Multi-objective Modeling for a Course Timetabling Problem

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Abstract: This paper presents a multi-objective modelling approach for Curriculum Based Course Timetabling (CB-CTT) problem. The problem comprises optimizing weekly scheduling by assigning offered courses to classrooms and time-periods. The model accommodates resource utilization of classroom occupation and the limited cost by given two objective functions of minimizing loss cost of an empty seat and minimizing the cost to open the course. The proposed model also satisfies the solutions that meet the lecturers time preference, thereby produce the applied schedule for the lecturers. In terms of response time and quality, the model outperformed manual alternatives to accommodate minimizing cost resources. The proposed model test using private university data in Taiwan. The computational results are favourable and interactive using CPLEX 12.9 solver builds on AMPL.

1 INTRODUCTION

Producing an excellent educational timetabling is an important issue and challenging task for every administrative staff in an academic institution. It's needed hard work to fulfills the important stakeholder (lecturers, students, and management) requirements. Mostly, accommodating the new situation for the current practice is to replicate the timetable in previous years to speed up the process with some minor modification. However, recently, some changes may frequently occur due to some new policy for each institution and mending of what has been developed previously take so much work. In these circumstances, given the progress made in achieving the growth of hardware and software systems, the scientific community continues to investigate this issue in order to establish general and automated processes for establishing effective and desirable timetables for stakeholders (Bettinelli et al., 2015).

The curriculum-based course timetabling problem defines as constructing the timetable by assigning the university courses to the time-periods over the working days in a week and to the specific classroom that suitable for the course need and the number of students who registered the course and lecturer for each courses in the weekly basis while satisfying various of constraint (De Cesco et al., 2008). In every university, the objective of producing a contented timetabling could be a difference among others due to the differences in preference and educational policy. However, the purpose is remaining the same to creates a compelling and feasible timetabling by satisfying the stakeholder's preferences for at least to a certain extent (Kristiansen and Stidsen, 2013).

The curriculum-based course timetabling problem has been explored extensively since 1980 by several well-known techniques of the operational research and the computer science field. In the last decade, the primary methodologies use categorized as swarm intelligence algorithm, evolutionary algorithm, local search algorithm, graph coloring algorithm, and the exact methods (Kristiansen and Stidsen, 2013). Among those methodologies, the accurate methods, integer programming, become one of the preferable techniques that used in solving the problem to overcome the quality of the solution found as the advancement in computer software and hardware (Caccetta and Aizam, 2012).

Clarence H. Martin (Martin, 2004) employed this approach for Ohio University's College of Business by considering the practical issue on lecturers, courses, classrooms, and timeslots. (Daskalaki et al., 2004) perform a novel 0-1 integer programming formulation by minimizing the linear cost function to accommodate providing a significant number of op-

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erational rules and requirements for the constraints, such as teaching periods, or days of week or classroom specified courses using real data from Department Electrical and Computer Science, University of Patras. Lach and Lübbecke (Lach and Lübbecke, 2012) approaching the problem through integer linear programming using two stages decomposed technique using real data from the University of Udine, Department Electrical and Computer Engineering.

The challenge in university course timetabling is keeping the studied problem as close as to the practical problem as possible. The multi-objective optimization does an influential part in this problem (Bettinelli et al., 2015). In a weighted cost objective function to be minimized, a common strategy is to implement constraints and penalize their violations. In actual, some universities have some rule to consider classroom capacity as the constraint that needs to fulfill (Bettinelli et al., 2015) as an approach in this study to give a real contribution and theoretical in the research community field. This paper organized as follows. The foundational problem of curriculum-based course timetabling described. Then comes with the explanation multi-objective model formulation, results, and discussion about the model performance and conclusion.

2 PROPOSED APPROACH

This section describe the problem description of the research area and the experimental design to construct the problem.

2.1 Problem Description

In university curriculum-based course timetabling, the problem formulated as given a set of course called curriculum and each curriculum consists of several lectures/courses. Each course is associated with a lecturer. Each course should be assigned in a classroom at a time-period, which a time-period on particular weekdays, without any conflicts. Each classroom also has a specific size and requirement to accommodate course needed. Fundamentally, to achieve an efficient and feasible objective, the mathematical formulation must be satisfied with all the related constraints. Every institution has the policy to deal with its timetable, so in many cases, adjustment much likely needed to satisfying each timetabling community. In this paper, the object of the study is a private university, Da-Yeh University which located in ChangHwa, Taiwan. Specifically, the data from the Industrial Engineering and Management Department undergraduate course in the College of Engineering with the time-period of analysis is fall semester in the last two academic years, 2017 and 2018. Figure 1 shows the collected data.

Year	Course	Classroom	Lecturer	Time-period
2018	17	6	8	15
2017	16	6	11	15

Figure 1: Timetable Data.

In this paper, we assume and construct the time preference for each professor for each semester as close as a practical problem and accommodate the classroom used for a particular equipped class, computer class. The unique attributes university appears, for the cost, every professor depends on the academic status (assistant professor, associate professor, and full professor) and the time-period (morning, afternoon, and night). The higher academic standing, the cost per hour, is higher. The time-period divides every three hours length based on the length of course offered, at morning, afternoon, and night. The night time-period value is higher than the morning and afternoon time-period. To satisfy the institution point of view, the preference in having a good classroom occupancy due to efficiency resources, classroom, and cost. Based on that, the model considering the funds to satisfy the classroom capacity constraint and get the feasibility timetabling.

2.2 Experimental Design

Constructing the university timetable using multi-objective programming approach and the following notation is needed to describe the model by given parameters that building the model as the essential structural element, the decision variables, objective function, and constraint. This model is a conceptual simplified cost-minimizing model.

Parameters
c : course
r : classroom
t : time-period
s : student group
l : lecturer
fr : maximal capacity of classroom r
ec : number of students enrolled in course c
$\text{cost}_{c,r,t}$: corresponding cost when the course c is assigned to classroom r, at period t
Il : set of course c taught by lecturer l
Is : set of course c attended by student group s
Tl : set of period t where the lecturer l is not available
Decision Variables
$x_{c,r,t}$: boolean function, the value is 1 once the course

c is assigned to a classroom r, at time-period t; otherwise, it is zero.

Objective Function

$$A_1 = Min\Sigma^{n}_{(c=1)}\Sigma^{m}_{(r=1)}\Sigma^{p}_{(t=1)}cost_{(c,r,t)}x_{(c,r,t)}(f_r - e_c) \quad (1)$$

Equation (1) is used to controlling the utilization of classroom by minimizing loss cost for each empty seat.

$$A_2 = Min\Sigma^{n}_{(c=1)}\Sigma^{m}_{(r=1)}\Sigma^{p}_{(t=1)}cost_{(c,r,t)}x_{(c,r,t)} \quad (2)$$

Equation (2) is used to design the timetabling by minimizing cost. The mathematical formulation of the problem is reads as follows:

$$Z = w_1A_1 + w_2A_2 \quad (3)$$

Constraint

$$\Sigma^{m}_{(r=1)}\Sigma^{p}_{(t=1)}X_{(c,r,t)} = 1$$

$$1 \leq c \leq n \quad (4)$$

Equation (4) indicates that each course must be assigned in a classroom and at a period

$$\Sigma^{n}_{(c=1)}x_{(c,r,t)} \leq 1$$

$$1 \leq r \leq m, 1 \leq t \leq p \quad (5)$$

Equation (5) indicates that each course cannot be assigned to the same classroom and period, no collision.

$$e_c x_{(c,r,t)} \leq f_r$$

$$1 \leq c \leq n, 1 \leq r \leq m, 1 \leq t \leq p \quad (6)$$

Equation (6) indicates the course capacity must be satisfying classroom capacity.

$$\Sigma^{n}_{(c\in I_l)}n\Sigma^{m}_{(r=1)}x_{(c,r,t)} \leq 1$$

$$1 \leq t \leq p, 1 \leq l \leq L \quad (7)$$

Equation (7) designates that each lecturer cannot be assigned to more than one course in a given period, no collision

$$\Sigma^{n}_{(c\in I_l)}\Sigma^{m}_{(r=1)}\Sigma^{p}_{(t\in T_l)}x_{(c,r,t)} = 0 \quad (8)$$

Equation (8) indicates the courses timetable must be satisfying the lecturer preference time.

$$\Sigma^{n}_{(c\in I_s)}\Sigma^{m}_{(r=1)}x_{(c,r,t)} \leq 1$$

$$1 \leq t \leq p, 1 \leq s \leq S \quad (9)$$

Equation (9) designates that the student cannot be assigned to more than one courses in a given period, no collision.

The multi-objective framework considered for this model, a weighted objective function is used to assist the preference of decision maker to get a feasible solution set (Hwang and Yoon, 1981). The subjective weighted method use as simulated function to show how each objective performs each other (Hwang and Yoon, 1981).The model is designed to propose a simple input / output interface to integrate theory and user practice (Chen, 2007).

3 RESULT AND DISCUSSION

Producing an excellent educational timetabling is an important issue and challenging task for every administrative staff in an academic institution. It's needed hard work to fulfills the vital issue of stakeholder (lecturers, students, and management) requirements. The result shows that timetable is favorably feasible, shown in Figure 2 and Figure 3. The example of computed timetable result applies 0.5 for each weight. The suggested timetable shown the courses are held in morning and afternoon time-period as a piece of evidence how the model works that there is no courses occur in the high-cost time-period.

Time-period	Mon	Tue	Wed	Thur	Fri
Morning	IEI3107 H44520	IEI3003 H44520	IEI4128 H72950	IEI4018 H44520	IEI1038 H72950
	IEI4106 H72950	IEI1025 H72950	IEI1026 H44520		IEI2088 H44520
		IEI4025 H53940			
Afternoon	IEI3101 H44520	IEI4042 H72950		IEI3006 H44520	IEI2085 H72950
		IEI1036 H44520			IEI2100 H44520
					IEI4017 H54140
Night					

Figure 2: Computed Timetable Academic Year 2018.

Figure 4 shows the variation value of Z in New Taiwan Dollar (NTD) with the simulation weight between A1 and A2 (Steuer, 1986). A1 as the objective to control the utilization of classroom to minimize the loss cost of an empty seat. A2 as the objective to find the feasible classroom, course and time-period that minimize the cost. The weight represented as subject

Time-period	Mon	Tue	Wed	Thur	Fri
Morning	IEI2085 H72950	IEI3101 H50750	IEI2088 H50750		IEI3107 H72950
	IEI4018 H50750	IEI1025 H72950			IEI3006 H54050
	IEI4113 H54050				IEI1036 H56320
Afternoon	IEI4106 H72950	IEI3108 H72750		IEI1026 H56320	IEI2100 H54050
		IEI2099 H72950			IEI1038 H72950
					IEI4025 H56320
Night					

Figure 3: Computed Timetable Academic Year 2017.

preferences to the decision maker. The more dominance penalty cost for the loss cost of an empty seat, the cost result is getting higher.

W_1	W_2	Z – 2018 Fall	Z – 2017 Fall
0.1	0.9	NTD 124,124	NTD 126,557
0.2	0.8	NTD 205,152	NTD 213,573
0.3	0.7	NTD 286,181	NTD 300,590
0.4	0.6	NTD 367,209	NTD 387,606
0.5	0.5	NTD 448,238	NTD 474,623
0.6	0.4	NTD 529,266	NTD 561,639
0.7	0.3	NTD 610,295	NTD 648,656
0.8	0.2	NTD 691,323	NTD 735,672
0.9	0.1	NTD 772,352	NTD 822,689

Figure 4: Computed Result of Model Decision.

Comparing to the existing timetable, the total fund that they need to spent to open the classroom for the selected professor is identical. The difference is in classroom occupancy operation; the proposed model utilizes each classroom until reach maximum by minimizing loss cost of an empty seat for available classroom and time-period for teacher except for particular equipped computer classroom, classroom H72950 and H72750, for the special equipment classroom for special course. Meanwhile, the existing timetable equalizes the classroom operation for each available classroom within a time-period in the absence of the empty seat consideration as shown in Figure 5 and Figure 6.

Classroom	Proposed Model Classroom Use / Occupancy	Existing Timetable Classroom Use / Occupancy
H44520	9/ 0.90	1/0.10
H53940	1/0.10	4/0.40
H54040	0/0	3/0.30
H54140	1/0.10	1/0.10
H55050	0/0	2/0.20
H72950	6/0.60	6/0.60

Figure 5: Classroom Occupancy Academic Year 2018.

Classroom	Proposed Model Classroom Use / Occupancy	Existing Timetable Classroom Use / Occupancy
H50750	3/0.30	1/0.10
H53950	0.0	5/0.50
H54050	3/0.30	2/0.20
H56320	3/0.30	1/0.10
H72750	1/0.10	1/0.10
H72950	6/0.60	6/0.60

Figure 6: Classroom Occupancy Academic Year 2017.

4 CONCLUSIONS AND RECOMMENDATIONS

Based on the results, the experimental work supports that multi-objective programming is capable of generating the university course timetable. The developed model considers the issue to satisfied the stakeholders by minimizing the cost objective to accommodate the university policy with favourable results within a second compared to the manual process. The model takes a penalty cost of an empty seat into consideration as the way how this model can help to support the decision maker giving broad options to optimize the course timetable.

Interestingly, while most scholars are very familiar with the concept, a few scholars consider cost in the mathematical formulation to solve the problem (Kristiansen and Stidsen, 2013). Since the finding is simple, basic, and practical, this very beginning conceptual simplified cost minimizing could be a basis for further model modification. The exploration of weight assessment method lead to more development in multi-objective modeling for future directions (Chen, 2007).

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