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JOURNAL INDUSTRIAL SERVICESS

journal homepage: http://jurnal.untirta.ac.id/index.php/jiss

eISSN 2461-0631

Original research

Mathematical model for university online exam scheduling considering lecturer preferences

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ARTICLE INFO

Article history:
Received 3 September 2024
Received in revised form 8 December 2024
Accepted 9 December 2024
Published online 10 December 2024

Keywords:
Branch and bound
Integer linear programming
Optimization
Scheduling

Editor:
Bobby Kurniawan

Publisher's note:
The publisher remains neutral concerning jurisdictional claims in published maps and institutional affiliations.

ABSTRACT

Zoom accounts are used as an alternative for online teaching and learning activities during the pandemic. The Industrial Engineering Study Program at Sultan Ageng Tirtayasa has been scheduling online exams and determining the number of Zoom accounts needed manually, which has resulted in an insufficient number of Zoom accounts to meet all course schedules. Proper online exam scheduling can optimize the number of Zoom accounts required. This study aims to determine the number of Zoom accounts needed for online exams by developing a mathematical model. The model developed is an Integer Linear Programming (ILP) model, with the objective of minimizing the number of Zoom accounts required. The problem is solved using an optimization approach with deterministic parameters. The model provides recommendations for decision-making in the implementation of online exams, including determining the exam timetable and the number of Zoom accounts to be rented. The computational results show that the developed model provides an optimal solution, requiring only three Zoom accounts.

1. Introduction

During the pandemic, all teaching and learning activities have been carried out online, including the implementation of exams. One of the institutions that conducts online teaching and learning activities is Sultan Ageng Tirtayasa University. There are several platforms available for online teaching and learning, including Zoom and Google Meet. However, to facilitate exam implementation, the university uses the Zoom platform with a paid account [1], [2], [3], [4]. This decision was made because Zoom offers important features such as scheduled meetings, screen recording, personal chat, and better video quality compared to Google Meet. Sultan Ageng Tirtayasa University must pay attention to exam scheduling to optimize the number of paid Zoom accounts used. During exam activities, a common problem that arises is that the number of rented Zoom accounts is insufficient, resulting in suboptimal usage [5], [6].

The factor that causes this to happen is that the preparation of the schedule at the university level is still done manually. Manual schedule preparation requires repeated revisions or improvements making it difficult to determine the optimal number of zoom accounts used. This revision or improvement is because manual schedule preparation can directly consider the wishes of lecturers and students, so it requires high accuracy and longer time [7], [8]. This can cause dissatisfaction for lecturers and students. Therefore, a solution or method is needed in solving the scheduling problem to be able to optimize the number of zoom accounts rented and be able to minimize the level of dissatisfaction of lecturers and students.

One solution to the scheduling problem is to use the integer linear programming (ILP) model. ILP is a method related to linear programs where some or all variables have integer or discrete values [9], [10], [11], [12]. Other research formulates the scheduling problem as a binary number programming model (0-1), to minimize student and faculty dissatisfaction while at the same time enforcing rules constrained by a set of constraints [13], [14]. The integer linear programming method and using *Lingo* 11.0 *software* with the aim of minimizing the space used, produces an optimal solution, namely from 19 lecture rooms provided only 5 rooms are used [14], [15]. The integer linear programming model in optimizing lecture scheduling

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http://dx.doi.org/10.62870/jiss.v10i2.28571

automatically obtained optimal schedule results, the resulting scheduling has no clashes and requests for lecture time periods for several courses by lecturers and students can be fulfilled [10], [14].

In this research, the exam implementation process is carried out using a paid online room, namely zoom. All students are required to join a zoom account in carrying out the exam from their respective places and are monitored by the exam supervisor. To minimize the paid zoom account, an optimization of the paid zoom account is used during the exam. One solution to optimize this is to use a mathematical model to help make decisions in scheduling with the aim of minimizing the number of *zoom* accounts used at the same time by taking into account the wishes of the lecturer in determining the ideal time for the exam [14], [16].

The purpose of this research is to determine the minimum number of paid Zoom accounts required during the implementation of online exams without considering the preferences of lecturers and determine the optimal number of paid Zoom accounts in the implementation of exams by considering the preferences of each lecturer.

2. Material and method

2.1. Research stages

In research methodology, there are several stages of data processing carried out. The following stages of data processing are presented in Fig. 1.

Model development. Development of a zoom account optimization model that corresponds to the situation in the Industrial Engineering Study Program, Faculty of Engineering, Sultan Ageng Tirtayasa University using Integer Linear Programming.

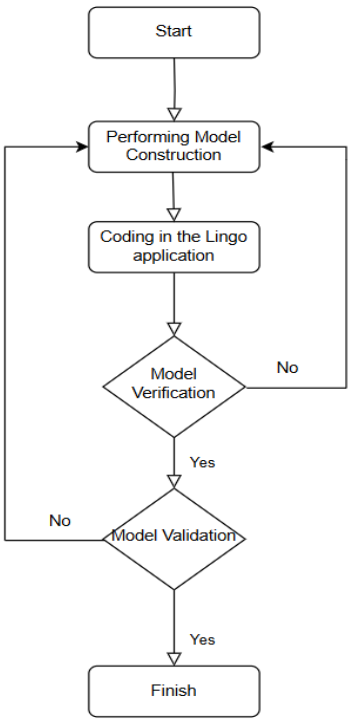

Figure 1: Stages of data processing

Coding the lingo application. Coding the lingo application based on its usage rules.

Model verification. Model verification is done by running on Lingo Solver to ensure there are no errors in the proposed model.

Model validation. Model validation is done using sensitivity analysis. Model sensitivity analysis to see whether the model shows logical results or not. Sensitivity analysis is carried out to study the effect of changes in ILP model parameters on optimum solution [17].

Interpret the output of the lingo application. Simplify the form of results in the *lingo* application into an exam scheduling table in the Industrial Engineering Study Program, Faculty of Engineering, Sultan Ageng Tirtayasa University.

2.2. Anaysis

Data analysis is conducted to determine the results of the data processing that has been performed. To assess how sensitive a decision is to changes in the factors or parameters that affect it, every decision-making process involving multiple alternatives should include a sensitivity analysis. This analysis provides an overview of the extent to which a decision remains robust in the face of changes to the influencing factors or parameters [18], [19], [20], [21].

The purpose of sensitivity analysis is to determine the sensitivity of the optimal solution that has been obtained. If there is a change in the linear programming coefficient, it may result in one of the following outcomes: a. The optimal solution does not change, b. The solution becomes non-optimal, c. The solution becomes infeasible, d. The solution becomes both non-optimal and infeasible.

In this study, the sensitivity analysis will focus on the objective function coefficient, which represents the ranking assigned to the Zoom accounts during exam activities. The sensitivity analysis in this study uses the simulation method as a model experiment, due to the inability of the software used to perform sensitivity analysis [17].

3. Results and discussions

3.1. Model formulation

In modeling exam scheduling, there is an objective function and several constraints that are adjusted to reflect actual conditions. There are two alternatives: the first alternative is the minimization of the number of Zoom accounts used during the exam, without considering the lecturer's preferences, while the second alternative is the optimization of the number of Zoom accounts used, considering the lecturer's preferences.

The mathematical model requires notations such as data symbols, parameters, and variables. The following table presents the notations used in the mathematical model for exam scheduling.

Sets

L	Set of lecturers
C	Set of courses offered
S	Set of students
H	Set of session
K	Set of Zoom account

Parameters

D	Number of days
K	Number of Zoom account
L_{cl}	1 if course c is taught by lecturer l , 0 otherwise
Z_{cs}	1 if course c is scheduled for student group s, 0 otherwise

Variables

X_{lcsdhk}	1 if lecturer l, course c, student group s are scheduled on day d, session h, and *zoom* account k, 0 otherwise
Y_k	1 if the provided *zoom* account will be used, 0 otherwise

There are four data points, four parameters, and two variables. The data symbols are the lecturer index, course index, student group index, and session index. The parameters are the day index, Zoom account index, course references to lecturers, and course references to student groups. Meanwhile, the variables are the exam schedule, and the number of Zoom accounts required. The objective function of the exam scheduling model in the Industrial Engineering Study Program, Faculty of Engineering, Sultan Ageng Tirtayasa University, is to minimize the number of paid Zoom accounts used during the exam by optimizing the scheduling process.

$$Min\ Z = \sum_{k\in K} Y_k \tag{1}$$

$$\sum_{l\in L}\sum_{d\in D}\sum_{h\in H} X_{lcsdhk} = \mathrm{Z}_{cs}, \forall c, s \tag{2}$$

$$\sum_{s\in S}\sum_{d\in D}\sum_{h\in H}\sum_{k\in K} X_{lcsdhk} = \sum_{s} Z_{cs}\, L_{cl}, \forall\ c, l \tag{3}$$

$$\sum_{l\in L}\sum_{c\in C}\sum_{k\in K} X_{lcsdhk} \le 1\ \forall s,d,h \tag{4}$$

$$\sum_{l\in L}\sum_{c\in C}\sum_{s\in S} X_{lcsdhk} \le 1\ \forall\ d.\, h, k \tag{5}$$

$$\sum_{l\in L}\sum_{c\in C}\sum_{s\in S}\sum_{d\in D}\sum_{h\in H} X_{lcsdhk} \le \mathrm{B}\, Y_k, \forall\ k \tag{6}$$

$$\sum_{c\in C}\sum_{s\in S}\sum_{k\in K} X_{lcsdhk} \le 1, \forall\ l, d \tag{7}$$

$$\sum_{c\in C}\sum_{s\in S}\sum_{k\in K} X_{lcsdhk} = 0, \forall\ l, d, h \tag{8}$$

Eq. (1) represents the objective function, which is to minimize the number of Zoom accounts required for the online exam. Eq. (2) ensures that every group of students and lecturers are scheduled for the exam. Firstly, for each course c and student group s, it will only schedule to one lecturer l, one day d, one session h, and one zoom account k based on course references to student groups. Eq. (3) states that for each lecturer l who is plotted to teach course c, at least 1 must be cheduled to student group s on day d, session h, and *zoom* account k with student group s based on course reference to student group and course reference to lecturer. Eq. (4) ensures that each student group s and day d and session h can only be scheduled a maximum of once. First, to ensure that each student group s, day d, and session h, will not be scheduled to lecturer l, course c, and zoom account k at the same time. Eq. (5) states that for each day d, session h, and zoom account k, will not be scheduled to lecturer l, course c, and student group s more than once. Eq. (6) regulates the number of *zoom* accounts required not to exceed the *zoom* accounts available for all courses during the exam activity. For each zoom account k to be used by lecturer l, course c, student group s, day d, and session h no more than the number of *zoom* accounts that have been made available. Eq. (7) implements conditions where lecturers have recommendations and rejections for certain times, as well as schedule vacancies on days 5 and 10 of session 3. First, for each lecturer l, day d , and session h, it will be prioritized to conduct exams on course c, student group s, and zoom account k. Eq. (8) states that for each lecturer l, day d, and session , there will be no exam scheduled for course c, student group s and zoom account k. Eq. (9) states that for each lecturer l, day d, and session , there will be no exam scheduled for course c, student group s and zoom account k.

3.2. Model implementation

In this study, the mathematical model was carried out using Lingo software [16]. To run the software, several components are required, such as the objective function and the constraints contained in the problem to be solved in the form of a mathematical model. Two alternative solutions are considered: alternative one, which does not take the lecturer's preferences into account, and alternative two, which incorporates the lecturer's preferences.

3.3. Sensitivity analysis

Sensitivity analysis is used to determine the effect of parameter changes on the objective function. Additionally, this analysis also serves to examine changes in decision variables when there is a change in parameter values. In this case, the sensitivity of the model is analyzed for an important parameter, namely the day of the exam, to observe changes in the decision variable (the number of Zoom accounts used) and the resulting exam schedule. The table below presents the parameter changes and the resulting changes, as shown in Table 1.

Based on Table 1, changing the parameters of the day of the exam affects the decision regarding the number of Zoom accounts used. The change in the number of Zoom accounts used is directly proportional to the change in the exam schedule.

Tabel 1.
Sensitivity analysis

No	Number of Day	Zoom Account Used
1	6	4
2	8	3
3	10	3
4	12	2
5	14	2

3.4. Results

To make it easier to understand the output results from Lingo software, the output interpretation is done by changing the language. The Lingo software output, which consists of a series of numbers, is transformed into an exam schedule table. Based on the results of the processing that has been completed, the exam scheduling results for alternative one is presented in Table A1, A2, and A3 (see Appedices).

The number of Zoom accounts used during the implementation of the mid-term and final exams for alternative semester one in the Industrial Engineering Study Program, Faculty of Engineering, Sultan Ageng Tirtayasa University, is three. All courses have been scheduled once per session, day, and specified Zoom account. As a result, the objective function and all restrictions established in the alternative one have been fulfilled. There are Zoom accounts and sessions on some days that are not used due to the lecturers' preferences regarding the day and session times. Additionally, on Friday, the third session is not used for exam activities due to religious worship. As a result, the objective function and all restrictions established in the alternative two have been fulfilled.

4. Conclusions

The conclusion of this study is that, in the implementation of odd semester exams in the Industrial Engineering Study Program at the Faculty of Engineering, Sultan Ageng Tirtayasa University, both scenarios—those without regard to lecturer preferences and those with regard to lecturer preferences—can be carried out using three Zoom accounts.

Declaration statement

Evi Febianti: **Conceptualization, Methodology, Writing-Original Draft**. M. Adha Ilhami: **Collecting data.** Arif Hidayat: **Writing-Review & Editing.**

Acknowledgement

The acknowledgement was given to anonymous refrees for constructive feedback.

Disclosure statement

The authors report there are no competing interests to declare.

Funding statement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Data availability statement

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

References

[1] F. Irmada and I. Yatri, "Keefektifan Pembelajaran Online Melalui Zoom Meeting di Masa Pandemi bagi Mahasiswa," *J. Basicedu*, vol. 5, no. 4, 2021.

[2] J. Monica and D. Fitriawati, "Efektivitas Penggunaan Aplikasi Zoom Sebagai Media Pembelajaran Online Pada Mahasiswa Saat Pandemi Covid-19," *J. Communio J. Jur. Ilmu Komun.*, vol. 9, no. 2, 2020, doi: 10.35508/jikom.v9i2.2416.

[3] G. I. E. Soen, M. Marlina, and R. Renny, "Implementasi Cloud Computing dengan Google Colaboratory pada Aplikasi Pengolah Data Zoom Participants," *JITU J. Inform. Technol. Commun.*, vol. 6, no. 1, 2022, doi: 10.36596/jitu.v6i1.781.

[4] R. E. Putri H. and T. A. Wulandari, "Pemanfaatan aplikasi Zoom cloud meeting sebagai media e-learning dalam mencapai pemahaman mahasiswa di tengah pandemi COVID-19," *J. Common*, vol. 4, no. 2, 2021, doi: 10.34010/common.v4i2.4436.

[5] M. Lindahl, A. J. Mason, T. Stidsen, and M. Sørensen, "A strategic view of University timetabling," *Eur. J. Oper. Res.*, vol. 266, no. 1, 2018, doi: 10.1016/j.ejor.2017.09.022.

[6] M. Mokhtari, M. Vaziri Sarashk, M. Asadpour, N. Saeidi, and O. Boyer, "Developing a Model for the University Course Timetabling Problem: A Case Study," *Complexity*, vol. 2021, 2021, doi: 10.1155/2021/9940866.

[7] M. C. Torres, K. K. S. Villegas, and M. K. A. Gavina, "Solving faculty-course allocation problem using integer programming model," *Philipp. J. Sci.*, vol. 150, no. 4, 2021.

[8] N. A. H. Aizam, N. F. Jamaluddin, and S. Ahmad, "A survey on the timetabling communities' demands for an effective examination timetabling in universiti malaysia terengganu," *Malaysian J. Math. Sci.*, vol. 10, 2016.

[9] H. A. Taha, "Riset Operasi," *Jakarta: Bina Rupa Aksara*, vol. 3, no. 2. 1996.

[10] D. Wungguli and N. Nurwan, "Penerapan Model Integer Linear Programming Dalam Optomasi Penjadwalan Perkuliahan Secara Otomatis," *Barekeng J. Ilmu Mat. dan Terap.*, vol. 14, no. 3, 2020, doi: 10.30598/barekengvol14iss3pp413-424.

[11] O. Czibula, H. Gu, A. Russell, and Y. Zinder, "A multi-stage IP-based heuristic for class timetabling and trainer rostering," *Ann. Oper. Res.*, vol. 252, no. 2, 2017, doi: 10.1007/s10479-015-2090-3.

[12] Y. Chung and H. Kim, "The University Examination and Course Timetabling Problem With Integer Programming," *J. Korea Soc. Comput. Inf.*, vol. 24, no. 9, 2019.

[13] M. Akif Bakir and C. Aksop, "A 0-1 integer programming approach to a university timetabling problem," *Hacettepe J. Math. Stat.*, vol. 37, no. 1, 2008.

[14] D. Lalang and D. R. Alohaja, "Penggunaan integer linier programming untuk meminimumkan ruang kuliah pada Mata Kuliah Dasar Umum (MKDU) Studi Kasus di Universitas Tribuana Kalabahi," *J. Saintek Lahan Kering*, vol. 4, no. 2, 2022, doi: 10.32938/slk.v4i2.1554.

[15] A. E. Phillips, C. G. Walker, M. Ehrgott, and D. M. Ryan, "Integer programming for minimal perturbation problems in university course timetabling," *Ann. Oper. Res.*, vol. 252, no. 2, 2017, doi: 10.1007/s10479-015-2094-z.

[16] H. Algethami and W. Laesanklang, "A mathematical model for course timetabling problem with faculty-course assignment constraints," *IEEE Access*, vol. 9, 2021, doi: 10.1109/ACCESS.2021.3103495.

[17] M. A. Ilhami, Subagyo, and N. A. Masruroh, "A mathematical model at the detailed design phase in the 3DCE new product development," *Comput. Ind. Eng.*, vol. 146, 2020, doi: 10.1016/j.cie.2020.106617.

[18] V. Pereira and H. Gomes Costa, "Linear integer model for the course timetabling problem of a faculty in rio de janeiro," *Adv. Oper. Res.*, vol. 2016, 2016, doi: 10.1155/2016/7597062.

[19] Z. Mohd Zaulir, N. L. A. Aziz, and N. A. H. Aizam, "A General Mathematical Model for University Courses Timetabling: Implementation to a Public University in Malaysia," *Malaysian J. Fundam. Appl. Sci.*, vol. 18, no. 1, 2022, doi: 10.11113/MJFAS.V18N1.2408.

[20] M. Khamechian and M. E. H. Petering, "A mathematical modeling approach to university course planning," *Comput. Ind. Eng.*, vol. 168, 2022, doi: 10.1016/j.cie.2021.107855.

[21] E. Guzman, R. Poler, and B. Andres, "A matheuristic approach combining genetic algorithm and mixed integer linear programming model for production and distribution planning in the supply chain," *Adv. Prod. Eng. Manag.*, vol. 18, no. 1, 2023, doi: 10.14743/APEM2023.1.454.

Apppendices

Table A1.
Alternative exam schedule 1 Zoom account 1

Sessions	1st Monday		1st Tuesday		1st Wednesday		1st Thursday		1st Friday	
1	Facility Layout Design	B							Engineering Economics	B
2	Manufacturing Simulation	A	Engineering Economics	C	System Modeling	B			Production Planning and Control	B
3	Introduction to Industrial Engineering	A			Engineering Materials	C	Operational Research 1	B		
4	Computer Programming	B	Marketing Management	A	Industrial Statistics1	C	Industrial Environmental System	C	Food Security	A
5					Supply Chain Risk Management	B	Transportation Ergonomics	B	Religion	A

Sessions	2nd Monday		2nd Tuesday		2nd Wednesday		2nd Thursday		2nd Friday	
1	Operational Research 1	A	Quality Control and Assurance	A	System Modeling	C	Religion	B	Manufacturing Process	C
2			Marketing Management	B			Ergonomics and Work System Design 1	A		
3					Pancasila	C	English	C		
4	Production Planning and Control	A	Pancasila	A	Logistics Engineering	A	Mechatronics and Production System Automation	C	Quality Engineering	A
5	Engineering Mechanics	B	Productivity Engineering	B	Mechatronics and Production System Automation	A			Project Management	B

Table A2.
Alternative exam schedule 1 Zoom account 2

Sessions	1st Monday		1st Tuesday		1st Wednesday		1st Thursday		1st Friday	
1	Manufacturing Simulation	B	Change Management	B			Ergonomics and Work System Design 1	C	Industrial Environmental System	B
2					Industrial Ergonomics	A	Manufacturing Process	A		
3	Computing Intelligence	B	Work Psychology	B						
4	Computer Programming	C	Quality Control and Assurance	B			Ergonomics and Work System Design 1	B	Entrepreneurship	C
							Facility Layout Design			
5			Productivity Engineering	A	System Modeling	A		C	Data Mining	B

Sessions	2nd Monday		2nd Tuesday		2nd Wednesday		2nd Thursday		2nd Friday	
1	Computing Intelligence	A	Basic Physics 1	A	Basic Chemistry	C	Linear Algebra	C	Manufacturing Process	B
2			Facility Layout Design	A	Food Security	C				
3	Calculus 1	B	Basic Physics 1	C	Linear Algebra	B	Introduction to Industrial Engineering	B		
4			Work Psychology	A	Quality Control and Assurance	C	Religion	C	Introduction to Industrial Engineering	C
5			Entrepreneurship	B	Linear Algebra	A	Industrial Statistics 1	A	Transportation Ergonomics	A

Table A3.
Alternative exam schedule 1 Zoom account 3

Sessions	1st Monday		1st Tuesday		1st Wednesday		1st Thursday		1st Friday	
1	Data Mining	A	Technology and Innovation Management	A	Engineering Mechanics	C			Quality Engineering	B
2	Calculus 1	A			Calculus 1	C	Basic Chemistry	A	Engineering Materials	A
3	Supply Chain System	A	Basic Chemistry	B	Health Ergonomics	A				
4	Technology and Innovation Management	B			English	B			Decision Analysis	B
5	Supply Chain System	B	Industrial Statistics 1	B			Change Management	A		

Sessions	2nd Monday		2nd Tuesday		2nd Wednesday		2nd Thursday		2nd Friday	
1	Pancasila	B	Decision Analysis	A			Engineering Mechanics	A	Mechatronics and Production System Automation	B
2	Basic Physics 1	B	Industrial Environmental System	A	Food Security	B	Project Management	A	Engineering Economics	A
3							English	A		
4	Engineering Materials	B	Entrepreneurship	A	Computer Programming	A	Supply Chain Risk Management	A	Operational Research 1	C
5	Logistics Engineering	B			Industrial Ergonomics	B	Health Ergonomics	B	Production Planning and Control	C