Teaching Load Allocation using Linear Programming

A Case Study in Mathematics Department

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***Abstract*— Allocation of teaching loads in a teaching unit refers to the distribution of teaching hours among academic staff. The most ideal outcome would be to assign the best person to teach the right course based on his/her expertise and experience. In many teaching units, the task is done manually through trial-and-error which is rather time-consuming, inefficient and subject to bias judgement. Furthermore, the allocation is probably unfavourable to many academic staff. Hence, a linear programming model was developed in order to find an optimal allocation of teaching loads which subject to considered constraints. A survey was conducted to determine the preferences of academic staff towards teaching the offered courses. The mathematical model was applied in a case study in Mathematics Department in a selected semester where 141 teaching hours were distributed among nine lecturers. A feasible solution was found with the use of optimization software LINGO®. The task proved to be more efficient and time-effective. Therefore, the model serves as a good tool to assist head of teaching units in allocating teaching loads.**

Keywords*— *teaching load; allocation problem; linear programming

I. INTRODUCTION

Allocation of teaching loads refers to the task of distributing teaching hours amongst academic staff in a teaching unit. The most ideal outcome would be to assign the best person to teach the right subject based on his/her expertise and experience. The number of teaching hours depends on the courses offered and the number of students. Not only that, the availability of academic staff in a semester is another factor to consider. Thus, making it a requirement for the head of the unit to perform this task routinely at the beginning of the semester is very significant.

In most teaching units, the task of allocating teaching loads is a daunting task as it is usually done manually through trial-and-error [1]. The head of unit needs to assign the best academic staff to teach the most suitable course while at the same time considering all possible restrictions and requirements. Hence, the task is rather time-consuming, ineffective and subject to bias judgement. Furthermore, the final outcome of the allocation is probably unfavourable to many academic staff as the allocation also depends on their satisfaction, preferences and teaching experiences in a certain course.

The problem of allocation is considered as an optimization problem where the optimal solution is found under different constraints. Evidently, some similar problems have been widely investigated and solved by applying mathematical modelling and computer algorithms [2]. Such solution proposes a two-phased model where the first stage emphasizing the priorities to academic staff in the workload allocation. Additionally, preferences of academic staff are taken into account in modelling the time table [3] where integer programming is utilized. For instance, timetabling and scheduling based on faculty-course-time with multiple constraints [2]–[7]). However, each model is tailored to a specific problem depending on its complexity and size [5].

Hence, the objective of this study was to develop a linear programming model based on an optimization model [1]. This approach is vital in order to find the optimal teaching load allocation for a teaching unit which subject to the preferences and previous teaching experiences in offered courses. In this case study, the mathematical model was applied in Mathematics Department of a university for the purpose of allocating the teaching loads in a given semester.

This paper is organized as follows where in the next section; it describes the teaching load allocation problem at Mathematics Department. Section III presents the teaching load allocation model followed Section IV which discusses Results and Analysis of the model. Finally, the implications and conclusions are presented in Section V.

II. CASE STUDY IN MATHEMATICS DEPARTMENT

Teaching load allocation in June 2016 semester in Mathematics Department, Faculty of Computer and Mathematical Sciences, UiTM Pahang, Raub Campus. The problem is detailed as follows:

A. Contact Hours for Each Course

Seven diploma courses with a total of 141 contact hours per week are to be assigned among nine lecturers. Each course has different distribution of contact hours per week and requires different number of classes depending on student enrolment. For example, ‘Business Mathematics’ course (MAT112) has four contact hours with 9 classes; while ‘Pre-Calculus’ course (MAT133) has four contact hours with three classes. Thus, the total contact hours for MAT112 and MAT133 are 36 and 12, respectively.

The contact hours of each course and the required number of classes in the given semester are shown in Table I.

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TABLE I. CONTACT HOURS AND NUMBER OF CLASSES FOR COURSES OFFERED FOR JUNE – OCTOBER 2016 SEMESTER

Courses	Contact Hours	Number of Classes
MAT112	4	9
MAT133	4	3
MAT183	4	5
MAT210	4	5
MAT222	4	1
MAT223	5	1
MAT263	4	12

B. Teaching Hours for Academic Staff

A lecturer has minimum and maximum required teaching hours each week. For example, a senior academic staff with an administrative post is required to fulfill a minimum of 12 teaching hours. Meanwhile, the minimum and maximum teaching hours for a junior academic staff are 16 and 18 hours, respectively. Both the junior and senior academic staff bear similar minimum and maximum teaching hours as shown in Table II.

TABLE II. MINIMUM AND MAXIMUM TEACHING HOURS AND NUMBER OF CLASSES FOR EACH LECTURER

Lecturers	Total Teaching Hours		Number of Classes	
	Minimum	*Maximum*	*Minimum*	*Maximum*
MFA	16	18	4	5
MM	16	18	4	5
FS	16	18	4	5
AD	16	18	4	5
AS	16	18	4	5
M1	16	18	4	5
M2	16	18	4	5
M3	16	18	4	5
M4	16	18	4	5

C. Total Number of Classes per Semester

Each lecturer is set to teach a minimum of three classes to a maximum of five classes in a semester. For example, Lecturer AD is possibly to be assigned to four classes in a semester consisting of two of MAT112 classes, one of MAT133 class and one of MAT183 class. The minimum and maximum classes for each lecturer are presented in Table II.

D. Number of Classes of the Same Course

The maximum numbers of classes for each course are two for each lecturer. For example, Lecturer MM can be assigned to at most two 'Calculus 1' course (MAT183) classes.

E. Preference Weights of Academic Staff to Offered Courses

As different lecturers have different preferences and experiences in each course, a survey was conducted to obtain the required information. As a result, the preference weights are broken down into four different categories.

Category 1: Lecturer prefers to teach and has experience teaching the course. For example, Lecturer MFA prefers to teach MAT112 and at the same is experienced in teaching the course.

Category 2: Lecturer prefers to teach but has no experience teaching the course. For example, Lecturer MFA prefers to teach MAT133 but is inexperienced in teaching the course.

Category 3: Lecturer does not prefer but has experience teaching the course. For example, Lecturer MFA does not prefer to teach MAT183 but has teaching experience.

Category 4: Lecturer with unknown preference and no teaching experience. Hence, it is not possible to be decided by a newly appointed academic staff.

The preference weights are assigned to every lecturer corresponding to each course, as presented in Table III. The weights '3', '2', '1' and '0' are given to Category 1, Category 2, Category 3 and Category 4, respectively.

TABLE III. PREFERENCE WEIGHTS FOR EACH LECTURER AND COURSE

Courses	Lecturers								
	MFA	***MM***	***FS***	***AD***	***AS***	***M1***	***M2***	***M3***	***M4***
MAT112	3	1	1	3	0	3	2	2	2
MAT133	1	3	3	0	1	0	2	2	2
MAT183	3	3	3	3	3	0	2	2	2
MAT210	0	0	3	0	3	3	2	2	2
MAT222	0	2	3	1	0	0	0	0	0
MAT233	3	0	0	3	3	3	0	0	0
MAT263	3	3	3	3	2	3	0	0	0

Therefore, the goal of the teaching load allocation model is to allocate the lecturer to the course based on his/her preference and experience without any condition.

III. TEACHING LOAD ALLOCATION MODEL

The mathematical model is developed to minimize and resolve the problems of teaching load allocation. This model is based on an optimization model proposed [1]. The notations used in this paper are listed below.

I : The set of all courses, *i*

J : The set of all lecturers, *j*

x_{ij} : Number of teaching hours (decision variable) for course *i*, lecturer *j*

p_{ij} : Preference weight for course *i*, lecturer *j*

C_i : The number of classes for course *i*

t_i : The contact hour for course *i*

$t_j^{\min}$: The minimum contact hours for lecturer *j*

$t_j^{\max}$: The maximum contact hours for lecturer *j*

$n_j^{\min}$: The minimum number of classes for lecturer *j*

$n_j^{\max}$: The maximum number of classes for lecturer j

The linear programming model can be formulated as:

$$\max \sum_{i \in I} \sum_{j \in J} p_{ij} x_{ij} \quad (1)$$

Subject to

$$\sum_{j \in J} x_{ij} = C_i, \text{ for } i \in I \quad (2)$$

$$t_j^{\min} \le \sum_{i \in I} t_i x_{ij} \le t_j^{\max}, \text{ for } j \in J \quad (3)$$

$$n_j^{\min} \le \sum_{i \in I} x_{ij} \le n_j^{\max}, \text{ for } j \in J \quad (4)$$

$$0 \le x_{ij} \le 2, \text{ for } i \in I, \quad j \in J \quad (5)$$

The objective function (1) is to maximize the total number of courses taught by the lecturers according to their preference weights. Constraint (2) imposes the number of classes for each course. Constraint (3) defines the contact hours that lecturer should teach. Meanwhile constraint (4) refers to a number of classes that lecturer should teach and constraint (5) allocates at most two classes of the same course.

IV. Results and Discussions

The linear programming model was run through LINGO® optimization software, and a feasible solution was found. The teaching load allocation is presented as in Table IV.

TABLE IV. ALLOCATION OF CLASSES TO LECTURERS BY COURSES

Courses	Lecturers								
	MFA	***MM***	***FS***	***AD***	***AS***	***M1***	***M2***	***M3***	***M4***
MAT112	2	0	0	1	0	0	2	2	2
MAT133	0	0	0	0	0	0	2	1	0
MAT183	0	2	0	0	0	0	0	1	2
MAT210	0	0	1	0	2	2	0	0	0
MAT222	0	0	1	0	0	0	0	0	0
MAT233	0	0	0	1	0	0	0	0	0
MAT263	2	2	2	2	2	2	0	0	0

As demonstrated in Table IV, nine classes of MAT112 course are assigned to Lecturers MFA, AD, M2, M3, and M4. For MAT133, three classes are assigned to Lecturers M2 and M3. Meanwhile for MAT183, five classes are assigned to Lecturers MM, M3, and M4. Five 'Discrete Mathematics' (MAT210) classes are distributed to Lecturers FS, AS, and M1. Lecturer FS is assigned to one 'Mathematical Logic and Proving Techniques' (MAT222. In addition, Lecturer AD is assigned to one 'Calculus II' (MAT233) class. Lastly, 12 classes of 'Linear Algebra I' (MAT263) are assigned to Lecturers MFA, MM, FS, AD, AS, and M1.

Each lecturer is assigned to a minimum of 16 teaching hours except for lecturer AD with 17 teaching hours. Not only that, a total number of classes for each lecturer is four. Six lecturers get to teach two different courses while the others have to teach three different courses. Table V presents the list of courses and total teaching hours for each lecturer.

TABLE V. LIST OF COURSES AND TOTAL TEACHING HOURS VERSUS LECTURERS

Lecturers	**List of Courses**	**Total Teaching Hours**
MFA	MAT112, MAT263	16
MM	MAT183, MAT263	16
FS	MAT210, MAT222, MAT263	16
AD	MAT112, MAT233, MAT263	17
AS	MAT210, MAT263	16
M1	MAT210, MAT263	16
M2	MAT112, MAT133	16
M3	MAT112, MAT133, MAT183	16
M4	MAT112, MAT183	16

The objective function (1) of the linear programming model has been achieved due to the maximized allocating teaching hours based on the preference weights. Every lecturer is assigned to the courses that he or she prefers. Lecturer MFA gets to teach MAT112 and MAT263 where the preference weight is '3'. However, Lecturer AS gets to teach MAT210 and MAT263 where the preference weights are '3' and '2', respectively. The allocation of teaching loads for the remaining lecturers are consistent with the preference weights as presented in Table III.

The teaching hours for MAT263 are allocated to all lecturers with preference weight '3', except for Lecturer AS with preference weight '2'. This is unavoidable due to the number of MAT263 classes in the given semester is 12 where it should be distributed to at least six lecturers. Nevertheless, Lecturer AS still prefers to teach the course even though he/she has no experience in teaching the course.

The teaching unit applied the case study by only considering four constraints. Feasibility issues may arise if this model is to be used to solve allocation problem involving more calculated constraints. The model can be further extended to scheduling and timetabling problems where more constraints need to be considered. For instance, number of available classes or students' and lecturers' availability in a given semester due to medical or sabbatical leave will be taken into account.

V. Conclusion

This study is to determine which courses are best taught by the most suitable lecturer. The optimization model (1) proposed is meant to optimize the teaching load allocation at the Mathematics Department, Faculty of Computer and Mathematical Sciences, UiTM Pahang, Raub campus for June 2016 semester. A survey was conducted to obtain the preference weights for each lecturer towards each course. As a result, the allocation problem was formulated as a linear programming model and solved using LINGO® optimization

software. The feasible solution was found and all the constraints were satisfied. The task required less time and proven more efficient as the allocation was obtained via the software. The optimal solution was able to maximize lecturers' preferences towards teaching the courses. Future improvement of the mathematical model is suggested by considering more constraints and expanding the application onto faculty-course-class timetabling and scheduling problems.

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REFERENCES

[1] X. Qu, S. Wang, S. Easa, and Z. Liu, "Teaching load allocation in a teaching unit: Optimizing equity and quality," *25th Annu. Conf. Australas. Assoc. Eng. Educ. Eng. Knowl. Econ. Collab. Engagem. Employab.*, p. 1275, 2014.

[2] M. A. Badri, "A two-stage multiobjective scheduling model for [faculty-course-time] assignments," *Eur. J. Oper. Res.*, vol. 94, no. 1, pp. 16–28, 1996.

[3] S. Daskalaki and T. Birbas, "Efficient solutions for a university timetabling problem through integer programming," in *European Journal of Operational Research*, 2005, vol. 160, no. 1, pp. 106–120.

[4] H. Heitmann and W. Brüggemann, "Preference-based assignment of university students to multiple teaching groups," *OR Spectr.*, vol. 36, no. 3, pp. 607–629, Jul. 2013.

[5] N. Aidya Aizam and L. Caccetta, "Computational models for timetabling problem," *Numer. Algebr. Control Optim.*, vol. 4, no. 3, pp. 269–285, 2014.

[6] H. Babaei, J. Karimpour, and A. Hadidi, "A Survey of Approaches for University Course Timetabling Problem," *Comput. Ind. Eng.*, vol. 86, pp. 43–59, 2014.

[7] S. Ribic, R. Turcinhozic, and A. Muratovic-Ribic, "Modelling constraints in school timetabling using integer linear programming," in *2015 XXV International Conference on Information, Communication and Automation Technologies (ICAT)*, 2015, pp. 1–6.