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YST030 - OPTIMIZING SCHOOL EXAMINATION TIMETABLES WITH INTEGER LINEAR PROGRAMMING

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ABSTRACT

Scheduling school examinations is a complex and time-consuming process which often required school administrators to manually arrange numerous subjects across limited period or timeslots while avoiding student and resource conflicts. This study addresses the School Examination Timetabling Problem (SETP) by developing an optimization model using Integer Linear Programming (ILP) to create efficient and conflict free examination schedules. The study utilizes real data from a secondary school in Kelantan and applies the ILP model using Microsoft Excel's Solver. The data consist of the timetabling of 28 examinations, each with a duration ranging from 1 to 2.5 hours, for three students' classes over nine days. The study develops an ILP model with the objective function to maximize the effective allocation of examination hours while considering two hard constraints and one soft constraint. All examinations are scheduled exactly once and the limit number of examinations per day are considered as the hard constraints in this study. For a more convenient examination timetable, the soft constraint includes grouping certain examinations on the same day. Results demonstrate the applicability of ILP in examination timetabling problem especially in school and offers a practical solution that can be adapted by other academic institutions facing similar scheduling challenges.

Keywords – School Examination Timetabling Problem (SETP), Integer Linear Programming (ILP), Microsoft Excel's Solver

INTRODUCTION

According to Güler and Geçici (2020), examination timetabling is an inevitable problem of educational establishments. Integer Linear Programming (ILP) demonstrates strong capabilities to automate this process by emerging as a powerful optimization tool. Research demonstrates that ILP serves as a mathematical modelling method which transforms restrictions and business targets into linear formulas for optimizing decision outcomes (Jamaluddin & Aizam, 2017). The application of ILP in school examination timetabling helps administrators create linear mathematical models which lead to the identification of optimal examination arrangements throughout the timetable. Besides, ILP offers user-friendly features that expedite the resolution of timetabling problems.

OBJECTIVE

The objectives of this study are:

i. To optimize the school examination timetabling problem using integer linear programming model.
ii. To solve integer linear programming model using Microsoft Excel's Solver.

SCHOOL EXAMINATION TIMETABLING PROBLEM

Table 1 presents 28 examinations and their respective durations, which range from 1 to 2.50 hours. The allocation of examinations to three different classes (4SN, 4SK, and 4AK) are shown too. This table serves as a reference to schedule examinations according to the time available and the constraints relating to the examination timetable. This examinations data are taken from a secondary school in Kelantan.

Table 1: List of examinations and its duration

Examination	Subject	Duration (Hour)	4SN	4SK	4AK
E1	Bahasa Melayu 1	2	/	/	/
E2	Bahasa Melayu 2	2.5	/	/	/
E3	Bahasa Inggeris 1	1.5	/	/	/
E4	Bahasa Inggeris 2	1.5	/	/	/
E5	PJPK	1	/	/	/
E6	Pendidikan Islam	2.5	/	/	/
E7	Tasawwur Islam	2.5		/	
E8	Sejarah 1	1	/	/	/
E9	Sejarah 2	2.5	/	/	/
E10	Matematik 1	1.5	/	/	/
E11	Matematik 2	2.5	/	/	/
E12	Matematik Tambahan 1	2	/		
E13	Matematik Tambahan 2	2.5	/		
E14	Sains Komputer	2.5		/	
E15	Kesusasteraan Melayu	2.5			/
E16	Sains 1	1.25		/	/
E17	Sains 2	2.5		/	/
E18	Fizik 1	1.25	/		
E19	Fizik 2	2.5	/		
E20	Kimia 1	1.25	/		
E21	Kimia 2	2.5	/		
E22	Ekonomi 1	1.25			/
E23	Ekonomi 2	2.25			/
E24	Prinsip Perakaunan 1	1.25			/
E25	Prinsip Perakaunan 2	2.5			/
E26	Biologi 1	1.25	/		
E27	Biologi 2	2.5	/		
E28	Reka Cipta	2.5		/	

The examination schedule spans a total of nine days, with each examination allocated to specific days to optimize the examination flow. The common examination, which is the examination taken by all students, will be set over the first four days. The examination includes E1 to E6 and E8 to E11. The remaining five days will be used for the elective examinations. These examinations pertain to certain classes or groups of students, so they are scheduled after the common examinations to ensure there is no overlap. The

examining structure makes sure that all examinations, either common or elective, are placed well in the schedule, avoiding conflicts and ensuring smooth examinations for all students.

ILP FORMULATION

These models effectively incorporate three key constraints critical to solving the school examination timetabling problem, particularly in secondary schools. Before the model is discussed in detail, some notations used are introduced.

Set of examination (E) : $\{E1, E2, \dots, E28\}$
Set of common examination (E_c) : $\{E1, E2, E3, E4, E5, E6, E8, E9, E10, E11\}$
Set of elective examination (E_e) : $\{E7, E12, E13, E14, E15, E16, E17, E18, E19, E20, E21, E22, E23, E24, E25, E26, E27, E28\}$
Set of days : $\{D1, D2, \dots, D9\}$
Duration of each exam : $\{H_{E1} = 2, H_{E2} = 2.5, \dots, H_{E28} = 2.5\}$

Decision variable, $X_{Ei,Di} = \begin{cases} 1, \text{if an examination Ei is aasigned to a day, Di} \\ 0, \text{ otherwise} \end{cases}$

Objective function

$$\text{Max } Z = \sum H_{E1} X_{Ei,Di}$$

Subject to

Constraint 1: All examinations must be assigned once

$$\sum_{D1}^{D4} X_{Ei,Di} = 1 \qquad \forall Ei \in E_c$$

$$\sum_{D5}^{D5} X_{Ei,Di} = 1 \qquad \forall Ei \in E_e$$

Constraint 2: The maximum number of examinations per day

$$\sum_{\mathrm{E_c}} X_{Ei,Di} \leq 3 \qquad \text{for D1, D2, D3, D4}$$

$$\sum_{\mathrm{E_e}} X_{Ei,Di} \leq 5 \qquad \text{for D5, D6, D7, D8, D9}$$

Constraints 3: Some examinations should be scheduled on the same day

$$X_{Ei,Di} - X_{Ej,Di} = 0 \qquad Ei, Ej \in E$$

RESULTS AND CONCLUSION

This study optimized the school examination timetabling problems by using Microsoft Excel's Solver, hence satisfying defined constraints. Figure 1 shows the generated examination timetable. The ILP method succeeded in satisfying all three constraints, such that all examinations must be assigned (Constraint 1), which means that every examination was assigned to a valid timeslot, and no examination has been left unassigned.

Constraint 2 limits the number of examination sittings per day and is also adhered to. Specifically, during the first four days of common examinations, no more than three examinations were scheduled per day, while in the following five days of elective examinations, the schedule allowed up to five examinations per day. It is to ensure that students are not overburdened with too many examinations on a given day, thus keeping the schedule manageable.

Day	8.00	9.00	10.00	11.00	12.00	1.00	2.00
1	E8 1 Hour				E9 2.50 Hours		
2	E10 1.50 Hours				E11 2.50 Hours		
3	E1 2 Hour				E2 2.50 Hours		
4	E3 1.50 Hours		E5 1 Hour		E4 1.50 Hours		
5	E6 2.50 Hours				E7 2.50 Hours		
					E15 2.50 Hours		
6	E16 1.25 Hours				E17 2.50 Hours		
	E18 1.25 Hours				E19 2.50 Hours		
7	E20 1.25 Hours				E21 2.50 Hours		
	E22 1.25 Hours				E23 2.25 Hours		
8	E12 2 Hour				E13 2.50 Hours		
					E14 2.50 Hours		
9	E24 1.25 Hours				E25 2.50 Hours		
	E26 1.25 Hours				E27 2.50 Hours		
					E28 2.50 Hours		

Figure 1: Generated school examination timetable

Furthermore, the model adhered to Constraint 3, which is that some examinations should be scheduled on the same day, which was achieved by scheduling related examinations on the same day. For example, E1 and E2 were scheduled on the same day. This ensures consistency in the subject matter since both examinations are focused on the same language, allowing students to experience a continuous testing environment.

In conclusion, the optimization process successfully satisfied the three constraints, leading to the establishment of an ILP technique for examination timetabling in educational institutions.

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