COLLEGE COURSE TIMETABLING OPTIMIZATION CONSIDERING INSTRUCTOR'S WORKLOAD

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Abstract - Course timetabling for schools, colleges, and universities is normally a complex educational problem. Without any decision-making tools in management process, it definitely requires a long period of time to complete a practical and optimal timetable since there are various limitations to consider as well as a plenty of data such as the number of students, number of courses, teaching periods, classroom types, and instructor expertise, etc. In addition, the results from such timetable sometimes are unsatisfied including teaching workload among instructors which is always not well balanced. Therefore, this research aims to develop a nonlinear binary integer programming model for the timetabling problem of a technical college in order to minimize the variance of workload. Premium Solver is used to find an optimal solution which can also reduce time to generate a timetable. By the proposed approach, the results show that the variance of teaching workload is decreased by 10% and the time spent on scheduling decreased by 96% compared to the traditional approach.

Index Terms - Timetabling Problem, Workload Balancing, Mathematical Model.

I. INTRODUCTION

Course timetabling is an essential for educational institutions. A Couse schedule is necessary to be organized in every semester of each academic year. Courses in most schools, colleges, or universities are structured according to the national curriculum which have to be set up in each academic year. The problem of overlapping classrooms usually happens. Therefore, course timetabling is absolutely found complicated. It is also found that the course schedules are organized without balancing the workload of the instructors because the planners schedule the teaching timetable by using only their experience. Therefore, teaching schedules are needed to be conducted by experienced lesson planner due to the complexity and limitations, as well as the number of students, teaching hours per week and the teacher's expertise [1]. Sanjay Sutar and Rajan Bichkar [2]. studied the high school timetabling problem and proved that it is a combinatorial optimization problem and an NP-hard problem. It is a task to assign class–teacher interactions to rooms and timeslots of a weekly schedule. The nature of the problem varies depending on the region and institution. It has several hard and soft constraints. It means finding an assignment, such that no hard constraints are violated and the number of violations of soft constraints is minimized. Large and complex high school timetabling problem taken from real life, often takes long time to do manually. As a result, the teaching hours of each instructor are not distributed equally. The imbalance between workload is occurred. Pichet Poomjang, Supim Sripunvoraskul and Poonpong Suksawang [3]. studied on the variable which had a statistically significant negative indirect effect on the teacher job satisfaction. The results were found that teacher stress from workloads is the key variable. Mathematical model and computer program are widely used in many researches as a problem-solving tool for course timetabling problem. Mathematical model is used to simulate the actual situation and computer program is used to calculated and construct a mathematical model [4]. The mathematical model is used to solve the problems and find the best or the closest solutions. By using the Excel Premium Solver, it can reduce the time compare to the traditional manual calculation method. As a result, the program can provide the best solution. Sujanya Kaewprayta and Wanida Rattanamanee [5]. developed a computer program with scheduling method and compared between the developed scheduling and the manual one done by the facilitator and scheduler. From the comparison, the results obtained from the use of computer program were more reliable because it could check the error of scheduling and no errors were found. The research results were also compliant with the study from Shaukat Ali Brah, John Hunsucker, and Jaymeen Shah [6]. Goal Programming is one of the efficient methods to solve timetabling problem as Wood and Whitaker [7] studied. They formulated a secondary school timetabling problem as a non-linear goal program, where student freely courses of study from a complete list of subjects rather than the usual restricted sets of subjects. Course timetabling problem of a technical college in Thailand which is a case study in this research is studied focusing in the Machine Tool department. The current instructional management is not efficient. Overlapping classrooms frequently occur. Teaching is not organized according to the instructor's expertise. Instructor's workload per week is unbalanced. Some instructors are assigned too many courses while some instructors are assigned too few courses, With the unfair teaching load, it effects to instructor satisfaction and teaching effectiveness. Furthermore, the current process to schedule a

timetable consumes a long period of time. It usually spends over a week to finish since much of information and many limitations have to be considered. Mathematical optimization is proposed in this research to solve such problem. The expected timetable is to balance the instructor's teaching hours without the overlap of classrooms. A mathematical model is developed according to the defined problem. Later, a spreadsheet model is built. Excel Solver is used to find the best solution under the problem constraints. Workload balancing and solving time are expected to be improved.

II. METHOD

The research methodology of this study includes studying the current process of course scheduling; gathering information, conditions and restrictions to schedule a course timetable; collecting all data such as number and type of students, instructors, courses, and classrooms. In this research, a mathematical programming approach is applied. A nonlinear binary integer programming model is developed with its objective to minimize the variance of workload. If the variance equals zero, it means the workload is completely balanced. In order to assist on teaching scheduling, Premium Excel Solver is used as a tool to optimally schedule and provides ease of use to the planners.

A. Indices

i Classroom
Where i = 1 Classroom 1
i = 2 Classroom 2
…
i = 7 Classroom 7

j Day
Where j = 1 Day 1 (Monday)
j = 2 Day 2 (Tuesday)
…
j = 5 Day 5 (Friday)

k Time period
Where k = 1 Time period 1 (08.00-12.00 hr.)
k = 2 Time period 2 (13.00-17.00 hr.)

l Subject
Where l = 1 Subject 1
l = 2 Subject 2
…
l = 65 Subject 65

m Instructor
Where m = 1 Instructor 1
m = 2 Instructor 2
…
m = 8 Instructor 8

B. Sets

A Set of subjects required to study in classroom 1
Where $A = \{l \mid l = 1,2,3,4,5,6,14,15,16,17\}$

B Set of subjects required to study in classroom 2
Where $B = \{l \mid l = 18,19,20,21\}$

C Set of subjects required to study in classroom 3
Where
$$C = \begin{Bmatrix} l \mid l = 22,26,27,28,29,30,31,32,33,34,35,36,37, \\ 38,39,40,41,42,43,44,45,54,55,56,57,58,59,60, \\ 61,62,63,64,65 \end{Bmatrix}$$

D Set of subjects required to study in only classroom 4
Where $D = \{l \mid l = 23,24,25\}$

E Set of subjects required to study in only classroom 5
Where $E = \{l \mid l = 46,47,50,51,52,53\}$

F Set of subjects required to study in only classroom 6
Where $F = \{l \mid l = 7,8,9,10,11,12\}$

G Set of subjects required to study in only classroom 7
Where $G = \{l \mid l = 13,48,49\}$

H, I, J Set of subjects required the same instructor
Where $H = \{l \mid l = 46,47\}$
$I = \{l \mid l = 50,51\}$
$J = \{l \mid l = 52,53\}$

K Set of subjects specified the teaching date
Where $K = \{l \mid l = 7,8,9,10,11,12\}$

C. Parameters

n Number of instructors
t_l Teaching hours of subject l
$\overline{T}$ Average teaching hours

D. Decision Variables

xijklm = 1 if there is a class in classroom *i* day *j* time period *k* subject *l* by Instructor *m*; 0 Otherwise

E. Mathematical Models

$$Minimize \frac{\sum_{m=1}^{8}\left[\sum_{i=1}^{7}\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{l=1}^{65} t_l x_{ijklm} - \overline{T}\right]^2}{n} \quad (1)$$

Where $$\overline{T} = \frac{\sum_{i=1}^{7}\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{l=1}^{65}\sum_{m=1}^{8} t_l x_{ijklm}}{n} \quad (2)$$

Subject to

$$\sum_{l=1}^{65} X_{ijklm} \le 1 \qquad \forall i, j, k, m \quad (3)$$

$$\sum_{i=1}^{7}\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} x_{ijklm} = 1 \qquad \forall l \quad (4)$$

$$\sum_{i=1}^{7}\sum_{j=1}^{5}\sum_{k=1}^{2} X_{ijkl1} = 1 \qquad \forall l \in I \quad (5)$$

$$\sum_{i=1}^{7}\sum_{j=1}^{5}\sum_{k=1}^{2} X_{ijkl2} = 1 \qquad \forall l \in H, J \quad (6)$$

$$\sum_{i=1}^{7}\sum_{m=1}^{8} X_{i12lm} = 1 \qquad \forall l \in K \quad (7)$$

$$\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} x_{1jklm} = 1 \qquad \forall l \in A \qquad (8)$$

$$\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} x_{2jklm} = 1 \qquad \forall l \in B \qquad (9)$$

$$\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} x_{3jklm} = 1 \qquad \forall l \in C \qquad (10)$$

$$\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} X_{4jklm} = 1 \qquad \forall l \in D \qquad (11)$$

$$\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} x_{5jklm} = 1 \qquad \forall l \in E \qquad (12)$$

$$\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} x_{6jklm} = 1 \qquad \forall l \in F \qquad (13)$$

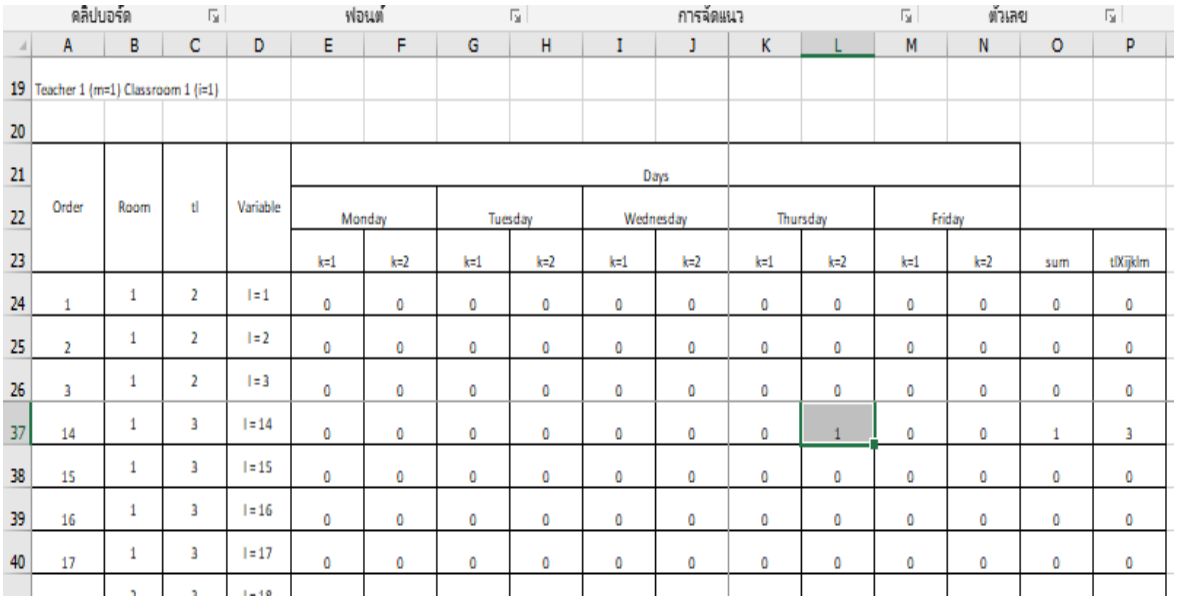
$$\sum_{j=1}^{5}\sum_{k=1}^{2}\sum_{m=1}^{8} x_{7jklm} = 1 \qquad \forall l \in G \qquad (14)$$

$$x_{ijklm} = Binary \qquad \forall i, j, k, l, m \qquad (15)$$

The objective function is to balance workload by minimizing the variance of workload of all instructors (see equation (1)). Equation (2) is an equation of the average teaching hours calculated from the total teaching hours divided by the number of instructors. All problem constraints are shown in Equation (3) to (15). Each instructor cannot teach more than one course in each classroom in each time period each class and each day (see Equation (3)). Equation (4) expresses that every subject has to be assigned to an instructor. Equation (5) and (6) both are the constraint of instructor's expertise which Equation (5) means the first instructor must teach only the subjects in set I, and Equation (6) means the second teacher must teach only the subjects in set H and J. Refer to Equation (7), all subjects in set K must be taught on only Monday in the afternoon. Subjects that requires classroom 1, 2, 3, 4, 5, 6 and 7 is shown in Equation (8), (9), (10), (11), (12), (13) and (14), respectively. In the last equation (Equation (15)), all decision variables must be a binary (0 or 1) number.

F. Finding Optimal Solution Using Premium Solver

Since there are 7x5x2x65x8 or 36,400 decision variables which is beyond the variable limitation of basic version of Solver which is an add-in tool in Microsoft Excel, therefore Premium Solver is required to cope with the larger size of the problem. It can schedule a timetable so that the variance of the teaching workload is minimal. The advantage of Solver is that it can be conveniently used by users or planners with its clear and easy solving steps. Premium Solver is processed by defining all constraints, objectives, parameters and variables according to the mathematical model on an Excel worksheet. Based on Nonlinear model, nonlinear solution method has to be defined in Solver to find an optimal solution which is displayed as 0 and 1 in the same Excel worksheet as shown in Figure I. The timetable is found practical and optimal. No constraints are violated. There are no overlaps of subject, classroom, time, and instructor. Figure II shows an assigned timetable of the first instructor as an example.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
19	Teacher 1 (m=1) Classroom 1 (i=1)															
20																
21	Order	Room	tl	Variable	Days											
22					Monday		Tuesday		Wednesday		Thursday		Friday			
23					k=1	k=2	k=1	k=2	k=1	k=2	k=1	k=2	k=1	k=2	sum	tlXijklm
24	1	1	2	l=1	0	0	0	0	0	0	0	0	0	0	0	0
25	2	1	2	l=2	0	0	0	0	0	0	0	0	0	0	0	0
26	3	1	2	l=3	0	0	0	0	0	0	0	0	0	0	0	0
37	14	1	3	l=14	0	0	0	0	0	0	0	1	0	0	1	3
38	15	1	3	l=15	0	0	0	0	0	0	0	0	0	0	0	0
39	16	1	3	l=16	0	0	0	0	0	0	0	0	0	0	0	0
40	17	1	3	l=17	0	0	0	0	0	0	0	0	0	0	0	0

Figure I Binary solutions on Excel worksheet

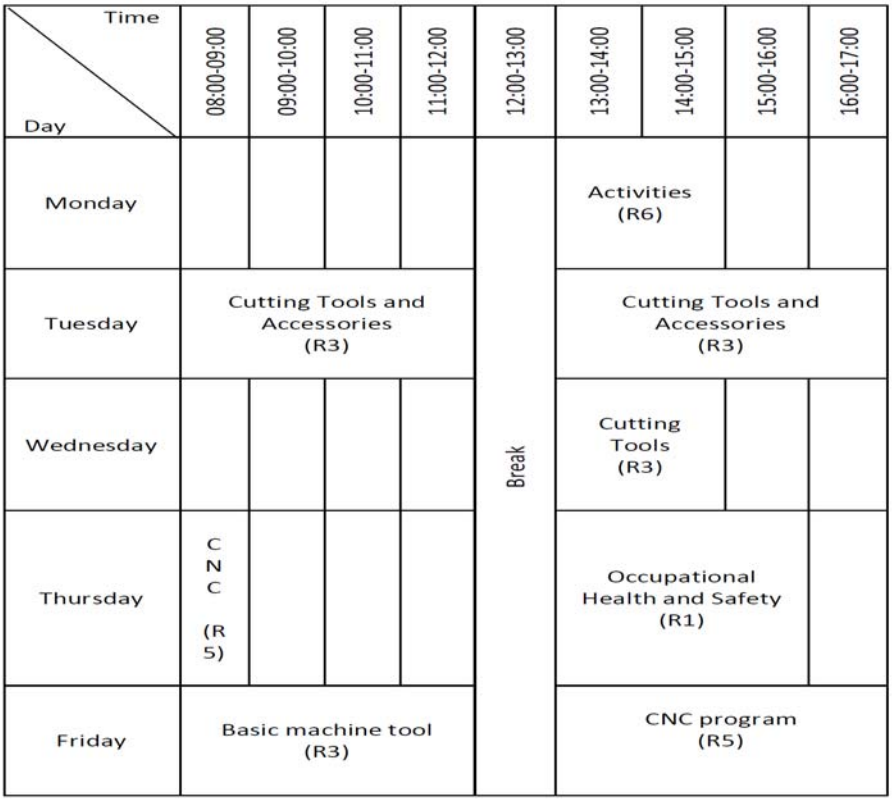


Figure II Example of the new timetable

Note: R = Classroom

Each instructor's workload is changed in comparison with their workload assigned by the current method as shown in Table I. While Table II shows comparisons of the variance and scheduling time. It is found that both performances in terms of workload balancing and solution time are improved significantly.

Table I Workload comparison

Instructor	Workload obtained by using planner's experience (Hours)	Workload obtained by using mathematical programming (Hours)
1	23	24
2	26	33
3	32	24
4	31	26
5	24	28
6	21	26
7	26	31
8	31	22

Table II Variance and scheduling time comparisons

Result	By using planner's experience	By using mathematical programming	Difference (Decrease)
Variance (Hours^2)	4.13	3.73	10 %
Scheduling time (Hours)	56	2.50	96 %

CONCLUSIONS

The paper presents a nonlinear binary integer model for course timetabling problem of one technical college in Thailand which is a case study in this research. The objective is to optimize instructor's workload balancing by minimizing the variance of workload. Excel spreadsheet modeling is developed to construct the model. This problem size is somewhat large since there are 36,400 decision variables to solve. Premium Solver is used to solve and find an optimal solution under various scheduling constraints. The research results show that the proposed method can increase performance in terms of workload balancing and solving time. Workload balance is 10% improved by reducing a variability in workload. While time spent for arranging timetable is extremely decreased by 96%.

By this efficient method, it can avoid overlapping of subjects, classrooms, days, periods, or instructors in the course timetable.

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