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Research Article

Development and Validation of an Integer Linear Programming Model for the Lecturer-to-Course Assignment Problem

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Abstract

This study developed and validated a formalized and robust integer linear programming (ILP) model to optimize the lecturer-to-course assignment problem (concerning balancing workload) for a university department that offers engineering programs. Questionnaire surveys with 4 groups of a total of 159 informants (10 lecturers, 1 head of department, 1 program coordinator, and 147 mechanical engineering students) were conducted. Enumeration was used for lecturers, the head of the department, and the program coordinator, whilst convenience sampling was used for students, with a response rate of 60%. A binary integer linear programming (ILP) model was developed by considering workload-related constraints such as class capacity, course contact hours, course credits, and the number of courses per lecturer. The ILP model was implemented in optimization software and the results were validated using the Delphi method. The results demonstrate the robustness and efficiency of the model in balancing workload by objectively (reducing biases) assigning under-utilized lecturers to more courses and over-utilized lecturers to fewer courses, in terms of simultaneously considering other workload-related variables, unlike existing studies. These results were used to instill a timely, formal, and consistent assignment approach that is fair and free from biases. The proposed model contributes to enhancing fairness and hence collective satisfaction of lecturers, program coordinators, and students, given a formalized, consistent, and timesaving assignment approach that considers other workload-related variables other than the number of courses per lecturer. Another contribution lies in a deeper understanding of a comprehensive range of factors that play a role in lecturer-to-course assignments for higher education institutions. Moreover, this study has implications for practice, given that other academic institutions may benefit from this work, in terms of policy considerations.

Keywords: Integer linear programming; Workload, Optimization; Delphi; Assignment

1. Introduction

The lecturer-to-course assignment is an assignment problem that represents an extension of a transportation problem (Taha, 2007). The transportation problem is a special class of linear programming problems that deal with shipping a commodity from sources to destinations to determine the shipping schedule that minimizes the total shipping cost while satisfying supply and demand limits. Applications of the transportation problem include inventory control, employee scheduling, and personnel assignment (Taha, 2007). The lecturer-to-course assignment problem, which is the focus of this study, is an application of the transportation problem under the application category of personnel assignment. In this study, personnel refers to lecturers, who are assigned to courses or modules (Caselli et al., 2022; da Cunha and de Souza; 2018; Ferland et al., 2001). Existing empirical studies in operations research literature have contributed to an understanding of the assignment of lecturers to courses, referred to in this study as the lecturer-to-course assignment problem. This assignment problem, viewed as a process, has become an important area of interest for most higher education institutions, given the evolving nature of academic activities concerning the need for assignment model is a special tool for operationalizing the assignment, with the capacity to help heads of departments and course coordinators in determining an optimal assignment concerning maximizing lecturer's effectiveness.

The head of the department is responsible for making decisions associated with assigning lecturers to courses that have to be taught each academic semester.

In the existing assignment process within an engineering department at the case organization, the head of the department uses his intuition, knowledge of lecturers on post as well as his understanding of lecturer's capacity. However, this approach is limited in terms of the need to complement it with scientific techniques of job assignment (Mallicka et al., 2021). The process starts with the head of the department using his intuition and managerial skills as well as past experiences to make a draft lecturer-to-course assignment (Ramotsisi et al., 2022). The head of the department considers lecturer's preferences, and workload in terms of the number of courses per lecturer, the lecturer's level of seniority, and years of teaching experience. After completing the draft lecturer-to-course assignment, the head of the department sends it to two coordinators for each of the two programs (industrial engineering and mechanical Engineering), as well as the lecturers, to get their input. The stakeholders

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then propose amendments, where appropriate. The head of the department then consolidates all proposed amendments and makes a final decision on the lecturer-to-course assignment, which he then officially releases to all stakeholders for implementation at the beginning of an academic semester. This process usually takes between two to five days. Whilst this approach may be necessary for creativity, there is a need to complement it with a formal and balanced approach that accommodates a number of important decision criteria. This formalized approach adds not only to our understanding of what constitutes an effective lecturer-to-course assignment process but also enhances quality assurance in teaching (Kabiru et al., 2017). This need is crucial given the complexity of the assignment process, as a multi-criteria decision-making problem (Belding et al., 2009; Seboni and Tutesigensi, 2015b; Seboni, 2021; Seboni and Moreri, 2022; Triantaphyllou, 2000; Zavadskas et al., 2008). The need for a formal decision-making tool in the lecturer-to-course assignment is necessitated by imbalances in workload distribution among lecturers.

1.1. Gap and study motivations

Although existing studies have contributed to an understanding of assignment problems in general, the gap lies in the need for a comprehensive approach. For example, existing studies have proposed assignment models that do not explicitly consider workload (Patanakul et al., 2007). Other studies consider workload in general and not explicit variables associated with workload other than the number of courses per lecturer (Caselli et al., 2022; da Cunha and de Souza; 2018; Ferland et al., 2001; Güler et al., 2015; Johnson et al., 2022; Saleh et al., 2019; Schniederjans and Kim, 1987).
Motivated by the above gap, this study aims to develop a comprehensive but effective approach that considers several variables, including specific workload-related variables, to not only contribute to existing knowledge but also improve the existing lecturer-to-course assignment practice of the case organization in terms of performance. Assignment processes have been proven to affect performance indicators (Patanakul and Milosevic, 2006; Seboni and Ssegawa, 2022). The proposed model fills the identified literature gap by considering a robust combination of variables such as the number of contact hours, the number of course credits, class capacity for each course, and the number of courses per lecturer.

1.2. Scope and contributions

This study was confined to the following:

- Different aspects of the factors that play a role in the lecturer-to-course assignment process.
- Undergraduate engineering degree students in one large university department offering engineering degree programs.
- Resources within the immediate scope of the lecturer-to-course assignment process.
- Four informant groups namely: Head of department, program coordinator, lecturers, and students.

Notwithstanding the added value of a user interface for practitioners such as the head of department in relation to user-friendliness (Seboni, 2018), the development of a user interface for the proposed model is out of scope. The contributions of this study are:

1. A conceptual framework that identifies variables for an effective lecturer-to-course assignment, including the addition of new variables for measuring workload. These variables are; lecturer to student ratio, the lecturer's service to the community, and the lecturer's research work.
2. Mathematical model results that reveal a practical but effective approach to assigning lecturers to courses in less time when implemented in an optimization software, as well as superiority to both existing studies and the existing practice.
3. A validated model that uses real-life data, in terms of both accuracy and consistency of model results.

The rest of the article is divided into four sections. Section 2 provides a theoretical foundation for the research, in the context of literature review on lecturer-to-course assignment gaps and solution approaches. Section 3 describes the research approach used to achieve the study's aim. Section 4 discusses the implementation of the mathematical model in an optimization software, including the validation of model results. Section 5 concludes the study by providing contributions and implications for both theory and practice, including limitations that give rise to avenues for future research.

2. Literature Review

2.1. Studies on course assignment (stream 1)

Algethami and Laesanklang, (2021) conducted a study about the assignment of lecturers to courses at a departmental level and found that the lecturer-to-course assignment method at Taif University requires administrators to manually generate the assignment plan, which must be completed before each semester's registration period. This manual process includes three primary stages namely timeslots to courses assignment, rooms to courses assignment, and lecturer-to-course assignment. This study focuses on the lecturer-to-course assignment. MirHassani (2006), contents that among other approaches, goal programming models are extensively used for solving lecturer-to-course assignment problems. The most common goals in this type of goal programming model are to distribute courses evenly among students, teachers, and research assistants. It is evident from the above-mentioned studies that goal programming and linear programming are the most widely used techniques for solving decision-making problems such as the lecturer-to-course assignment problem since they produce the most optimal and practical result.

2.2. Methods to solve assignment problems (stream 2)

Solaja et al, (2020) carried out a study on the assignment problem and its application in Nigerian institutions, using the Hungarian method. On the contrary, Akpan and Abraham (2016) conducted a study to critique the

Hungarian Method of solving assignment problems to the alternate method of the assignment problem by Mansi. Akpan and Abraham (2016)'s study showed that although the Hungarian method improves the effectiveness of lecturers, both methods give the same optimal solution, although the alternate method yielded the optimal solution in a few steps. In their study, Domenech and Lusa (2016), developed a mixed integer linear programming (MILP) model while Arinze and Partovi (2000) conducted a study to examine the problem of assigning lecturers to courses at a university. Arinze and Partovi (2000) argue that traditional operations research methods emphasizing the use of mathematical models suffer several shortcomings. These shortcomings include poor handling of qualitative data, undue abstraction from the problem, the difficulty of problem formulation, and the combinatorial problem.

2.3. Variables for the lecturer-to-course assignment problem (stream 3)

Following a critical appraisal of operations research literature (Arinze and Partovi, 2000; Babad et al., 2004; Awang et al., 2020; Bhoi and Dhodiya, 2021; Caselli et al, 2022; Faudzi et al., 2020; Malik and Nordin, 2018; McClure and Wells, 2007; Ramotsisi et al., 2022; Saleh et al., 2019), the variables for this study are summarized in Table 1, along with underpinning references.

2.4. Summary of critical appraisal of existing literature on lecturer-to-course assignment

McClure and Wells (2007) developed a binary integer programming model for assigning lecturers to courses such that lecturer's preferences were maximized while satisfying the requirements of the education system in place. Ngo et al. (2021) added more variables other than lecturer's preferences such as the number of lecturers, and the maximum and minimum number of courses per lecturer in each semester. The number of courses per semester is a parameter to be considered when developing a model for the lecturer-to-course assignment. The assignment of lecturers to courses takes into consideration the contact hours per week for a course (credit load) and the teaching load per week for each staff. Ekhosuehi (2016) further states that contact hours in a week for a course should never be exceeded, the reason being that the entire period for a course is exactly scheduled on the lecture timetable. Ngo et al. (2020) conducted a study to maximize the lecturer's preferences for courses, and the number of classes that the lecturer expects to teach. Similarly, Shohaimay et al. (2016) developed a teaching load allocation model, using linear programming, and corroborated the findings in (Ekhosuehi, 2016), regarding parameters considered important in the assignment problem.

The current study builds on existing studies in terms of a comprehensive framework that considers a combination of decision variables, including the modelling of explicit workload-related variables, to illustrate the model's superiority over previous studies (Ramotsisi et al., 2022).

A summary of the theoretical foundation for this study is depicted in Table 2.

Table 1
Variables for the lecturer-to-course assignment problem

Variable	**Description**	**References**
Lecturer's expertise	Lecturer's research interests	Saleh et al. (2019); Wicaksono & Wisesa (2020);
Lecturer's experience	Lecturer's years of teaching experience	Na & Hussin (2021); Solaja et al. (2020);
Lecturer's preference	Lecturer's preference for a course	Malik & Nordin (2018); Sharma & Tuli (2020); Saleh et al (2019); Shohaimay et al. (2016); Ekhosuehi (2016); Bhoi & Dhodiya (2021); Domenech & Lusa (2016)
Lecturer's workload	The number of courses per lecturer, class contact hours, class capacity, and course credits.	Babad et al. (2004); Canady and Rettig (1996); Carbonetto (2022); Gillian and Sigrid (2018); Russell (2000);Sharma & Tuli (2020); Gunawan & Ng (2011); Saleh et al. (2019); Shohaimay et al. (2016); Smith (1994); Ekhosuehi (2016); Wicaksono & Wisesa (2020); Sze et al. (2017); Arinze & Partovi (2000); Arratia-Martinez et al., (2021); Ramotsisi et al. (2022).

Table 2
Summary of the theoretical foundation for this study

Author (s)	Study purpose	Level	Method	Identified gaps
Mallick et al. (2021)	Maximizing effectiveness. Minimizing lecture preparation time	Department	Linear programming, Hungarian method	The author did not take into consideration other important variables for the lecturer-to-course assignment.
Martinez et al. (2021)	Minimizing the number of courses without lecturers.	Department	Integer linear programming, Branch and bound algorithm	The number of students was not considered despite being an important variable in the assignment of lecturers to courses.
Ngo et al. (2021)	Maximizing lecturer's preference by minimizing mismatch between lecturer's competence and subject.	University	Genetic algorithm	The genetic algorithm gives a feasible but not optimal solution compared to linear programming.
Wicaksono & Wisesa (2020)	Maximizing lecturer's capability by adjusting teaching load.	University	Linear programming, Branch and bound algorithm	Considered only the lecturer's capability and teaching load.
Faudzi et al. (2018)	Maximizing lecturer-to-course assignments in the educational domain.	University	Exact method, Heuristic, Metaheuristic, Local search based, Population search based and Hybrid methods.	The solution approaches used give a feasible but not optimal solution compared to linear programming.
Ongy (2017)	Maximizing total competence score.	Department	Mixed integer programming	Excluded other variables such as workload and parameters used to measure workload (e.g., class size and course contact hours).
Gunawan & Ng (2011)	Balancing lecturer's workload.	University	Simulated annealing, Tabu search	The solution approaches used give a feasible but not optimal solution compared to linear programming
Na & Hussin (2021)	Maximizing lecturer's years of teaching experience.	University	Python	One needs to develop a new program to solve a specific problem compared to linear programming.
Saleh et al. (2020)	Maximizing lecturer's preferences and balancing lecturer's workload.	Department	Integer programming	Did not consider the class capacity to measure workload.
Bhoi & Dhodiya (2021)	Maximize lecturer's course preferences and satisfy student preferences.	University	Multi-objective linear programming	Preference alone may not represent a robust solution
This study	Balance lecturer's workload using a combination of variables.	Department	Binary integer linear programming	

3. Materials and Methods

An overview of the methodology employed in this study is depicted in Table 3.

Table 3
Outline of Methods to address objectives

Objective	Methods
To develop a conceptual framework for understanding an effective lecturer-to-course assignment.	Content analysis.
To study the existing lecturer-to-course assignment at the case organization.	Questionnaire survey.
To identify areas for improvement in the existing lecturer-to-course assignment.	Framework method.
To develop a mathematical model.	Mathematical modelling (Binary integer linear programming).
To implement the mathematical model in an optimization software.	Optimization modelling, spreadsheet modelling.
To validate the proposed model.	Expert judgments.

Table 3 shows the different methods implemented to address the six objectives of this study. The methods used to address the objectives are content analysis, mathematical modelling, and expert judgment. Gaps in existing literature were identified, based on a conceptual framework for the lecturer-to-course assignment developed for this study. The conceptual framework represents a component of the theoretical foundation, similar to existing empirical studies relating to an effective approach to examine potential areas for improvement in existing practice (Rocco and Plakhotnik, 2009; Seboni, 2021, Wilson et al., 2010). Subsequently, questionnaire surveys were administered to 4 groups of informants (10 lecturers, 1 program coordinator, 1 head of department, and 147 students) that make a total of 159 informants, using the approach reported in (Ramotsisi et al., 2022). No sampling was used for all informants except students, given the small population size of those informants. Although the total number of inside informants was small given the small nature of the entire population, the response rate was 60%, deemed acceptable (Baruch, 1999; Nulty, 2008) to provide reliable insights about the lecturer-to-course assignment.
Content analysis was used to analyze the data, to uncover an accurate depiction of the existing lecturer-to-course assignment at the case organization. The developed conceptual framework was then compared with the outcome from content analysis, to enable the identification of areas for improvement in the existing lecturer-to-course assignment. The literature review discussed in section 2, along with the literature on mathematical modelling (Conway and Ragsdale, 1997; Jensen and Bard, 2003; Meerschaert, 2007; Murthy et al., 1990; Seboni and Tutesigensi, 2015b), were used to guide the development of a mathematical model for this study. The developed mathematical model was then implemented in Opensolver (Mason, 2011), to obtain an optimal solution. Justification for using Opensolver over competing alternatives such as Solver studio (Mason, 2013; Ragsdale, 2021) and Xpress-Mosel (Gueret et al., 2002; Fico, 2012) was based on the absence of licensing costs (Meindl and Templ, 2013).
Model validation was then carried out using expert judgment, where a set of questions in the form of a questionnaire were administered to participating experts. An expert was defined as someone who has experience in lecturer-to-course assignments. A demonstration of how the model functions was shown to the experts and they had to answer questions about the model, concerning different model validation criteria namely: usefulness, relevance, structure, sufficiency, coherence, and verifiability. Moreover, reliability analysis was performed concerning Cronbach's alpha coefficients for all datasets and was found to be between 0.85 and 0.95, which is deemed acceptable (Cortina, 1993; Dobela and Seboni, 2022).

3.1. Model notation

The notation used in our mathematical model formulation is presented next, in terms of model parameters, decision variables, constraints, formulation, and assumptions. The methods reported by (Ramotsisi et al., 2022), were used to guide the development of the mathematical model for this study.

3.2. Model parameters

$_i$ is the number of lecturers available for assignment per academic semester, where i=(1,2,…….k).
$_j$ is the number of courses available for assignment per academic semester, where j=(1,2,...........l).
H_j is the contact hours per week for course j.
H_j^{min} is the minimum number of contact hours a lecturer can be assigned.
H_j^{max} is the maximum number of contact hours a lecturer can be assigned.
CO_i is the number of courses assigned to lecturer i.
C_j is the number of course credits for course j.
C_j^{min} is the minimum number of course credits a lecturer can be assigned.
C_j^{max} is the maximum number of course credits a lecturer can be assigned.
CC_j is class capacity for course j.
CL_j is the total number of classes for a course.

3.3. Decision variables

Let X_{ij} be the set of lecturers i to be assigned to a set of courses j, to be offered in a specific academic semester. The objective function is to maximize the lectures' workload in the lecturer-to-course assignment, in order to optimize lecturer's utilization. This decision variable definition is expressed next, using binary variables (Chang, 2008; Ragsdale, 2021; Seboni and Tutesigensi, 2015a).

$$X_{ij} = \begin{cases} 1 \text{ if lecturer i is assigned to course j,} \\ 0 \text{ otherwise} \end{cases}$$

$$\boldsymbol{MAX}: \sum_{i=1}^{k} \sum_{j=1}^{l} (X_{ij}H_j)(X_{ij}C_j)\,(X_iCO_i)\,(X_iCC_j)\} \quad (1)$$

Where equation 1 = total workload.

Subject to:

$$\sum_{i=1}^{k} \sum_{j=1}^{l} (X_{ij}H_j) \leq H_j \max \quad \forall i \qquad (2)$$

$$\sum_{i=1}^{k} \sum_{j=1}^{l} (X_{ij}H_j) \geq H_j \min \quad \forall i \qquad (3)$$

$$\sum_{i=1}^{k} \sum_{j=1}^{l} (X_{ij}C_j) \leq C_j \max \quad \forall i \qquad (4)$$

$$\sum_{i=1}^{k} \sum_{j=1}^{l} (X_{ij}C_j) \geq C_j \min \quad \forall i \qquad (5)$$

$$X_{ij} = 0 \text{ or } 1 \qquad (6)$$
$$CL_j = 1 \qquad (7)$$

3.4. Explanation of the constraints

The model constraints and their respective explanations are given in Table 4.

Table 4
Model constraints and explanations

Constraints	Explanation
$\sum_{i=1}^{k}\sum_{j=1}^{l} Xij.Hj \leq H_j^{max}\ \forall_i$ (equation 2)	Contact hours assigned to lecturer *i* should be less than the maximum contact hours that can be assigned to a lecturer, for all lecturers.
$\sum_{i=1}^{k}\sum_{j=1}^{l} Xij.Hj \geq H_j^{min}\ \forall_i$ (equation 3)	Contact hours assigned to lecturer *i* should be more than the minimum contact hours that can be assigned to a lecturer, for all lecturers.
$\sum_{i=1}^{k}\sum_{j=1}^{l} Xij.Cj \leq C_j^{max}\ \forall_i$ (equation 4)	Course credits assigned to lecturer *i* should be less than the maximum course credits that can be assigned to a lecturer, for all lecturers.
$\sum_{i=1}^{k}\sum_{j=1}^{l} Xij.Cj \geq C_j^{min}\ \forall_i$ (equation 5)	Course credits assigned to lecturer i should be more than the minimum course credits that can be assigned to a lecturer.
X_{ij} = 0 or 1 (equation 6)	Binary restriction on the assignment of lecturers to courses.
CL_j= 1 (equation 7)	Total number of lecturers for a course is 1.

3.5. Model formulation and assumptions

The following assumptions were made in the formulation:

1. All the lecturers assigned to teach courses are available to teach in that semester.
2. No lecturer is idle.
3. All courses that are offered must be assigned.
4. Maximum teaching load (in terms of credits, number of courses per lecturer, and course contact hours per week) must not be exceeded.
5. The contact hours per week for a given course must not be exceeded.
6. External commitments of lecturers are not considered as part of their workload.
7. There is no co-teaching, hence equation 7.

4. Results and Discussion

The variables identified in the literature review, which were also measured from the informant groups during data collection, were divided into 2 different categories. These categories are variables that examine the nature of the lecturer-to-course assignment and variables that measure the lecturer's performance. These 2 categories of variables are depicted in Table 5.

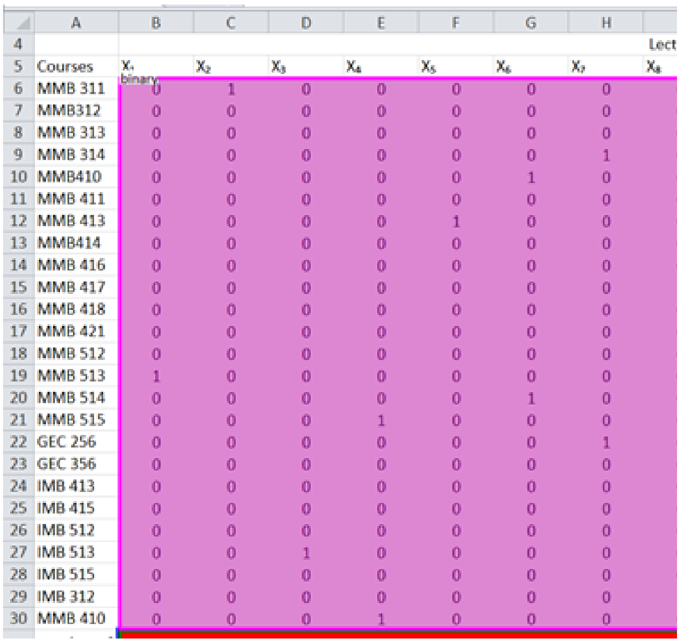
Table 5
Variables for the nature of existing lecturer-to-course assignments and their performance

Nature of existing lecturer-to-course assignment variables	Performance variables
Class capacity.	Lecturer's effectiveness.
Lecturer's workload.	Quality of course delivery.
Lecturer's experience.	Student performance.
Lecturer's preference.	Lecturer's effectiveness, student performance.
Lecturer's academic position	Quality of course delivery.

The analysis of variables that examine the nature of the lecturer-to-course assignment and performance variables was done on Minitab software. Spearman correlation coefficients between the variables and the p-values for the relationship revealed that there is a relationship between the variables.

4.1. Model output and discussion

An output from optimization software (see Figure 1) indicates that the optimization software took 0.29 seconds to find an optimal solution that maximizes the workload of lecturers (as presented in the model formulation), with a solution precision of 99%. This output is superior in



	A	B	C	D	E	F	G	H	
4									Lect
5	Courses	X_1 binary	X_2	X_3	X_4	X_5	X_6	X_7	X_8
6	MMB 311	0	1	0	0	0	0	0	
7	MMB312	0	0	0	0	0	0	0	
8	MMB 313	0	0	0	0	0	0	0	
9	MMB 314	0	0	0	0	0	0	1	
10	MMB410	0	0	0	0	0	1	0	
11	MMB 411	0	0	0	0	0	0	0	
12	MMB 413	0	0	0	0	1	0	0	
13	MMB414	0	0	0	0	0	0	0	
14	MMB 416	0	0	0	0	0	0	0	
15	MMB 417	0	0	0	0	0	0	0	
16	MMB 418	0	0	0	0	0	0	0	
17	MMB 421	0	0	0	0	0	0	0	
18	MMB 512	0	0	0	0	0	0	0	
19	MMB 513	1	0	0	0	0	0	0	
20	MMB 514	0	0	0	0	0	1	0	
21	MMB 515	0	0	0	1	0	0	0	
22	GEC 256	0	0	0	0	0	0	1	
23	GEC 356	0	0	0	0	0	0	0	
24	IMB 413	0	0	0	0	0	0	0	
25	IMB 415	0	0	0	0	0	0	0	
26	IMB 512	0	0	0	0	0	0	0	
27	IMB 513	0	0	1	0	0	0	0	
28	IMB 515	0	0	0	0	0	0	0	
29	IMB 312	0	0	0	0	0	0	0	
30	MMB 410	0	0	0	1	0	0	0	

Fig .1. Output from optimization software

Table 6
Proposed lecturer-to-course assignment

Lecturer (l_1 to l_{15})	Courses assigned (c_1 to c_{25})
X_1	MMB 513 (c_1)
X_2	MMB 311(c_2)
X_3	IMB 513 (c_3)
X_4	MMB 515 (c_4), MMB 410 (c_5)
X_5	MMB 413 (c_6)
X_6	MMB 410 (c_7), MMB 514 (c_8)
X_7	MMB 314 (c_9), GEC 256 (c_{10})
X_8	MMB 417 (c_{11}), IMB 312 (c_{12})
X_9	MMB 418 (c_{13}), MMB 421(c_{14})
X_{10}	MMB 411 (c_{15}), GEC 356 (c_{16})
X_{11}	MMB 512 (c_{17}), IMB 415(c_{18})
X_{12}	MMB 414 (c_{19}), MMB 416(c_{20})
X_{13}	MMB 313 (c_{21})
X_{14}	IMB 413 (c_{22}), IMB 515 (c_{23})
X_{15}	MMB 313(c_{24}), IMB 512(c_{25})

l_1 to l_{15} Lecturer number 1 to lecturer number 15.
c_1 to c_{25} Course number 1 to course number 25.

comparison to the existing lecturer-to-course assignment, which takes approximately 5 days to complete. The proposed model is therefore, more efficient than the status quo. Using an instance of the academic year 2022/2023 semester 1, an output from the optimization software, representing an optimal solution, was found as depicted in Table 6. The objective function value representing the maximum workload is 1147. This is the maximum value for this problem and is associated with balancing the workload among lecturers by assigning an optimum workload (i.e., maximum possible) to each lecturer……….

Table 6 depicts an optimal assignment decision for assigning 15 lecturers to 25 courses. This assignment shows possible combinations of course assignments associated with maximizing workload.

The robustness of the proposed mathematical model in handling large lecturer-to-course assignment problems was also demonstrated by assigning 15 lecturers to 50 courses and the model was able to optimally assign the lecturers by maximizing their workload. This assignment maximized the lecturer's utilization. Opensolver was able to solve this problem in 0.56 seconds, yielding an objective function value of 2294. This objective function value is the maximum value for the assignment.

4.2. Validation

The results of reliability analysis in the scale used to measure validation variables are shown in Table 7.

Table 7
Cronbach's Alpha coefficients for HOD's validation

Research variables	Cronbach's alpha coefficientfor HODs and the number of items (N) used
Relevance (V1)	0.889 (N=3)
Sufficiency (V2)	0.923 (N=4)
Coherence (V3)	0.889 (N=3)
Structure (V4)	0.889 (N=3)
Verifiability (V5)	0.923 (N=3)
Usefulness (V6)	0.923 (N=4)

HOD Head of Department.

Six variables were used for measuring reliability analysis (Table 7) regarding validation of the proposed mathematical model for the lecturer-to-course assignment problem. These variables were: relevance, sufficiency, coherence, structure, verifiability, and usefulness. All the variables were scored on the same bipolar scale from -5 through 0 to +5, with -5 representing maximum negative change, 0 representing no change, and +5 representing maximum positive change. The output presented Cronbach's alpha for standardized items, which reflected the overall reliability of the scale value of 0.912, in the case of data from the head of the department. This result implies that the scale used is reliable in that 91.2% of the time it will produce the same results when administered to the same participant in the same setting (Cortina, 1993; Dobela and Seboni, 2023). Table 7 shows Cronbach's alpha coefficients for all variables presented from 0.889 to 0.923, which is above the acceptable value of 0.60 to 01.0. However, the reliability of the measurement scale used cannot be 100% because individual variables within the scale incorporate an element of error, (Cortina, 1993).
charts for every variable (Esfahani et al., 2020). All the I-MR values were within limits, indicating that the experts agree. These results demonstrate that the model is useful, verifiable, relevant, coherent, and has a good structure.

Results for model validation were analyzed on Minitab software, using individual and moving range (I-MR)

5. Conclusions

This study not only developed a binary integer linear programming model to optimize lecturer-to-course assignments but also applied the model in practice, using real data from a mechanical engineering university department offering two engineering degree programs. The theoretical framework proposed in this study may be used to inform assignments of lecturers to courses in other university departments and universities, subject to context. The value lies in both a comprehensive and objective assignment process that can be justified in terms of reviews for continuous improvement.

Whilst existing studies have proposed assignment models for considering certain decision criteria, the current study adds to a deeper understanding of a specific assignment problem by incorporating a comprehensive range of decision criteria that play a role in this complex decision process. For example, additional criteria associated with workload other than the number of courses per lecturer (such as class capacity, course contact hours, and course credits) were brought to bear in the proposed model. These additions extend our understanding of existing knowledge by incorporating other aspects of real workload among lecturers. The need to balance workload may enhance quality assurance in teaching and learning, leading to the following: improved student and lecturer satisfaction, reduction in staff burnout, increased employee productivity, and increased performance of the department, faculty, and university at large.

Notwithstanding the contribution of the current study, a limitation lies in the capability of the optimization software used, in the context of a limit on the number of variables it can handle. This presents an avenue for future work involving the use of commercial optimization software packages that are more robust in simultaneously handling large numbers of variables. Another avenue for future work is the development of a user interface, with a view to separate multifaceted components of the mathematical model, such that intended users can interact with the mathematical model base via simple commands built into the user interface, to enhance user-friendliness to practitioners.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest concerning the publication of this paper.

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