	0	2	M6	T7					1																												1
42	0	1	M6	T11					1																												1
43	0	5	M6	T13					1																												1
44	0	2	M6	T14					1																												1
45	0	1	M6	T17					1																												1
46	0	4	M6	T25					1																												1
47	1	5	M6	T26					1																												1
48	1	3	M7	T3						1	1	1	1	1																					1		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
49	0	1	M7	T9						1	1	1	1	1																					1		
50	0	2	M8	T1						1	1	1	1	1																					1		
51	0	4	M8	T2						1	1	1	1	1																					1		
52	0	5	M8	T5						1	1	1	1	1																					1		
53	0	3	M8	T6						1	1	1	1	1																					1		
54	0	2	M8	T7						1	1	1	1	1																					1		
55	0	1	M8	T8						1	1	1	1	1																					1		
56	0	4	M8	T11						1	1	1	1	1																					1		
57	1	5	M8	T12						1	1	1	1	1																					1		
58	0	1	M9	T1						1	1	1	1	1																					1		
59	1	5	M9	T2						1	1	1	1	1																					1		
60	0	2	M9	T5						1	1	1	1	1																					1		
61	0	2	M9	T6						1	1	1	1	1																					1		
62	0	1	M9	T7						1	1	1	1	1																					1		
63	0	2	M9	T8						1	1	1	1	1																					1		
64	0	2	M9	T11						1	1	1	1	1																					1		
65	0	3	M9	T12						1	1	1	1	1																					1		
66	1	5	M10	T3											1	1	1	1																		1	
67	0	1	M10	T9											1	1	1	1																		1	
68	0	2	M10	T15											1	1	1	1																		1	
69	0	5	M11	T1											1	1	1	1																		1	
70	0	3	M11	T2											1	1	1	1																		1	
71	0	1	M11	T5											1	1	1	1																		1	
72	0	4	M11	T7											1	1	1	1																		1	
73	0	5	M11	T11											1	1	1	1																		1	
74	0	1	M11	T13											1	1	1	1																		1	
75	0	3	M11	T14											1	1	1	1																		1	
76	0	4	M11	T17											1	1	1	1																		1	
77	0	2	M11	T25											1	1	1	1																		1	
78	1	5	M11	T26											1	1	1	1																		1	
79	0	1	M12	T1											1	1	1	1																		1	
80	0	2	M12	T2											1	1	1	1																		1	
81	0	1	M12	T5											1	1	1	1																		1	
82	0	3	M12	T7											1	1	1	1																		1	
83	0	2	M12	T11											1	1	1	1																		1	
84	0	1	M12	T13											1	1	1	1																		1	
85	0	1	M12	T14											1	1	1	1																		1	
86	1	5	M12	T17											1	1	1	1																		1	
87	0	2	M12	T25											1	1	1	1																		1	
88	0	2	M12	T26											1	1	1	1																		1	
89	0	3	M13	T3															1	1	1	1														1	
90	1	5	M13	T9															1	1	1	1														1	
91	0	2	M13	T15															1	1	1	1														1	
92	0	2	M14	T1															1	1	1	1														1	
93	0	4	M14	T2															1	1	1	1														1	
94	0	1	M14	T5															1	1	1	1														1	
95	0	3	M14	T7															1	1	1	1														1	
96	0	1	M14	T11															1	1	1	1														1	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
97	0	3	M14	T13															1	1	1	1														1	
98	0	1	M14	T14															1	1	1	1														1	
99	0	4	M14	T17															1	1	1	1														1	
100	1	5	M14	T25															1	1	1	1														1	
101	0	4	M14	T26															1	1	1	1														1	
102	0	1	M15	T1															1	1	1	1														1	
103	0	5	M15	T2															1	1	1	1														1	
104	0	2	M15	T5															1	1	1	1														1	
105	0	3	M15	T7															1	1	1	1														1	
106	0	4	M15	T11															1	1	1	1														1	
107	1	5	M15	T13															1	1	1	1														1	
108	0	3	M15	T14															1	1	1	1														1	
109	0	2	M15	T17															1	1	1	1														1	
110	0	1	M15	T25															1	1	1	1														1	
111	0	4	M15	T26															1	1	1	1														1	
112	1	5	M16	T3																			1	1													1
113	0	2	M16	T9																			1	1													1
114	0	1	M16	T15																			1	1													1
115	0	2	M17	T1																			1	1													1
116	0	2	M17	T2																			1	1													1
117	0	3	M17	T5																			1	1													1
118	0	3	M17	T7																			1	1													1
119	0	4	M17	T11																			1	1													1
120	0	3	M17	T13																			1	1													1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
121	1	5	M17	T14																			1	1													1
122	0	2	M17	T17																			1	1													1
123	0	3	M17	T25																			1	1													1
124	0	4	M17	T26																			1	1													1
125	0	5	M18	T1																			1	1													1
126	0	1	M18	T2																			1	1													1
127	0	4	M18	T5																			1	1													1
128	0	5	M18	T7																			1	1													1
129	0	2	M18	T11																			1	1													1
130	0	5	M18	T13																			1	1													1
131	0	1	M18	T14																			1	1													1
132	0	3	M18	T17																			1	1													1
133	1	5	M18	T25																			1	1													1
134	0	3	M18	T26																			1	1													1
135	0	1	M19	T3																					1									1			
136	0	2	M19	T9																					1									1			
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138	1	5	M19	T21																					1									1			
139	0	3	M20	T2																					1									1			
140	0	4	M20	T5																					1									1			
141	0	4	M20	T8																					1									1			
142	0	2	M20	T11																					1									1			
143	0	1	M20	T14																					1									1			
144	0	2	M20	T17																					1									1			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
145	0	3	M20	T20																					1									1			
146	0	4	M20	T23																					1									1			
147	1	5	M20	T26																					1									1			
148	1	5	M21	T2																					1									1			
149	0	4	M21	T5																					1									1			
150	0	3	M21	T8																					1									1			
151	0	2	M21	T11																					1									1			
152	0	1	M21	T14																					1									1			
153	0	3	M21	T17																					1									1			
154	0	2	M21	T20																					1									1			
155	0	5	M21	T23																					1									1			
156	0	4	M21	T26																					1									1			
157	0	1	M22	T3																						1	1	1	1								1
158	1	3	M22	T9																						1	1	1	1								1
159	0	1	M22	T15																						1	1	1	1								1
160	0	2	M23	T1																						1	1	1	1								1
161	0	3	M23	T2																						1	1	1	1								1
162	0	4	M23	T5																						1	1	1	1								1
163	0	1	M23	T7																						1	1	1	1								1
164	0	3	M23	T11																						1	1	1	1								1
165	1	5	M23	T13																						1	1	1	1								1
166	0	1	M23	T14																						1	1	1	1								1
167	0	2	M23	T17																						1	1	1	1								1
168	0	1	M23	T25																						1	1	1	1								1

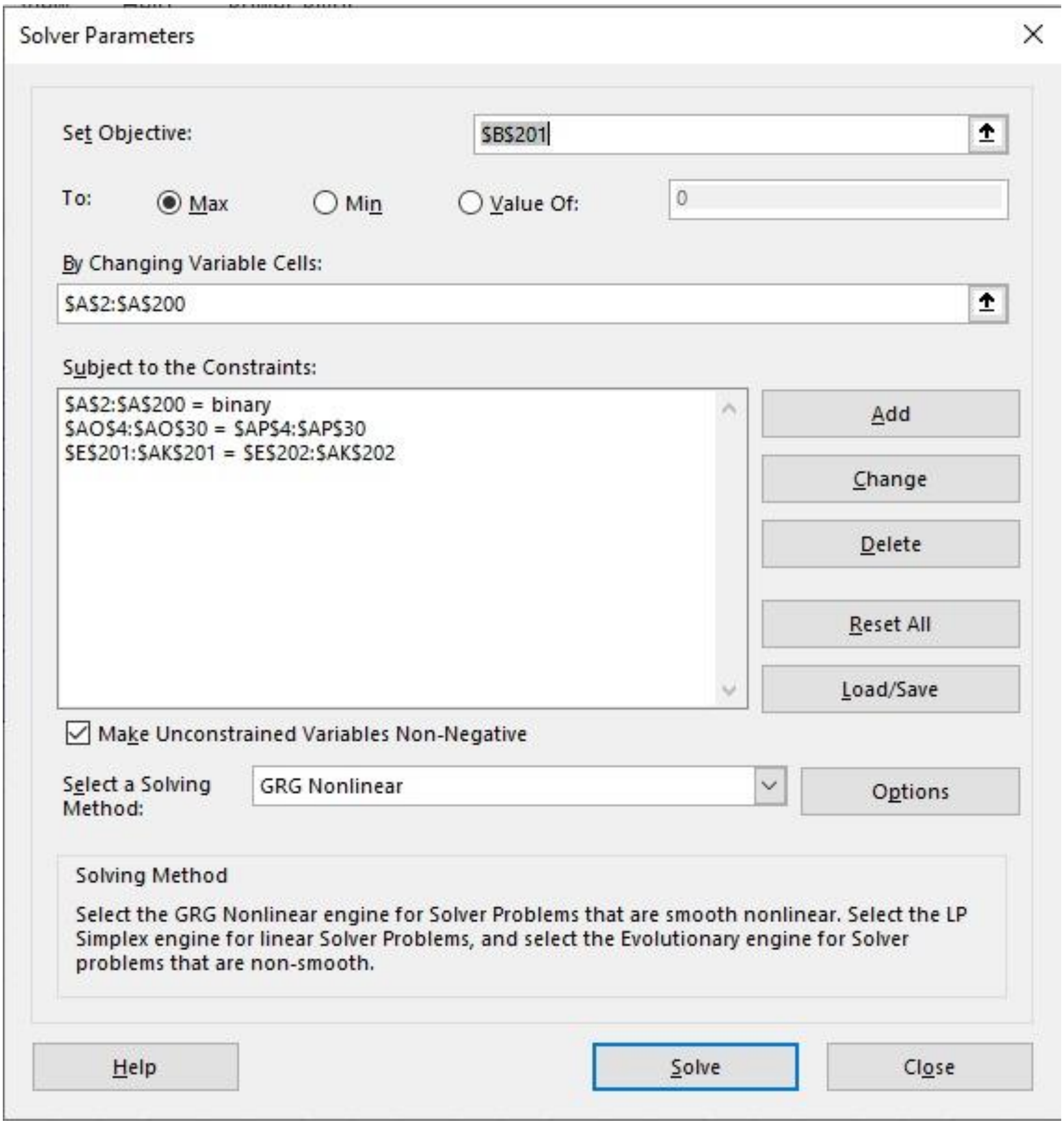
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
169	0	4	M23	T26																						1	1	1	1								1
170	0	3	M24	T1																						1	1	1	1								1
171	0	4	M24	T2																						1	1	1	1								1
172	0	2	M24	T5																						1	1	1	1								1
173	0	1	M24	T7																						1	1	1	1								1
174	0	1	M24	T11																						1	1	1	1								1
175	0	1	M24	T13																						1	1	1	1								1
176	0	3	M24	T14																						1	1	1	1								1
177	1	5	M24	T17																						1	1	1	1								1
178	0	2	M24	T25																						1	1	1	1								1
179	0	1	M24	T26																						1	1	1	1								1
180	1	4	M25	T9																										1	1	1	1				
181	0	3	M25	T15																										1	1	1	1				
182	0	2	M25	T21																										1	1	1	1				
183	0	3	M26	T2																										1	1	1	1				
184	0	2	M26	T5																										1	1	1	1				
185	0	3	M26	T8																										1	1	1	1				
186	1	5	M26	T11																										1	1	1	1				
187	0	4	M26	T14																										1	1	1	1				
188	0	2	M26	T17																										1	1	1	1				
189	0	3	M26	T20																										1	1	1	1				
190	0	1	M26	T23																										1	1	1	1				
191	0	2	M26	T26																										1	1	1	1				
192	0	3	M27	T2																										1	1	1	1				

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
192	0	3	M27	T2																										1	1	1	1				
193	1	5	M27	T5																										1	1	1	1				
194	0	4	M27	T8																										1	1	1	1				
195	0	3	M27	T11																										1	1	1	1				
196	0	2	M27	T14																										1	1	1	1				
197	0	1	M27	T17																										1	1	1	1				
198	0	2	M27	T20																										1	1	1	1				
199	0	3	M27	T23																										1	1	1	1				
200	0	3	M27	T26																										1	1	1	1				
201		127			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	9	9
202					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	9	9
203																																					
204																																					
205																																					

206	OBJECTIVE:	B201
207	VARIABLE	A2:A200
208	CONSTRAIN T1	A2:A200 binary
209	CONSTRAIN T2	E201:AK201 = E202:AK202
210	CONSTRAIN T3	AO3:AO29 = AP3:AP29

#there is only three constraint because the second constraint which is the availability of timeslot has already achieved by excluding the timeslot in the table. Also contraint 4 and 5 can be solved by combining it into one contraint because the condition for the constraint has the same meaning.

AM	AN	AO	AP	AQ
	M1	1	1	
	M2	1	1	
	M3	1	1	
	M4	1	1	
	M5	1	1	
	M6	1	1	
	M7	1	1	
	M8	1	1	
	M9	1	1	
	M10	1	1	
	M11	1	1	
	M12	1	1	
	M13	1	1	
	M14	1	1	
	M15	1	1	
	M16	1	1	
	M17	1	1	
	M18	1	1	
	M19	1	1	
	M20	1	1	
	M21	1	1	
	M22	1	1	
	M23	1	1	
	M24	1	1	
	M25	1	1	
	M26	1	1	
	M27	1	1	


Solver Parameters
Set Objective:
$B$201
To:
Max
Min
Value Of:
0
By Changing Variable Cells:
$A$2:$A$200
Subject to the Constraints:
$A$2:$A$200 = binary
$AO$4:$AO$30 = $AP$4:$AP$30
$E$201:$AK$201 = $E$202:$AK$202
Add
Change
Delete
Reset All
Load/Save
Make Unconstrained Variables Non-Negative
Select a Solving Method:
GRG Nonlinear
Options
Solving Method
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.
Help
Solve
Close