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Optimizing multi-objective lecturer-to-course assignments using the modified Hungarian method: Balancing competency and preferences

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ABSTRACT Efficiently assigning lecturers to courses is a critical aspect of ensuring both faculty satisfaction and optimal teaching outcomes in Higher Education Institutions. This study introduces an innovative Modified Hungarian Method (MHM) optimization model to address this challenge by incorporating lecturers' competency scores and preference levels. While previous studies have primarily utilized the traditional Hungarian Method, limited attention has been given to its modified counterpart. Additionally, the application of competency and preference-based criteria in lecturer-to-course assignments remains unexplored. To address these gaps, this research develops a mathematical programming approach to enhance the formulation of the MHM model. The proposed model, referred to as the Competency-Preference Multi-Objective MHM (CP MO-MHM), seeks to achieve two main objectives, maximizing lecturers' competencies and maximizing their preferences in course assignments. Competency is evaluated through three dimensions that are knowledge, skills and teaching motivation. Data for this study were collected via an online survey of Mathematics lecturers teaching undergraduate courses at UiTM Shah Alam, Malaysia. Using the gathered competency scores and preference levels, the CP MO-MHM model was implemented in MATLAB's *intlinprog* function to generate an optimal lecturer-to-course assignment plan, with a maximum limit of three courses per lecturer. The results demonstrate that the CP MO-MHM model effectively identifies the most suitable course assignments for lecturers based on their competencies and preferences. By adapting the MHM framework to integrate these multidimensional inputs, this study contributes a practical tool for improving educational planning. The model not only enhances teaching quality but also minimizes mismatches between lecturers and courses, promoting better academic performance and greater satisfaction among faculty members. This research offers significant advancements in lecturer assignment processes, paving the way for more efficient and effective resource management in academia.

KEYWORDS: Competency; Preferences; Lecturers-to-Courses Assignment; Mathematical Programming; Modified Hungarian Method
Received 6 June 2025 **Revised** 20 June 2025 **Accepted** 20 August 2025 **In press** 23 August 2025 **Online** 6 September 2025

Original Article

INTRODUCTION

The effective allocation and assignment of lecturers to courses is a critical factor in maintaining educational quality and ensuring faculty satisfaction within academic institutions. Traditionally, such assignments have been managed manually or through basic algorithms like the Hungarian Method (HM), which addressing the complex interplay of lecturer competencies and preferences are still lacking. However, with the rising number of students and the increasing diversity of courses, institutions are frequently faced with an imbalance between the number of lecturers and the courses available. This challenge necessitates the application of advanced methods such as the Modified Hungarian Method (MHM), which offers a robust solution for handling unbalanced assignment problems. Previous research has predominantly utilized the HM, with limited exploration of the MHM for lecturer-to-course assignment. While the HM excels in balancing assignments, it is less effective in scenarios where there is an unequal distribution of resources such as mismatched numbers of lecturers and courses. Our study is the first to apply the MHM model specifically to this context (Ibrahim *et al.*, 2024). Furthermore, past studies have often focused on either lecturers' competencies or their preferences, neglecting the benefits of addressing both simultaneously. In addition, mathematical programming models that considered both lecturer competency and preference as dual objectives are still lacking. This gap is critical, as lecturers possess varying expertise across different Mathematics courses, complicating assignment decisions. This paper proposes an enhanced Competency-Preference Multi-Objective Modified Hungarian Method (CP MO-MHM) model to address unbalanced lecturer-to-course allocations. The model simultaneously maximizes competency scores and preference levels, ensuring optimal, expertise-aligned assignments that support improved teaching outcomes.

BACKGROUND THEORY

Hungarian Method (HM) model

Assigning lecturers to courses in higher education is a complex task requiring a balance between institutional needs and lecturers' competencies and preferences. Traditional methods like manual allocation or the Hungarian Method (HM) model, introduced by Kuhn (1955), offer simplicity and effectiveness for balanced datasets but lack with unbalanced scenarios involving mismatched lecturer and course numbers. This task is part of optimization theory, focusing on distributing resources to maximize objectives such as cost-efficiency or quality. Lecturer competency, as emphasized by Abdul Latip *et al.* (2020), directly impacts student satisfaction and academic performance, while preferences, including scheduling and subject expertise, enhance lecturer satisfaction and effectiveness. Past studies have employed the HM model for lecturer assignments but primarily for balanced problems. For instance, Solaja *et al.* (2020) demonstrated improved lecturer effectiveness in Nigerian institutions by aligning tasks with assignments. Additionally, Kabiru *et al.* (2017) highlighted the utility of HM with LINGO software to create optimal staff-course schedules. Similarly, Udok & Victor-Edema (2023) validated HM's effectiveness through manual computations for postgraduate courses in Mathematics and Statistics. Despite these successes, HM's application is limited in handling unbalanced assignment scenarios, necessitating more advanced solutions. Studies like those by Wattanasiripong & Sangwaranatee (2021) and Ahmed *et al.* (2022) have used Hungarian Method (HM)-based solutions to match lecturers with courses, improving teaching quality and decision-making efficiency. However, these approaches often assume balanced scenarios with equal numbers of lecturers and courses, neglecting unbalanced cases.

Modified Hungarian Method (MHM) model

The MHM model is recommended for unbalanced problems and has demonstrated versatility across fields. For example, Zhang *et al.* (2021) applied it to multi-agent pursuit evasion and Wei *et al.* (2022) enhanced federated learning in wireless networks. In IoT systems, Liu *et al.* (2021) and Ge *et al.* (2020) used MHM model to optimize subchannel allocation, while Mukherjee and De (2023) employed it for resource allocation in 5G networks. Despite its proven efficacy, MHM remains unexplored for lecturer-to-course assignments. This study pioneers the application of MHM model in this domain, introducing five MHM model variants to optimize lecturer assignments. These models maximize either lecturers' preference levels, competency scores or both, addressing multiple objectives through goal programming methods (Ibrahim *et al.*, 2024). This innovative approach offers a robust solution for handling unbalanced scenarios in academic settings. This gap inspired the development of a novel Competency-Preference Multi-Objective MHM (CP MO-MHM) model to address unbalanced lecturer-to-course assignments.

METHODOLOGY

Phases of This Study

This study comprises four phases that are data collection and analysis, development of the enhanced MHM model, computational experiments and result analysis. Data were collected from March to August 2023 through an online survey involving 39 Mathematics Department lecturers at UiTM Shah Alam and covering 35 undergraduate courses. The Likert scale scores for competency and preference (1–4) were converted into interval values (0.25–1.0) to normalize ordinal data for optimization modeling, following established practices in educational resource allocation studies (Abdul Latip *et al.*, 2020). Preferences (p) were converted to percentages where a score of 1 corresponded to $p_{ij} = 0.25$, 2 is $p_{ij} = 0.5$, 3 is $p_{ij} = 0.75$ and 4 is $p_{ij} = 1$. The average score of the three competencies is to be assigned a value q_{ij}. If q_{ij} is between $0 < average \leq 0.25$, then it is in score 1. If q_{ij} is between $0.25 < average \leq 0.50$, then the score 2 whereas if q_{ij} is between $0.50 < average \leq 0.75$, the score is 3. Meanwhile if q_{ij} is between $0.75 < average \leq 1.00$, the score is 4. This is done by taking the sum of scores for all elements of competency for each course and divided it by 12, which is the maximum values for the three elements to get a value between 0 to 1. For example, Lecturer SA1 have scores for knowledge (2), skills (3) and teaching motivation (3), then the average competency score $= \frac{(2+4+3)}{12} = 0.75$. The final competency scores for lecturer SA1 is $q_{ij} = 0.75$ (score 3) because the average is between $0.50 < average \leq 0.75$. The expansion of MHM optimization model was done in Excel using the data gathered and competency scores (q_{ij}) and preference levels ($p_{ij)}$ as coefficients of the objective functions of the model. The input matrices derived from the Excel model were then used to solve the model using MATLAB's intlinprog function. The formulation of the enhanced MHM model is as follows.

The MHM Model for Competency-Preference Multi-Objective (CP MO-MHM Model)

Our study has developed five variants of the enhanced MHM model for lecturer-to-course assignment problem in which one of them is the MHM model for maximizing competency scores and maximizing preference levels of lecturers (CP MO-MHM) model as following.

CP MO-MHM Model Formulation

Notation – Sets, Indices, Parameters, and Input Variables:

m	:	number of lecturers ($m = 39$)
n	:	number of courses ($n = 35$)
i	:	index for lecturers
j	:	index for courses
q_{ij}	:	lecturer i competency to get course j
p_{ij}	:	lecturer i preferences to get course j
x_{ij}	=	$\begin{cases} 1, \text{lecturer } i \text{ is assigned course } j \\ 0, \text{otherwise} \end{cases}$

$$\text{Maximize} \quad Z_1 = \sum_{i=1}^{m} \sum_{j=1}^{n} q_{ij} x_{ij} \tag{1}$$

$$\text{Maximize} \quad Z_2 = \sum_{i=1}^{m} \sum_{j=1}^{n} p_{ij} x_{ij} \tag{2}$$

subject to

$$\sum_{i=1}^{m} x_{ij} \geq 1 \qquad , j = 1,2,3 \ldots n \tag{3}$$

$$\sum_{j=1}^{n} x_{ij} \geq 1 \qquad , i = 1,2,3 \dots m \tag{4}$$

$$\sum_{i=1}^{m} x_{ij} \leq 3 \qquad , j = 1,2,3 \dots n \tag{5}$$

$$\sum_{j=1}^{n} x_{ij} \leq 3 \qquad , i = 1,2,3 \dots m \tag{6}$$

$$x_{ij} = \{0, 1\} \qquad , i = 1,2,3 \dots m; \ j = 1,2,3 \dots n \tag{7}$$

The objective function is presented in Equation (1) which is to maximize the competency of lecturers for courses while the second objective function, Equation (2), is to maximize the lecturers' preference values. Constraint (3) is to ensure that one lecturer should be assigned to at least one course. On the other hand, Constraint (4) guarantees that a course must be assigned to at least one lecturer. Constraint (5) restricts that one lecturer can only be assigned to at most three courses. Meanwhile, Constraint (6) dictates that one course can only be assigned to at most three lecturers. The maximum limit of three course assignments per lecturer was set based on UiTM's workload guidelines to ensure balanced teaching loads and maintain instructional quality. Finally, Constraint (7) presents the decision variables in which the binary decision variables only take binary value of either 0 or 1.

RESULT AND DISCUSSION

A Cronbach's Alpha test was conducted to assess the internal consistency of the competency and preference scoring instruments. The results indicated a high reliability with Cronbach's Alpha value with more than 80% (very good and excellent) based on Hair *et al.* (2015), indicating internal consistency across items confirming the consistency of the survey instruments used. Additionally, a Spearman's rank correlation analysis was performed to investigate the relationship between lecturers' competency scores and their course preferences. The analysis demonstrated a very strong, statistically significant positive correlation ($\rho = 0.45$, $n = 1365$ (39 lecturers * 35 courses), $p < 0.000001$), reinforcing the dual-objective approach utilized in the CP MO-MHM model. A sensitivity analysis was conducted by reversing the priority order in the CP MO-MHM model. The top-preference assignment rate remained at 31.43%, while the average competency score decreased from 3.33 to 3.08 as shown in Table 1. This confirms the model's sensitivity, as prioritizing preferences reduces competency alignment without improving preference satisfaction. Table 1 presents the quantitative improvements observed through these benchmarking results.

Table 1. Benchmarking Results of Lecturer-Course Assignment Methods

Method	Top-preference assignment (%)	Average Competency Score
Traditional Hungarian	26.37	2.89
CP MO-MHM (proposed)	31.43	3.33
Preference First (Sensitivity Test)	31.43	3.08

The comparison revealed that while traditional HM resulted in 26.37% of lecturers receiving their top-preferred courses, the CP MO-MHM improved this to 31.43%. The average competency score for the CP MO-MHM is higher than traditional Hungarian method with 3.33. Table 2 shows the compilation of results. Examples of the optimal assignments include for instance, Lecturers SA3, SA21, SA26 and SA32 are assigned only one course. Meanwhile, there are also lecturers who have been assigned with two courses. For example, Lecturer SA4 is assigned two courses namely MAT406 (Foundation Mathematics) and MAT565 (Advanced Differential Equations) while Lecturer SA7 is assigned MAT491 (Calculus III) and MAT560 (Vector Calculus). Lecturers can be assigned up to three courses. For instance, Lecturer SA1 is assigned MAT495 (Partial Derivatives and Approximation Methods), MAT522 (Ordinary Differential Equations) and MAT612 (Partial Differential Equations) whereas Lecturer SA2 is assigned MAT415 (Discrete Mathematics), MAT530 (Introduction to Mathematical Modelling) and MAT570 (Mathematics Economics). Several lecturers are also assigned to teach courses at various levels of the undergraduate program such as lecturers SA1, SA16, SA28, SA31 and SA33 have three different levels with the first digit of the course code (4, 5, or 6). The courses might be in different course levels. Conversely, lecturer SA22 and SA39 get to teach all first-year courses with the first digit of 4 whereas there are a few lecturers that get to teach courses with second- and third-year courses which are with the first digit of 5 and 6. For instance lecturers SA5 and SA19. The analysis of the optimal solutions from the CP MO-MHM model, as shown in Tables 2, highlights the suitability and expertise of lecturers in their assigned courses.

Table 2. Result of Lecturer to Course Assignment Based on CP MO-MHM

Lecturer	Courses			Lecturer	Courses		
SA1	MAT495	MAT522	MAT612	SA21	MAT583		
SA2	MAT415	MAT530	MAT570	SA22	MAT441	MAT472	MAT491
SA3	MAT415			SA23	MAT402	MAT422	MAT570
SA4	MAT406	MAT565		SA24	MAT435	MAT441	MAT631
SA5	MAT578	MAT580	MAT633	SA25	MAT491	MAT530	MAT531
SA6	MAT402	MAT438	MAT522	SA26	MAT538		
SA7	MAT491	MAT560		SA27	MAT417	MAT560	MAT583
SA8	MAT435	MAT455	MAT633	SA28	MAT472	MAT525	MAT668
SA9	MAT512	MAT531	MAT571	SA29	MAT406	MAT423	MAT570
SA10	MAT438	MAT538		SA30	MAT480	MAT495	MAT578
SA11	MAT406	MAT612	MAT631	SA31	MAT422	MAT571	MAT631
SA12	MAT417	MAT455	MAT575	SA32	MAT522		
SA13	MAT523	MAT538	MAT575	SA33	MAT472	MAT531	MAT668
SA14	MAT423	MAT512	MAT523	SA34	MAT438	MAT530	MAT580
SA15	MAT423	MAT435	MAT523	SA35	MAT525	MAT668	
SA16	MAT417	MAT560	MAT612	SA36	MAT402	MAT421	MAT565
SA17	MAT415	MAT422	MAT652	SA37	MAT480	MAT565	MAT580
SA18	MAT525	MAT575	MAT633	SA38	MAT480	MAT578	MAT583
SA19	MAT512	MAT571	MAT652	SA39	MAT421	MAT455	MAT495
SA20	MAT421	MAT441	MAT652				

Note: MAT4XX = First-year course, MAT5XX = Second-year course, MAT6XX = Third-year course

This study has several limitations. First, the competency and preference data were self-rated by lecturers, which may introduce subjective bias. Second, the sample size was limited to 39 Mathematics lecturers from a single university, restricting the generalizability of the findings. Lastly, the study focused exclusively on Mathematics courses, and its applicability to other disciplines requires further exploration. Future work should expand the sample size, diversify academic fields and consider additional variables such as students' preferences.

CONCLUSION

This study proposes a Competency-Preference Multi-Objective Modified Hungarian Method (CP MO-MHM) model for lecturer-to-course assignments, optimizing both competency scores and preference levels. Applied to mathematics lecturers in UiTM Shah Alam, the model achieved an average competency score of 3.33 and a top-preference assignment rate of 31.43% outperforming the

TRANSACTIONS ON SCIENCE AND TECHNOLOGY

traditional Hungarian Method in both measures, ensuring balanced workloads, course coverage and expertise alignment. Sensitivity analysis confirmed the model's outcomes were influenced by the priority structure, with preference-first assignment reducing competency alignment without improving preference satisfaction. Findings highlight the value of systematic assignment approaches and suggest future research to enhance scalability, integrate additional factors and support institutional performance improvement.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknologi MARA (UiTM) for providing research facilities and support for this study.

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