Linear Programming Subject Allocation Model for Private School Teachers

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Abstract

Teaching subject allocation is one of the most crucial tasks that will be carried out in every academic institution. An appropriate teaching subject allocation based on preference, expertise, and experience is necessary to uphold a high teaching quality and bring job satisfaction to teachers. However, the current practice by most schools has been done without systematic allocation that takes into consideration those criteria in decision making. Although linear programming method has been applied in many studies to address subject allocation challenges faced by higher education institutions, its application in private schools has not been widely explored. Based on a case study of a private school in Malaysia, this study aims to develop an optimum teaching subject allocation model using linear programming method. A total of nine teachers participated in a survey to identify their subject preferences. By determining the parameters and variables involved, a Linear Programming Subject Allocation (LPSA) model was developed using Microsoft Excel Solver. Proven as an optimum model that satisfies the constraints, this model serves as a solution to address the dissatisfaction among the teachers due to inefficient allocation. This model benefits the school management to be more efficient, save time and avoid bias allocation.

Keywords: *Linear Programming, Optimization, Subject Allocation, Timetabling, Solver*

1. Introduction

Teaching subject allocation is an important process that will be carried out in every academic institution to decide the subjects that are to be given to each teacher before the academic timetable is generated [1]. The process of allocating the correct teacher to the right subject based on the teacher's subject knowledge, experience, and teaching preference is called teaching subject allocation [2]. School timetabling problem is scheduling or allocating a set of lessons over a set of time periods [3]. A timetable will be generated when a set of people are allocated to a set of tasks. This timetable is used to illustrate exactly when a particular task will occur and who is involved in it [4, 5]. The subject allocation process or also known as teacher scheduling, must be done without any conflicts to ensure the smoothness of the teaching and learning process. The allocation must be done in a way that no two or more subjects or classrooms are scheduled at the same time for the same teacher [6]. Mainly there are three objectives that should be achieved in the process of teaching load allocation. All the subjects that are provided by the school must be

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allocated to the teachers, teachers must be allocated with the proper number of teaching subjects and teaching hours and only allocate teachers with the subjects that they are proficient with [1].

The manual subject allocation method can contribute to a biased result. Due to that, a few complications might arise, such as unstandardized teaching hours allocation and also teachers get the subjects that they are not proficient with [2]. The teaching quality will be poor if the teachers are allocated with the subjects which they do not prefer, or they are not capable of teaching. This will very seriously impact students' achievement and could affect the school's image. In addition to this, the manual allocation also leads to dissatisfaction among the teachers. When the teachers are not happy with the allocation, they get stressed and dissatisfied. The dissatisfaction and stress could lead to teachers' burnout and lead to resignation or leaving the profession. Teaching quality is the goal that is expected in the whole teaching activity process.

Teachers' allocation is a process where many constraints and requirements need to be considered. This makes the teaching allocation process an optimization problem [7]. An optimization problem can be solved using Linear Programming method, which is a mathematical method that is used to determine an optimum solution for a situation with the consideration of certain constraints. The assignment problem is a class of Linear Programming that is used for assigning an individual to certain tasks or also could be assigning tasks to machines in an optimum way with respect to certain conditions to maximize the outcome (or profit) or to minimize the total cost.

This research is aimed to propose an optimum teaching subject allocation model for a private school teacher using Linear Programming method. The model will be developed with the consideration of teachers' preferences towards the subjects that are provided. This is expected to contribute towards the increase of teaching quality and, at the same time, could reduce the bias allocation and dissatisfaction among teachers.

2. Literature Review

Basically, academic timetabling can be classified into three main divisions, which are university course timetabling, examination timetabling, and school timetabling [8]. School timetabling is considered a subtype of course timetabling [9]. The head of the department and principals must carefully analyze all the possible conditions and restrictions in order to assign the right teacher to the right subject to achieve optimum performance from the teacher [7]. Different schools apply different methods for allocating the teachers, but when the size of the school increase, the complexity in allocation also will increase. Even virtually most schools use the same method, which is the manual way, the administrators must consider the student's number before the allocation is done [10]. Not only in schools but even in higher education institutions, the allocation process is done using the trial and error method. This manual method is not only time-consuming, but the result could lead to dissatisfaction among teachers, which will end up risking the teaching quality. It is a smart move to develop an orderly method for a better allocation [11]. There are many variables involved in the timetabling process, including times and

days preferred, combined, or not combined class, daily subject workload and the number of days. This makes the manual method very complicating and cannot achieve a satisfactory feasible solution in most schools nowadays. To overcome the problem, schools have to consider the automated timetabling method, which can contribute well to better-quality timetables [12].

Various methods were applied to solve the timetabling problem in past studies. A method called the simulated annealing technique was used to solve timetable problems of an Australian school [13]. Later, to solve the Portuguese school timetabling problem, [14] came up with a tool called THOR school timetabling tool. In another study, [15] has used a genetic algorithm to solve nine highly constrained school timetable problems. They have applied a parallel algorithm to which can make the process to be solved faster. A study by [16] on Brazilian High Schools primarily applied the constructive algorithm method to get a preliminary solution. To that solution, they have applied a tabu search using an informed diversification strategy, which has improved the timetabling quality. The research done by [17] used the graph coloring method using the adaptation of tabu search algorithm for graph coloring. It is named Modified Tabucol (MT). Integer Programming method was applied to solve the Greek High School timetabling problem by [18]. Meanwhile, [19] in their research has applied Mixed Integer Linear Programming method to solve the Brazilian High School timetabling problem. In the study done by [20], constraint programming was combined with local search to improve the quality of the timetable to solve the Greek High School timetabling problem. There are three stages in the method called GRASP. The first stage is the arrangement of lessons. In the second stage, the arrangement is further improved using local search. In the third stage, a path-relinking strategy gives the optimal solutions. The third stage of the GRASP was applied to solve three Brazilian High Schools timetable problems [21]. Tiling algorithm method was combined with hill climbing method to allocate the meeting between teachers and class. Tiling algorithm also was combined with an alternate path algorithm for assigning a course to meetings after the times are fixed [22, 23]. Then in a later study, [24] uses the bipartite matching model which is called global tixel matching to assign teachers to meetings in Australian High Schools.

Some researchers have combined the different approaches to improvise the timetabling solutions. [25] created initial timetable using a parallel heuristic algorithm with priority rules. They then applied standard tabu search to produce a feasible timetable. To further improve the quality of the timetable, they applied the graph theory approach using the Floyd-Warshall algorithm. [26] has used a four-phase approach to solve the timetabling problem. The first phase uses a branch-and-bound algorithm. The second phase used dynamic priority rule to assign a lesson to days. The third phase allocates the day-parts to the time slots using a graph-coloring first-fit heuristic method. Lastly, the fourth phase uses Tabu search to improve the feasible timetable.

A Binary Integer Programming model was applied by [27] to assign teachers to classes with the consideration of teachers' preferences. In a study to solve teacher-course assignment problem at the Department of Management at the School of Industrial Engineering of Barcelona, [28] has developed a Mixed Integer Linear Programming model with the objective function to balance teacher's teaching load

and to maximize the teacher's preferred course. In a study conducted at Dutse Model International School of Jigawata State, Nigeria by [29], two assignment problem methods were applied, namely, Hungarian Algorithm method and Linear interactive & discrete optimization technique, which is also known as LINGO. The study was about finding optimal staff-subject allocation which will maximize the quality of their education.

3. Materials and Methods

3.1. Subjects and Allocation Details

The school that the study was done is a newly started private school in the state of Johor Bahru, Malaysia. There are only four primary levels and a total of 9 teachers. The school implements five days of school per week, and there are eight periods in a day with every period's duration of 35 minutes. This means there are 40 periods in a week that need to be distributed to the nine teachers. The number of periods and classes for each teacher is based on the category of teacher. There are three categories of teachers in that school, normal teachers with no additional duties, teachers with special duties, and part-time teachers. Out of nine teachers, five are normal teachers, three teachers with special duties, and one part-time teacher. The limits for teaching periods and the number of classes of each category of the teacher is shown in table 1 below.

Table 1. Teacher's Teaching Period and Class Allocation Limits

Teachers	Minimum Number of Periods	Maximum Number of Periods	Minimum Number of Classes	Maximum Number of Classes
NORMAL ($T_1 – T_5$)	20	28	2	8
WITH SPECIAL DUTIES ($T_6 – T_8$)	10	20	2	8
PART TIME (T_9)	6	10	2	5

3.2. Survey

The proposed model in this study is based on teachers' preferences. A survey was done to identify the teacher's preferred subjects in this school by utilizing a simple questionnaire. All the subjects that are provided for the four levels were listed in a table format. Four different scales were given to describe the preference levels. The scales are numbered from 0 to 3. If a teacher does not have any experience in that subject and they don't want to teach that subject, they select 0. If a teacher has experience teaching that subject, but they do not prefer to teach that subject, then they go for scale 1. Scale 2 is for teachers who do not have any experience in the subject but prefer to teach that subject. Finally, if the teacher is experienced in the subject and prefers to teach the subject, they select scale 3. So, the scale value increases with the teacher's preference. The results of the survey were compiled into a table to be used in developing the model.

3.3. Linear Programming Subject Allocation Model

To form the model, first, the constraints, namely hard constraints and soft constraints, must be listed. Then, the parameters that are involved will be identified, followed by the objective function, and finally the model constraints will be listed. The model will be developed using Integer Linear Programming method.

3.3.1. Hard and Soft Constraints: There are two types of constraints in allocation and timetabling problems, namely hard constraints and soft constraints. The hard constraints are known as the requirements. Whereas the soft constraints were known as the preferences. When a timetable is created by fulfilling all the requirements without considering any preferences, it is called a search problem. Meanwhile, if the timetable is created by fulfilling all the requirements and considering most of the preferences, then it is called the optimization problem [30]. In this model, the soft constraint that will be considered is the teacher's preference towards the subject which can be identified from the survey result. The model will be developed so that it can allocate the teachers with the subjects that get the highest scoring from them. The hard constraints that must be fulfilled are as the followings:

- There must be only one class for every subject at every level
- The number of classes and teaching periods must follow the limits as in table 1.
- No teachers should be teaching two subjects at the same time
- The total number of periods for every class must be equal to 40 per week

3.3.2. Parameters: The complete list of indices, sets, parameters, and decision variables for the model were listed as follows:

i - Index for subjects, (i = 1, 2, …, m)
j - Index for teachers, (j = 1, 2, …, n)

I - Set of subjects, $I = \{i : i = 1, 2, \ldots, m\}$
J - Set of teachers, $J = \{j : j = 1, 2, \ldots, n\}$

W_{ij} - Teaching preference weightage for subject i by teachers j
C_i - Number of classes for subject i
t_i - Number of periods for subject i
t_j^{min} - Minimum number of teaching periods for teacher j
t_j^{max} - Maximum number of teaching periods for teacher j
n_j^{min} - Minimum number of classes for teacher j
n_j^{max} - Maximum number of classes for teacher j

Decision Variable:

$$X_{ij} \begin{cases} 1 & if\ subject\ i\ asigned\ to\ teacher\ j \\ 0 & if\ subject\ i\ not\ assigned\ to\ teacher\ j \end{cases}$$

3.3.3. Constraints and Optimization Model: The optimization model was formulated with the list of parameters and constraints as below:

The objective of the function is to:

Maximize
$$\sum_{i \in I} \sum_{j \in J} W_{ij} X_{ij}$$

The objective function is to maximize the total number of subjects taught by teachers according to their preference weight. This objective function is subject to the following constraints.

With respect to the constraints:

$$\sum_{j \in J} X_{ij} = C_i \qquad \text{for } i \in I \qquad [1]$$

Constraint [1] imposes the number of classes for each subject.

$$t_j^{min} \leq \sum_{i \in I} t_i X_{ij} \leq t_j^{max} \qquad \text{for } j \in J \qquad [2]$$

Constraint [2] defines the minimum and the maximum number of teaching periods that a teacher should teach.

$$n_j^{min} \leq \sum_{i \in I} X_{ij} \leq n_j^{max} \qquad \text{for } j \in J \qquad [3]$$

Constraint [3] defines the minimum and the maximum number of classes that can be allocated to a teacher.

$$X_{ij} \; is \; Binary \qquad \text{for } i \in I, j \in J \qquad [4]$$

Constraint [4] defines that the decision variable is binary. If the teacher is allocated to a subject, then the value will be 1, and if not, then the value will be 0.

3.4. Software Analysis

To get the optimum allocation for teachers, the survey result and the allocation details were entered into Excel Spreadsheet and followed by the objective function and model constraints into Solver add-in.

4. Results and Discussions

The solver took 0.188 seconds to generate the result after 223 different iterations with a precision of 0.000001. The maximum value that can be obtained by allocating

teachers with the subjects that has the highest preference weights for this study is 75. With the help of Excel Solver, the allocation problem was solved, and a feasible solution was obtained. The outcomes were compared, and it was found that all the teachers were allocated with the subjects that had the highest preference weight. This shows the result is 100 percent based on the teacher's preference. The allocation also fulfills all the limits set. Table 2 below shows the comparison between the allocation limits and the allocated number of classes and periods for each teacher.

Table 2. Comparison Between Allocation Limits and Allocated Results

TEACHER	ALLOCATION LIMITS				ALLOCATED RESULTS	
	MINIMUM CLASSES	MAXIMUM CLASSES	MINIMUM PERIODS	MAXIMUM PERIODS	NO. OF CLASSES	TOTAL PERIODS
T_1	2	8	20	28	4	23
T_2					6	22
T_3					3	22
T_4					5	21
T_5					6	20
T_6	2	8	10	20	2	12
T_7					3	18
T_8					8	12
T_9	2	5	6	10	4	8

5. Conclusion

This study was aimed to develop an optimum teaching subject allocation model with the consideration of teachers' preferences using Linear Programming method. By applying Microsoft Excel Solver, a feasible solution was obtained in a very short time. This Linear Programming subject allocation model was proven to be optimum as it is able to allocate teachers with their preferred subjects and, at the same time satisfies all the allocation limits. The model developed will be very useful in avoiding bias allocation, and stress among teachers, thus will improve the teaching quality. This model can be applied in all types of schools. For further improvement, the model could be applied for more constraints such as a greater number of teachers, subjects, and levels.

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