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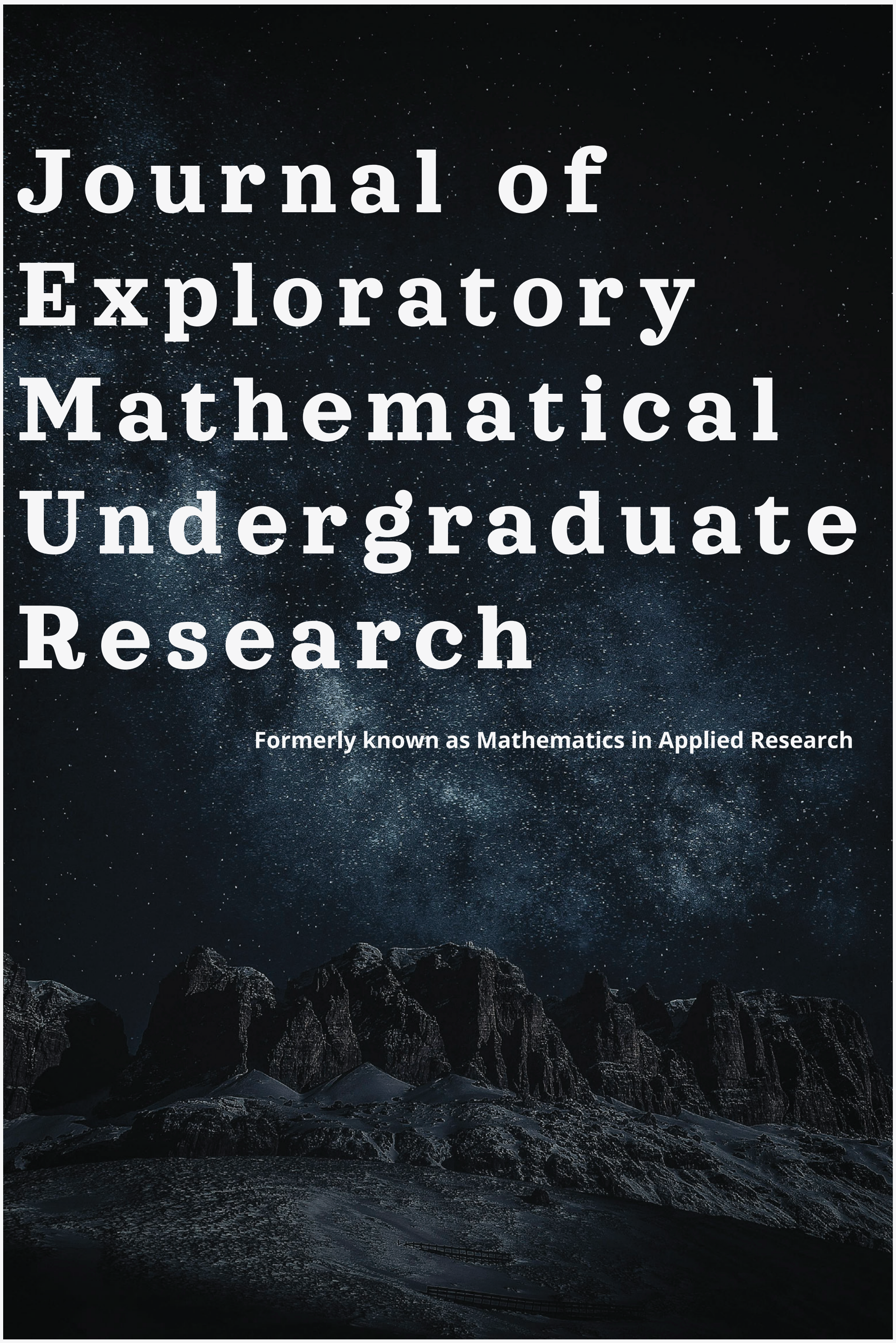

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MAXIMIZING TIMESLOTS PREFERENCE OF SCHOOL TIMETABLING PROBLEM USING INTEGER LINEAR PROGRAMMING

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Abstract

The school timetabling problem is a complex task that requires the allocation of resources and scheduling of classes to meet the preferences of both students and teachers. Integer linear programming (ILP) is proposed in this study where the objective is to generate a school timetable model while maximizing the timeslots preference of the school timetable using Excel solver. This study will demonstrate how well the ILP method works at generating the school timetable that maximizes the timeslots preference while complying with all the limitations. The school timetable data from a secondary school in Kedah is taken into consideration. The finding demonstrates that ILP technique can generate a timetable at the most preferred timeslot. As a result, the generated timetable by Excel Solver produced a school timetable without any clashes and all the class meetings are assigned to the most preferred timeslots.

Keywords: School timetabling problem, integer linear programming

1. Introduction

Educational is related to the process of education and providing knowledge while a school timetabling was defined as the assignment of teachers to groups of classes in a predefined number of timeslots in a predefined number of rooms (Tassopoulos et al., 2023). Creating a timetable was a recurring and complex problem in any academic institution. The goal was to build a feasible schedule for teaching activities by assigning teachers to rooms and periods (Muhlenthaler, 2015). The domain of secondary school timetabling was not well developed when compared to exam timetabling and university timetabling (Tan et al., 2021). As the evolution of the educational systems were continuous, new challenges often arise, requiring new models and solution methodologies. Over the years, a few methodologies have been developed to address secondary school timetabling problems. However, there were neither rigorous analyses nor comparative studies of these methodologies (Tan et al., 2021). Therefore, this study focused more on the school timetabling problem. Generally, this study will generate a feasible school timetable while maximizing the timeslots preference among the teachers by using integer linear programming (ILP). The main elements of school timetable are the students, teachers, class meetings and timeslots. The school timetable data from a secondary school in Kedah is taken into consideration.

2. Overview

Constraints in the school timetable are the requirements needed to develop a feasible timetable. This is a necessary step in the construction of a timetable. The constraints include rules issued by the school as well as demands of teachers and students for subjects to be scheduled within timeslots. There are two types of constraints: hard and soft. According to Hao et al. (2021), a good timetable is one that does not violate any hard restrictions, but a good timetable should first be feasible and then adhere to soft constraints as much as possible. The objective of the high school timetabling problem is to create a weekly schedule for classes, teachers, students, and classrooms that satisfies several hard and soft constraints. One example of a hard limitation is that a teacher cannot be assigned to more than one class during the same timeslot, while a soft constraint is that timeslots assigned to a teacher should be uniformly distributed throughout the week. The meeting pattern is one of several types of constraints. According to Aziz and Aizam (2018), the process through which classes are assigned is shown by meeting patterns. Thus, the following categories of school scheduling restrictions can be drawn from the literature:

Completeness: Timeslots must be allocated for each class meeting. The timetable must include tasks for the curriculum's course activities, including lectures, tutorials, and laboratories.

Conflict of resources: In a timeslot, there is no resource conflict. The term "resources" in this study refers to the teachers and student groups since the classroom had set out for each student group.

Availability of resources: This constraint involves the availability of teachers, spaces, students, and timeslots. For example, the teacher may be unavailable on a particular day or at specific timeslots.

Meeting patterns: This constraint specifies how the classes should be allocated and is typically based on the type of courses. There are different meeting patterns, which are listed as follows.

Based on Aziz and Aizam (2018), meeting patterns can be classified as follows:

a) Preferences for sessions (morning or afternoon timeslots)
b) Preferences for specific timeslots allocated for certain subjects.
c) Preferences for specific activities (break time, Zuhur prayer, and curriculum)
d) Preferences for compactness (consecutiveness)

According to Hoshino and Fabris (2020), school timetabling is a complex combinatorial optimization problem which requires for the best possible allocation of teachers, timeslots, and classrooms. In this study, the data has been taken from a secondary school in Kedah. It consists of list of subjects, groups, teachers, and timeslots. There are 18 teachers for 50 class meetings, teaching two different student groups and 35 timeslots.

Table 1: Timeslots in a week

	7.40-8.40	*8.40-9.40*	*9.40-10.10*	*10.10-11.10*	*11.10-12.10*	*12.10-1.10*	*1.10-2.10*
Sun	T1	T2	T3	T4	T5	T6	T7
Mon	T8	T9	T10	T11	T12	T13	T14
Tue	T15	T16	T17	T18	T19	T20	T21
Wed	T22	T23	T24	T25	T26	T27	T28
Thu	T29	T30	T31	T32	T33	T34	T35

Table 1 presents the 35 timeslots in a week. There are five working days and seven timeslots on each of those days. The timeslot of T1 is not available for any class meetings since all students and teachers were obliged to attend the assembly. Meanwhile, the timeslots of T3, T10, T17, T24 and T31 are unavailable for any class meetings since it is lunch break session. T21 also has been specifically assigned for NILAM activity only. Finally, the timeslots of T27 and T28 are not available for any class meeting because the co-curricular activities occurred.

3. Methodology

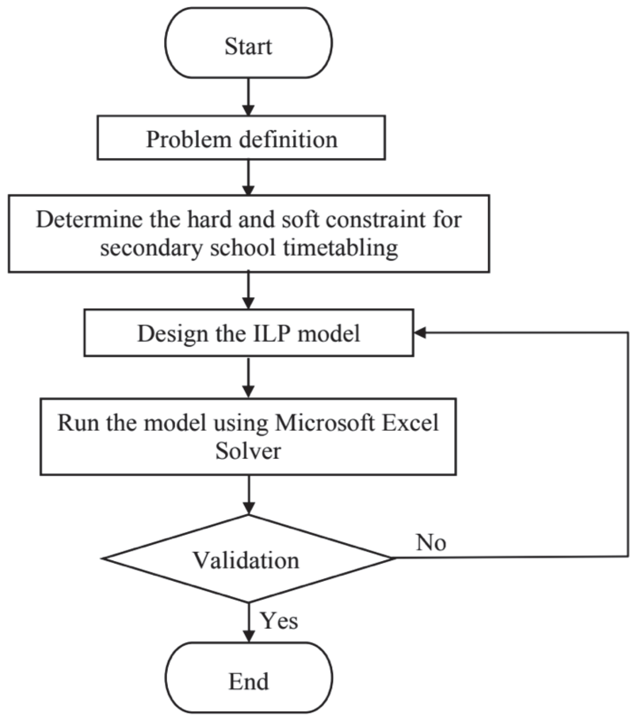

Figure 1:Flowchart of the research

As illustrated in Figure 1, this study started with problem definition. In this step, the data involving subjects, teachers who are teaching the subjects and a group of students will be collected as data input. Following that, soft limitations will be created, such as teachers' time preferences, which will be considered when creating the timetable. The next step was developed the integer linear programming model of the school timetable for this study and executed it by using Microsoft Excel Solver. Lastly, the model was validated by a timetabling problem in a secondary school in Kedah.

4. Integer Linear Programming Formulation

This study started with collecting the data involving subjects, teachers, and student groups, which will be used as data input. Following that, soft limitations such as teachers' time preferences will be considered when creating the timetable. In Zaulir et al. (2022), they have successfully constructed a university course timetabling model. The model was considered here with a little change to suit the school timetabling problem.

4.1. Notation

The following notation is needed to describe the model:

B	Set of class meetings
T	Set of timeslots
G	Set of student groups or class
C	Set of teachers
B_c	Class meetings that are taught by teacher c, $\forall c \in C$
B_g	Class meetings that have same group of students g, $\forall g \in G$
B_{theory}	Theoretical class meetings
B_{prac}	Practical class meetings
$T_{morning}$	Timeslot for theory class must be assigned in the morning
$T_{afternoon}$	Timeslot for practical class must be assigned in the afternoon
T_{break}	Timeslot for lunch break
T_c	Timeslot for teacher c, $\forall c \in C$ is not available
$P_{b,t}$	Preference of having class meeting b in timeslot t

4.2. Decision variable

$$X_{b,t} = \begin{cases} 1 & \text{if a class meeting } b \text{ is assigned to timeslot } t, \forall b\, \forall t \\ 0 & \text{otherwise} \end{cases}$$

4.3. Objective function

$$\text{Maximize} \sum_{b} \sum_{t} P_{b,t} X_{b,t}$$

The objective function of this study is to maximize the timeslots preference on the allocation of class meetings to timeslots. The value of the preference is based on the teacher. Different degrees of preference for the timeslots were expressed by each teacher. In this model, these parameters indicated the priority of allocating classes to the preferred timeslots. These preferences were determined at random using integer values between 1 (least preferred) and 5 (most preferred).

4.4. Constraints

According to Zaulir et al. (2022), there are three basic constraints commonly used in timetabling models found in the literature. One of them is completeness, where each subject must be allocated to a slot, along with availability and the prevention of resource conflicts (between teachers, students, and classrooms). The following were the constraints for this model:

a) All class meeting must be assigned to a timeslot:

$$\sum_{b} \sum_{t} X_{b,t} = 1 \, \forall b \tag{1}$$

b) Availability of teacher:

$$\sum_{b \in B_C} \sum_{t \in T_C} X_{b,t} = 0 \qquad \forall c \in C \tag{2}$$

c) Availability of timeslot:

$$\sum_{t \in T_{break}} X_{b,t} = 0 \qquad \forall b \tag{3}$$

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

$$\sum_{b \in B_C} X_{b,t} \leq 1 \qquad \forall b \qquad \forall t \quad \forall c \in C \tag{4}$$

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

$$\sum_{b \in B_g} X_{b,t} \leq 1 \qquad \forall b \qquad \forall t \quad \forall g \in G \tag{5}$$

f) Theoretical class must be schedule in morning session:

$$\sum_{t \in T_{morning}} X_{b,t} = 1 \qquad \forall b \in B_{theory} \tag{6}$$

g) Practical class must be schedule in the afternoon session:

$$\sum_{t \in T_{afternoon}} X_{b,t} = 1 \quad \forall b \in B_{prac} \tag{7}$$

Constraint (1) ensures that all class meetings are assigned to the respective timeslots while Constraint (2) will restrict the assignments of the certain class meetings at certain timeslots due to the unavailability of the related teacher. For Constraints (3), some timeslots such as break time are unavailable for the assignment of any class meeting. Constraint (4) and Constraint (5) are related to the conflict of the resources. Teachers and students should not attend more than one class meeting in any timeslot. Lastly, Constraint (6) and Constraint (7) are the additional constraints that need to be satisfied as much as possible.

5. Results and Discussion

Table 2 and Table 3 show that there is no class meeting during break and all students have only one class meeting per timeslot. It is clearly stated that none of the class meetings were assigned to the unavailable teachers' timeslots. For example, "BM" teacher for Class A was not available from 7:40 to 8:40 a.m., which are at T8, T15, T22, T29. As a result, in Table 2, BM was successfully assigned at T4, T16, T25 and T32 where the teacher are available. Next, all theoretical class meetings (green) are assigned in the morning session (7:40 a.m. to 11:10 a.m.) while all practical class meetings (blue) are assigned in the afternoon session (11:10 a.m. to 2:10 p.m.) which satisfied constraint (6) and (7).

Table 2: Generated timetable of Class A

	7.40-8.40	*8.40-9.40*	*9.40-10.10*	*10.10-11.10*	*11.10-12.10*	*12.10-1.10*	*1.10-2.10*
Sun	PER	BI	B	BM	SC	GEO	RBT
Mon	BI	SEJ	R	PI	PSV	SC	RBT
Tue	PJPK	BM	E	PI	MAT	GEO	NILAM
Wed	SEJ	BI	A	BM	MAT	KO	KO
Thu	PJPK	PI	K	BM	SC	PSV	MAT

Table 3: Generated timetable of Class B

	7.40-8.40	*8.40-9.40*	*9.40-10.10*	*10.10-11.10*	*11.10-12.10*	*12.10-1.10*	*1.10-2.10*
Sun	PER	PI	B	BM	RBT	MAT	SC
Mon	PI	SEJ	R	BI	GEO	SC	RBT
Tue	PJPK	BM	E	BI	PSV	MAT	NILAM
Wed	SEJ	PI	A	BM	GEO	KO	KO
Thu	PJPK	BM	K	BI	PSV	SC	MAT

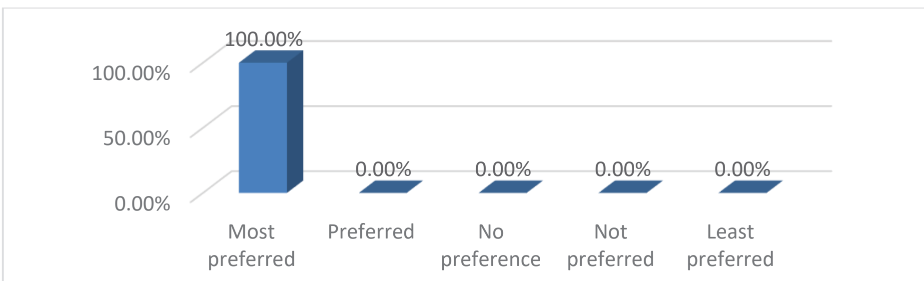

Figure 2: Overall percentage of timeslots matching teacher preferences problem

The objective function of the model was to maximize the timeslot preferences of each teacher. Based on the results obtained, all 50 class meetings for Class A and Class B were assigned to the timeslots with 5 as its value. This shows that 100% of the class meeting were assigned to the most preferred timeslots as in Figure 2. This ILP approach satisfies all the timeslot preferences and restrictions.

6. Conclusion

The main objective of this study was successfully achieved by generating a feasible secondary school timetable model based on ILP. The model was beneficial in determining the constraints that bind the scheduling problem and potential simplifications. In this study, generating a feasible timetable was difficult to avoid clashes between resources due to many class meetings for students to attend. Therefore, the preferences and other objective factors such as timeslot and teacher preferences throughout the week can be considered as objective criteria in the optimisation model. This ILP model consists of seven constraints, and the objective function is to maximize the timeslots' preference of a secondary school timetable using the Excel Solver. Based on the information gathered regarding the teachers' preferences, all 50 class meetings for Class A and Class B were allocated to the desired timeslots with a preference of five.

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