

OPTIMIZING TEACHING ALLOCATION WITH PREPARATION TIME CONSTRAINT: A LINEAR PROGRAMMING APPROACH

Fairuz Shohaimay^{1*}, Suriyati Ujang¹

¹*School of Mathematical Sciences, College of Computing, Informatics and Mathematics,
Universiti Teknologi MARA, Pahang Branch, Raub Campus*

**Corresponding author: fairuzshohaimay@uitm.edu.my*

Abstract

The process of allocating optimal teaching workload among lecturers is intricate. Various work requirements must be considered and balanced apart from teaching duties, such as research, publications, and administrative obligations. Traditionally, allocation of teaching load considers the number of courses, groups, and teaching hours without factoring the preparation time. However, with larger group size, preparation time increases significantly. This study introduces a new constraint to reflect the preparation time factor in the teaching load allocation problem. Using the linear programming model, nine courses and a total of 37 groups are to be distributed among nine lecturers, projected for the October 2024 semester. The model considers all the minimum and maximum requirements for each lecturer, and accounts for group size when estimating the preparation time. Then, the model is solved using an online optimization solver, NEOS Server. Results revealed an optimal teaching load distribution satisfying all seven constraints, including the preparation time factor. This model provides a better allocation of teaching duties, suggesting future improvements could be refined by examining how the preparation time scales with increased assignment of courses. Overall, this study proposed a practical approach for a more balanced teaching load distribution considering preparation time, facilitating a better management of lecturer workloads.

Keyword: higher education, linear programming, preparation time, resource optimization, teaching allocation

Introduction

Teaching load allocation in academic institutions presents complex challenges, balancing faculty expertise, course requirements, and institutional constraints. Most academics and administrative evaluators struggle to balance conflicting responsibilities other than teaching, such as research and service (Bajwa et al., 2024) or administration duties (Kenny & Fluck, 2022). Universities are also expected to increase their productivity and efficiency while receiving less financing from the government (Abbott & Doucouliagos, 2003) and can be considered financially stressed organisations (Kenny & Fluck, 2022). Achieving balance is essential not only for meeting academic needs but also for maintaining faculty well-being, which can directly impact teaching quality and institutional performance (Kenny & Fluck, 2022).

The allocation of teaching responsibilities is a critical task in academic planning, impacting educational quality (Muniandy et al., 2021), faculty workload, and institutional efficiency (Abbott & Doucouliagos, 2003). To maintain a high level of instruction and provide teachers with a sense of fulfilment in their work, a suitable distribution of teaching

subjects must be determined by factors such as experience, expertise, and preference (Muniandy et al., 2021). Traditional methods often struggle to account for multiple competing factors and changing constraints. Linear programming offers a powerful tool to navigate these complexities.

Previous linear programming model used in the teaching allocation problem by Shohaimay et al. (2016), Aziz and Aizam (2017), Mat Saleh et al. (2019), Alsaeed (2020), Na and Hussin (2021) and Zaulir et al. (2022) did not consider preparation time and total teaching and preparation time by the lecturer. Bajwa et al. (2024) also mentioned an extensive amount of study on teaching and learning, but not much on how approaches are arranged concerning the effort to result. It is impractical to expect the instructor to maximize student learning without considering the time and effort required. An examination of the literature and current practices by AlSaeed (2020) indicated that there is no structure or mechanism to track the amount of time spent on workload or to determine the proportion of the workload given.

This study applies linear programming to optimize teaching assignments for the upcoming semester, addressing evolving academic needs and faculty well-being. Therefore, this study aims to incorporate a new constraint to reflect the total workload cap, including preparation time to find the optimal teaching load allocation. The application of this model is applied to real-world data for the upcoming semester.

Materials and Methods

The teaching load allocation problem involves assigning different groups of each course to lecturers while satisfying various constraints and optimizing certain objectives. The course allocation requires a different number of groups per course based on the number of student course registration. The allocation of teaching load to lecturers needs to consider their preferences, expertise, and experiences to ensure the best possible teaching outcomes for students. Next, the minimum and maximum teaching loads guarantee each lecturer meeting the required teaching hours while avoiding teaching overload. However, the preparation time factor must be considered since the lecturer needs time to develop materials and evaluate assessments. Hence, a new constraint is introduced based on the calculation of total workload for lecturers which is based on the contact hours per week for each course and the preparation time for each group based on the number of students. The teaching load allocation for each lecturer must not exceed the maximum total workload cap.

Data collection

The data for this study was collected based on the information of student enrolment for the October 2024 semester. There are nine courses: CR1A, CR1B, CR1C, CR2, CR3, CR4, CR5, CR6, CR7, to be assigned to nine lecturers (L1-L9). The list of courses and lecturers involved is given in **Table 1**.

Table 1 The set of courses and lecturers for October 2024 semester

Set	Members of the set
Course	CR1A, CR1B, CR1C, CR2, CR3, CR4, CR5, CR6, CR7
Lecturer	L1, L2, L3, L4, L5, L6, L7, L8, L9

The number of groups for each course is decided according to the number of students registered for the semester. The contact hours for each course are based on the course requirement. Based on the existing practices and class capacity, the maximum number of

students per group is 30-40 students. The average preparation time factor considers the number of students per group. Specifically, the preparation time factors 0.5 or 0.6 is given for a group size of maximum 30 or 40 students, respectively. The number of groups, contact hours, estimated group size, and average preparation time factor per group for each course are presented in **Table 2**.

Table 2 The number of groups, contact hours, estimated group size, and average preparation time factor for each course

Course	Number of groups	Contact hours per group per week	Estimated group size (maximum 30 or 40 students)	Average preparation time factor per group per contact hour per week
CR1A	10	4	40	0.6
CR1B	5	4	40	0.6
CR1C	5	4	40	0.6
CR2	6	4	40	0.6
CR3	2	4	40	0.6
CR4	5	4	40	0.6
CR5	1	2	30	0.5
CR6	1	5	30	0.5
CR7	2	4	30	0.5

The minimum and maximum total teaching hours per week are determined based on the academic position. Senior lecturers (L1, L2, and L3) are expected to have higher research activity requirements are expected. Hence, the minimum-maximum range is 12-16 hours per week. For lecturers L4, L5, and L6, with lower research activity requirements, the minimum-maximum range is 16-18 hours per week. Part-time lecturers are appointed based on the number of groups that exceeds the maximum teaching load of the permanent lecturers. They are only required to focus on teaching duties, with a minimum-maximum range of 20-24 hours per week. However, the exact number of part-time lecturers is still being determined. Based on the university policy, appointed part-time lecturers must work at least 20 hours per week. If not, hiring a part-time lecturer is unnecessary to reduce costs. To accommodate this uncertainty, part-time lecturer L7 is assigned the minimum 20 teaching hours per week. Nevertheless, the minimum teaching hours and groups assigned to part-time lecturers L8 and L9 are set to zero. **Table 3** presents the total teaching hours, the number of groups, and the maximum total workload per week.

Table 3 Minimum and maximum total teaching hours and number of groups; and maximum total workload per week

Lecturer	Total teaching hours per week		Total number of groups per week		Maximum total workload (including preparation) per week
	Minimum	Maximum	Minimum	Maximum	
L1	12	16	3	4	27
L2	12	16	3	4	27
L3	12	16	3	4	27
L4	16	18	4	5	30
L5	16	18	4	5	30
L6	16	18	4	5	30
L7	20	24	5	6	36
L8	0	24	0	6	36

L9	0	24	0	6	36
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The preference weights for each lecturer are determined for the semester based on four different categories as explained in Shohaimay et al. (2016). **Table 4** shows the preference weight assigned to each lecturer based on each course.

Table 4 Preference weights for each lecturer based on each course

Course	Lecturer								
	L1	L2	L3	L4	L5	L6	L7	L8	L9
CR1A	0	0	1	1	1	3	1	1	1
CR1B	0	0	1	1	1	3	1	1	1
CR1C	0	0	1	1	1	3	1	1	1
CR2	3	1	0	1	0	1	1	0	0
CR3	0	1	1	3	1	1	1	0	0
CR4	1	3	1	1	0	0	0	0	0
CR5	0	3	1	0	0	0	0	0	0
CR6	3	0	0	1	3	0	0	0	0
CR7	0	0	3	0	0	0	0	0	0

Linear Programming Model

The teaching allocation problem is formulated as follows, based on the linear programming model presented in Qu et al. (2014) and Shohaimay et al. (2016).

1. Sets, Parameters, and Decision Variable

- I : Set of all courses, i
- J : Set of all lecturers, j
- p_{ij} : Preference weight for course i , lecturer j
- C_i : Number of groups for course i
- t_i : Contact hour per week for course i
- t_j^{min} : Minimum total contact hour per week for lecturer j
- t_j^{max} : Maximum total contact hour per week for lecturer j
- n_j^{min} : Minimum total number of groups per week for lecturer j
- n_j^{max} : Maximum total number of groups per week for lecturer j
- apt_i : Average preparation time factor for course i
- TW_j^{max} : Maximum total workload (including preparation) for lecturer j
- x_{ij} : Number of groups (decision variable) for course i assigned to lecturer j ,
such that x_{ij} are integers, $x_{ij} \in \mathbb{Z}$

2. Objective function and constraints

The objective is to maximize the total number of groups for each course assigned to lecturer based on their preference weights.

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

Subject to

- a. Course allocation constraint: For each course i in I

$$\sum_{j \in J} x_{ij} = C_i. \quad (2)$$

- b. Minimum contact hours constraint: For each lecturer j in J

$$\sum_{i \in I} t_i \cdot x_{ij} \geq t_j^{min}. \quad (3)$$

- c. Maximum contact hours constraint: For each lecturer j in J

$$\sum_{i \in I} t_i \cdot x_{ij} \leq t_j^{max}. \quad (4)$$

- d. Minimum groups constraint: For each lecturer j in J

$$\sum_{i \in I} x_{ij} \geq n_j^{min}. \quad (5)$$

- e. Maximum groups constraint: For each lecturer j in J

$$\sum_{i \in I} x_{ij} \leq n_j^{max}. \quad (6)$$

- f. Decision variable constraint: For each course i in I , each lecturer j in J

$$0 \leq x_{ij} \leq 3, \quad (7)$$

- g. Total workload cap constraint: For each lecturer j in J

$$\sum_{i \in I} t_i \cdot (1 + apt_i) \cdot x_{ij} \leq TW_j^{max}. \quad (8)$$

The first constraint in (2) ensures that the total number of groups for each course must be equal to the required number of groups for the course. Constraints in (3) and (4) guarantee that each lecturer must be assigned at least their minimum required total contact hours per week and must not exceed their maximum limit. Constraints in (5) and (6) allocate the minimum number of groups to each lecturer and must not exceed his/her maximum limit. Constraint (7) restricts the number of groups of the same course for each lecturer must be at most three groups. Finally, the new constraint in (8) ensures that the total teaching workload, including preparation time, for each lecturer must not exceed their maximum allowed workload. The constraint accounts for both teaching and preparation time, ensuring a balanced overall workload.

Results and Discussion

The teaching allocation model was implemented and solved by using an online optimization solver, the NEOS Server (<https://neos-server.org/neos/>), utilizing the CPLEX solver, version 22.1.1.0. The solver obtained an optimal allocation of teaching loads as displayed in **Table 5**.

Table 5 Optimal teaching load allocation, number of groups for each course and each lecturer

	L1	L2	L3	L4	L5	L6	L7	L8	L9
CR1A	0	0	0	2	3	1	0	1	3
CR1B	0	0	0	0	0	3	0	2	0
CR1C	0	0	0	0	0	0	2	1	2
CR2	3	0	0	0	0	0	3	0	0
CR3	0	0	0	2	0	0	0	0	0
CR4	0	3	2	0	0	0	0	0	0
CR5	0	1	0	0	0	0	0	0	0
CR6	0	0	0	0	1	0	0	0	0
CR7	0	0	2	0	0	0	0	0	0

Table 6 shows the distribution of groups for each course among the lecturers. The course CR1A, CR1B, and CR1C were assigned to six lecturers (L4-L9). Next, the courses CR2 and CR4 were assigned to two lecturers. While the other courses CR3, CR5, CR6, and CR7 were assigned to one lecturer only.

Table 6 Course distribution among lecturers

Course	Lecturer
CR1A	L4, L5, L6, L8, L9
CR1B	L6, L8
CR1C	L7, L8, L9
CR2	L1, L7
CR3	L4
CR4	L2, L3
CR5	L2
CR6	L5
CR7	L3

Table 7 presents the courses, total contact hours and total workload assigned to each lecturer. The total contact hours are calculated based on the number of groups by course and their corresponding contact hours, as shown in **Table 2**. For example, L1 is assigned three groups of CR2 course, which is 12 total contact hours (3 groups $\times$ 4 contact hours). The total workload is calculated based on the contact hours and preparation time factor per course multiplied by the number of groups assigned per course. Lecturer L2 ($j = 2$) is assigned to CR4 and CR5, with the preparation time factors 0.6 and 0.5, respectively based on **Table 2**. Therefore, the total workload for L2, $TW_{j=2}$ is computed as follows:

$$\begin{aligned}
 TW_{j=2} &= [CR4: t_4 \times (1 + apt_4) \times x_{42}] + [CR5: t_5 \times (1 + apt_5) \times x_{52}] \\
 &= [4 \text{ hours} \times (1 + 0.6) \times 3 \text{ groups}] + [2 \text{ hours} \times (1 + 0.5) \times 1 \text{ group}] \\
 &= 19.2 + 3 \\
 &= 21.2
 \end{aligned} \tag{9}$$

Table 7 Number of groups by course, total contact hours and total workload for each lecturer

Lecturer	No. of Group $\times$ Course	Total contact hours	Total workload
L1	3 $\times$ CR2	12	19.2
L2	3 $\times$ CR4, 1 $\times$ CR5	14	21.2
L3	2 $\times$ CR4, 2 $\times$ CR7	16	24.8
L4	2 $\times$ CR1A, 2 $\times$ CR3	16	25.6
L5	3 $\times$ CR1A, 1 $\times$ CR6	17	26.7
L6	1 $\times$ CR1A, 3 $\times$ CR1B	16	25.6
L7	2 $\times$ CR1C, 3 $\times$ CR2	20	32
L8	1 $\times$ CR1A, 2 $\times$ CR1B, 1 $\times$ CR1C	16	25.6
L9	3 $\times$ CR1A, 2 $\times$ CR1C	20	32

The solution satisfies all constraints while maximizing the overall preference-weighted assignment.

- Course requirements: The sum of assignments for each course matches the number of groups. For example, CR1A, CR1B and CR1C has a total of 20 groups assigned to lecturers L4, L5, L6, L7, L8, and L9. While CR2 has a total of six groups assigned to lecturers L1 and L7.
- Minimum contact hours: Each lecturer is assigned to at least his/her minimum required contact hours. For example, L1 is assigned three groups of course CR2, meeting the 12 minimum contact hours; and L7 is assigned to his/her minimum 20 contact hours.
- Maximum contact hours: No lecturer exceeds his/her maximum contact hour limit. Only L3 is assigned to his/her maximum 16 contact hours.
- Minimum groups: All lecturers are assigned at least their minimum number of groups. For example, L1, L4, L5, L6, and L7 are assigned to 3, 4, 4, 4, and 5 groups, respectively.
- Maximum groups: No lecturer exceeds his/her number of allowed groups. For example, L2 and L3 are both assigned to 4 groups each.
- Decision variable: No lecturer is assigned to more than 3 groups of the same course. For example, L1, L2, L5, and L6 are assigned to at most three groups of courses CR2, CR4, CR1A, and CR1B, respectively.
- Total workload cap: The solution satisfies the new constraint on total workload, including the preparation time factor. For example, L2 is assigned to three groups and one group of courses CR4 and CR5, respectively. The total workload is 21.2, less than 27 maximum total workload cap.

The results demonstrate several critical advantages of the proposed approach. Firstly, the linear programming model helps to provide an optimal allocation solution by balancing multiple constraints for different lecturers. The total workload for teaching must also reflect the time allocated to prepare before and after the teaching activity. Incorporating the additional total workload constraint leads to an improved solution for the teaching allocation problem, as it considers the preparation time required by each lecturer based on the number of assigned groups. Despite the advantages, the total workload calculation only considers different numbers of groups and fixed preparation time factors based on the group size (maximum 30 or 40 students). The calculation must reflect the additional preparation time needed for a lecturer assigned to two or more courses. The total workload increases significantly for the lecturer since the teaching and preparation time are multiplied by the number of courses to be taught in a semester. Therefore, the total workload constraint can be refined to improve this limitation. Thus, the optimal teaching allocation solution will facilitate greater efficiency for lecturers in meeting the demands of their work in addition to

teaching, such as research, publication, and supervision.

Conclusion

This study aims to incorporate a new constraint to reflect the total workload cap, including preparation time to find the optimal teaching load allocation. The optimal solution satisfies all constraints while considering the preparation time required where it is often overlooked when the teaching load allocation is done. Maintaining the optimal productivity and efficiency of the faculty while considering the time and effort needed to fulfil the workload given would significantly improve the teaching quality and the learning process. Most academics and administrative evaluators struggle to balance conflicting responsibilities other than teaching, such as research and service or administration. Acknowledging the effort and time required is a good start to develop a structure or better mechanism for measuring the actual workload given to faculty members. In conclusion, while the current model provides a solid foundation for course allocation, there is room for refinement to better capture the complexities of real-world academic scheduling. The suggested improvements could lead to a more robust and flexible system that not only optimizes current preferences but also supports long-term departmental goals and lecturer career development.

Ethics Statement

The research does not require research ethics approval.

Authors Contribution

Writing – Original draft preparation, Shohaimay, F; Literature Review, Ujang, S; Methodology, Shohaimay, F; Writing – Review and editing, Shohaimay, F & Ujang, S.

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Conflict of interests

All authors declare that they have no conflict of interest.

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