Research Article

Solving the Course - Classroom Assignment Problem for a University

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Abstract

A large number of courses and the different classroom capacities with difference in study periods make the assignment between classrooms and courses complicated. The scheduler always takes long time to solve the problem. The purpose of the study is to develop mathematical model and design methods to solve the problem. The assignment problem uses the information from the Faculty of Engineering and Industrial Technology at Silpakorn University in the first semester, 2012. Excel's Premium Solver is applied in this study. It was found that Excel's Premium Solver can solve this classroom allocation problem with the process time in seconds. The total cost was reduced 27,920 baht / semester.

Key Words: Classroom timetable; Integer linear programming

Introduction

Nowadays an officer of Faculty of Engineering and Industrial Technology has primary responsibility for doing the timetable scheduling before a semester starts. The timetables are prepared manually which is a high time-consuming process since a scheduler has to concern limitations. For example, the classroom capacity should be compatible with the number of enrolled students in each course. The scheduler expects that each course should be assigned a classroom. The increasing number of students, a large number of courses and the different classroom capacities make the assignment complicated. The scheduler usually takes time at least one week to solve the problem. Furthermore, cost is another important factor. The faculty spends approximately five hundred thousand baht a year for the classroom cost. Consequently, this study presents a guideline to improve the solutions for classroom allocation problem and the goal is to assign courses to classrooms to minimize the cost.

The university timetabling problem is defined as the process of assigning university courses to specific time periods throughout the five working days of the week and to specify classrooms suitability for the number of registered students and the requirements of each course. In practice, there are three main steps. First, each department processes the lecturers and course assignment depending on their skills and experience. In this step, the balancing load is considered based on the department policy. The second step is that the department will specify the day and study period in that day based on the lecturer and students' availability. Finally, in the

third step all the information of each department will come together to the scheduler for assigning all courses to the suitable classrooms. Since the courses are different in period, it is complicated for the scheduler. For example, the course 612 410 is set in 8:30 - 9:20 period, the course 615 451 is set in 8:30 - 11:10 period and the course 618342 is set in 9:25-12:05 period. This shows that the length of each period, the duration and the starting time are all different.

This paper focuses on the third step, i.e. assigning the courses to the classrooms in order to minimize cost. This study develops a mathematical model to solve the courses - classrooms assignment problem. The data input required in the model consists of the number of courses, the number of enrolled students in each course and the capacity of each classroom. The classrooms have the different costs which depend on the number of seats or classroom capacity with the higher expense for the larger-size classrooms. The objective of the model is to minimize cost. Integer Linear Programming is applied and solved by the computer program with Premium Solver for Excel software.

Theory and Literature Review

Integer Linear Programming (ILP)

Optimization problem is the problem involving one or more decisions with restrictions. A goal or an objective is considered. The objective is represented by an objective function which identifies the function of the decision variables. The decision maker may want to either maximize or minimize the objective e.g. minimizing cost and maximize profit. The constraint is represented in a mathematical model, e.g. $f(x_1,x_2,..,x_n) \leq b$, $f(x_1,x_2,..,x_n) \geq b$ (Ragsdale et al., 2004).

Linear programming (LP) involves an optimization problem with linear objective functions and linear constraints. LP model has three basic components (Taha, 2003).

1) Objective of goal that is aimed to optimize the problem.

2) Constraints or restrictions that are needed to satisfy, for example a limited amount of raw materials or labors.

3) Decision variables or the solutions, the non-negativity restrictions accounting for this requirement.

Integer linear programming (ILP) is linear programming in which some or all the variables are restricted to integer value.

Assignment Problem

An assignment problem is a special case of a transportation model in which the workers represent the sources and the jobs represent the destinations (Ragsdale et al., 2004) e.g. the resource allocation of labors, equipments or machine to workplaces.

The course time tabling problem is an assignment of courses to classrooms and time slots with restrictions in order to minimizing cost.

Literature Review

There are two major approaches to solve the university timetabling problems as instance of the discrete constrained optimization problem. The second approach involves some local search method such as the GA or SA and other heuristics and also a Hybrid Algorithm (Gunawan et al., 2007). Sarin et al. (2010) developed the integer programming formulation for a university-timetabling problem with the objective minimizing the total distance traveled by the lecturer from their offices to the classroom. Oladokun and Badmus (2008) studied about assigning a number of courses to classrooms taking into consideration constraints like classroom capacities and university regulations and using Integer linear programming (ILP) to solve the problem. Daskalaki et al. (2004) proposed ILP of the problem with consider the preferences regarding teaching periods or days of the week.

Research Methodology

1. Interviewing the scheduler and gathering the information as data input for the mathematical model as follows:

- The courses of all departments opened in the first semester in year 2012 of the Faculty of Engineering and Industrial Technology.
- Classroom capacity, classroom rate.

2. Designing the solving method and the mathematical model.

3. Running Premium Solver for Excel software.

4. Comparing the solution to the previous results.

Problem Statement

This is an assignment of courses to the classrooms where the number of the registered students and the period time of each course are known. The day and period in that day are already specified in each course based on the lecturer and students' availability as shown in Table 1. The number of the students in a course is varied which depends on the number of registered students. There are *i* courses and *j* class rooms. The capacity of each class room is known. The cost of each classroom depends on its capacity. Cost of classroom is money charge by the Faculty of Engineering or the other faculties due to classroom utilization.

This research intends to solve the problem where all courses must be assigned to classrooms. Each class room in a period must be used for only one course. The class room capacity is compatible for the number of students.

1. The proposed method

1) The data such as courses and period of each course was collected. Table 1 shows the collected data. It was found that some courses had already been specified the classrooms. For example, room no. T.144-6 was booked for course 618 342 on Tuesday at 9:25-12:05.

2) There were 115 courses. The courses were grouped by date, Monday to Friday. Then the courses were sorted by the period.

3) The sorted courses of each day were grouped by the time. The courses were sorted by time which consisted of the time before lunch and time after lunch as seen in Table 1. It was found that the courses were dissimilar in period.

For example 8:30 - 9:20 had one study period and 8:30 -11.10 had two study periods. The idea of the assignment is to assign the long study period first then assigning the courses which have shorter study period in order to fill the empty period after the long courses were assigned.

Table 1 The courses on Tuesday

	Code	No. Student	Period	Class room
1	612410	101	8.30-9.20	Meeting
2	615451	45	8.30-11.10	
3	615321	39	8.30-11.10	
4	618342	125	9.25-12.05	T.144-6
5	619351	82	9.25-12.05	T.137
6	619441	53	9.25-12.05	
7	619452	80	9.25-12.05	
8	615 211	45	9.25-12.05	
9	615 231	40	9.25-12.05	
10	611 201	169	9.25-12.05	Meeting
11	612 332	186	9.25-12.05	SR.1201
12	614392	57	9.25-12.05	
13	614201	80	9.25-12.05	
14	619441	65	13.00-15.40	

4) In each step of the assignment, a mathematical model was used to find the solution. The process started with the courses having longer than 2 study periods as the input for a mathematical model. Then the available classroom was updated based on the solution from the previous run. Then the courses which had shorter study period were assigned to the empty period by the mathematical model.

5) Finally, the assignment step no.3-4 was applied for the other days.

2. Mathematical Model

The mathematical model presented the model solving the problem in each day within one time. This is the generalized assignment problem with objective minimizing cost. The mathematical model presented below determines which course $\{i = 1,\ldots,I\}$ has to be assigned to a classroom $\{j=1,\ldots,J\}$. The model uses a binary decision variable (x_{ij}),

The integer linear programming problem for this problem will be defined using the following notations:

Indices

i = Course , i = 1, 2, …, I

j = Class room , j = 1, 2, …, J

p = study period , p = 1, 2, …, P

Parameters

V_j = Capacity of class room j

N_i = The registered student of course i

Sp_{ip} = The study period p of each course i

C_j = Classroom Cost per period j

Np_i = The number of period of each course i

1) Decision Variables

$$X_{ij}=\begin{cases}1 & \text{if course i taught in classroom } j\\ 0 & \text{otherwise}\end{cases}$$

2) Objective Function

Minimizing Classroom cost

$$Min\ Z = \sum_{i=1}^{I}\sum_{j=1}^{J} C_j Np_i X_{ij}$$

3) Constrained

$$N_i X_{ij} \leq V_j \qquad ;\forall_i,\forall_j \qquad (1)$$

Constraint 1 shows the capacity limits. The number of students in each class rooms has to be less than classroom capacity.

$$\sum_{i=1}^{I} Sp_{ip} X_{ij} \leq 1 \qquad ;\forall_j,\forall_p \quad (2)$$

Constraint 2 forces all classrooms to be assigned to at least one course.

$$\sum_{j=1}^{J} X_{ij} = 1 \qquad ;\forall i \quad (3)$$

Constraints 3 represents that all courses have to be assigned in the timetable.

Result and Conclusion

To test the improvement of the solution obtained from the mathematical model by Excel'Premium Solver for Excel software, the courses of the Faculty of Engineering and Industrial Technology at Silpakorn University in the first semester, 2012 were applied. An example of the course - classroom assignment problem on Monday is presented in this topic. Table 2-3 provides the example of data applied in the problem. The solver setting is applied to solve this problem as shown in Figure 1. Excel's Premium Solver was used to test the solutions obtained from the mathematical model. The solutions of the example are showed in Figure 2. The binary number 1 indicates that the assignment on Monday, e.g. Course 612 321 was assigned to classroom no. T.144-6.

The solution from the model was compared to the solution from the practical use or the manual assignment with total 115 courses (all courses from Monday to Friday). The findings are as follows.

a) The solutions from the manual assignment are investigated. It was found that some solutions violated the constraints in the model For example, the study periods were overlapped and the number of students of the assigned course was over classroom capacity in some courses. This problem can be eliminated by the use of the proposed method.

b) In practical use, some classrooms were unavailable since they were specified or reserved for some courses before doing courses - classrooms assignment. On average, 33 percent of all courses were already reserved. This reservation had reduced the quality of the solution and increased the operation cost. The mathematical model was used to solve the problem and compared the quality of the solution between with and without the reservation. It was found that the cost of assignment reduced 11% on average or 27,920 Baht/semester (16 weeks) as shown in Table 4.

c) The method can solve the problem in short time while the manual assignments consume time for a week to solve the problem. Figure 3 shows the running time from the software output which are scheduled on Monday. The proposed method consumed 3.16 seconds of the running time for solving the problem as shown in Table 5.

Table 2 Classroom capacity and classroom cost

Classroom (j)	Classroom capacity (V_j)	Cost (C_j) (baht/ hr.)
T.135	85	30
T.136	85	30
T.138	85	30
T.139	85	30
T.142-3	120	40
T.144-6	180	60
Meeting	200	120
KT	415	120
O50-522	72	65
O50-523	73	65
O50-517	42	45
O50-518	47	45
SR 1201	265	120

Table 3 Example data of registered students and the study periods of each course

No. student (N_i)	Course (Sp_i)	8:30 9:30	9:25 10:15	10:20 11:10	11:15 12:05
60	612312	1	1	1	
60	623231		1	1	1
30	615211		1	1	1
45	614392		1	1	1
30	615231		1	1	1
120	611202		1	1	1
30	614241		1	1	1
30	614101		1	1	1
120	614201		1	1	1
65	613311			1	1

Table 4 Cost comparison (baht/week)

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Cost :Manual(Baht)	3,360	2,640	4,155	2,400	1,590	1,080	630
Cost Software (Baht)	3,080	2,515	3,555	2,340	1,270	720	630
	280	125	600	60	320	360	0
% save cost	8%	5%	14%	3%	20%	33%	0%

Table 5 The running time (second)

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total
Solving time (sec.)	0.56	0.35	0.72	0.44	0.35	0.35	0.39	3.16

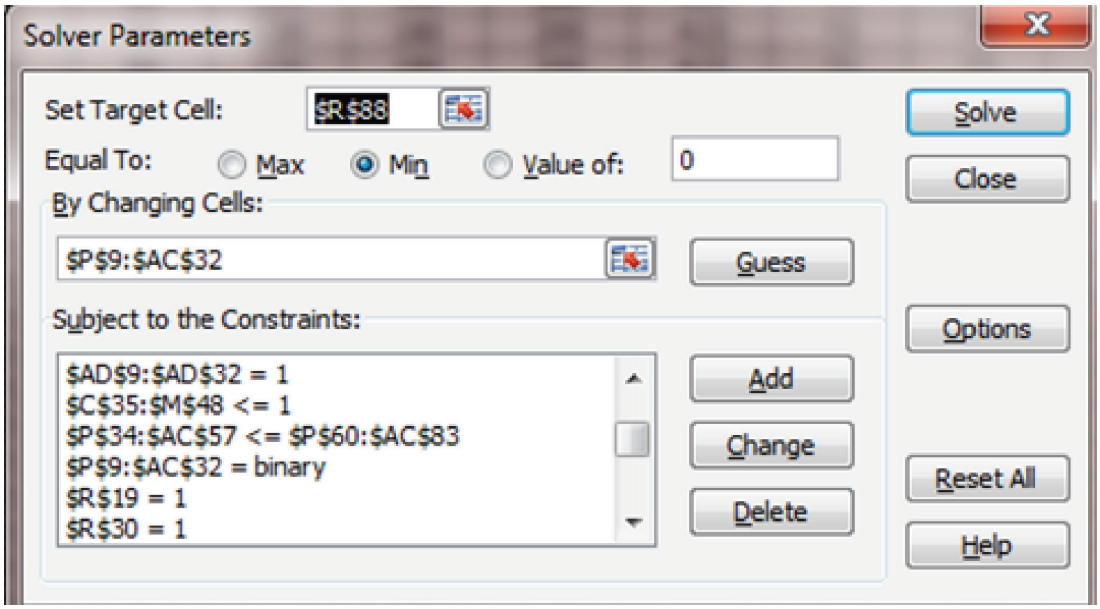

Figure 1 The Excel solver setting

	A	B	C	D	E	F	G	H	I	J
1										
2			T.135	T.136	T.137	T.138	T.139	T.142-3	T.144-6	Meeting
3		612 312-51	0	0	0	0	0	0	1	0
4		623 231-51	0	0	0	1	0	0	0	0
5		615 211-51	0	1	0	0	0	0	0	0
6		614392	0	0	1	0	0	0	0	0
7		615 231-51	0	0	0	0	0	0	0	0
8		611 202-50	0	0	0	0	0	0	0	1
9		614241	0	0	0	0	1	0	0	0
10		614 101-50	1	0	0	0	0	0	0	0
11		614 201-55	0	0	0	0	0	0	0	0
12		613 311-52	0	0	0	0	0	1	0	0
13		618 445-50	0	0	1	0	0	0	0	0
14		623 231-51	0	1	0	0	0	0	0	0
15		614241	0	0	0	0	1	0	0	0
16		614 201-50	0	0	0	0	0	0	0	0
17		614301	0	0	0	0	0	1	0	0
18		614392	1	0	0	0	0	0	0	0
19		614311	0	0	0	1	0	0	0	0

Figure 2 The results of assignment courses to classrooms on Monday (x_{ij})

Output Monday

```
---- Start Solve ----
No uncertain input cells.
Using: Full Reparse.
Parsing started...
Diagnosis started...
Model diagnosed as "LP Convex".
User engine selection: Gurobi Solver
Model: [design model14may.xlsx]model monday
Using: Psi Interpreter
Parse time: 0.52 Seconds.

Engine: Gurobi Solver
Setup time: 0.03 Seconds.

Engine Solve time: 0.01 Seconds.
```

Figure 3 The software output

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