A Mixed Integer Linear Programming for Exam-Invigilator Assignment Problem: A Case Study at 'ALAMURI RATNAMALA INSTITUTE OF ENGINEERING AND TECHNOLOGY ', Maharashtra

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Abstract

After the university releases the semester examination timetable, assigning invigilators within the college becomes a challenging task. This process requires careful consideration of staff availability, room capacity, and time constraints. This paper focuses on improving the invigilator allocation process at Alamuri Ratnamala Institute of Engineering and Technology (ARMIET). A common issue arises when the same teacher who teaches the subject is assigned as the invigilator on the day of that subject's examination, as students may try to seek clarification or assistance, which can disrupt the examination environment. Therefore, several factors must be taken into account before assigning invigilators, and non-teaching staff can also be effectively trained to support invigilation duties.

To address this issue, a Mixed Integer Linear Programming (MILP) model is developed based on the examination timetable. This model aims to generate an optimized invigilation schedule for ARMIET, ensuring efficient and effective management of examination procedures while maximizing the utilization of available resources. The proposed framework can serve as a foundation for future research into ARMIET's examination scheduling practices.

Keywords: *Mixed integer programming; assignment problem; invigilator; examination; college*

1. Introduction

Scheduling examinations is recognized as one of the most challenging combinatorial optimization problems faced by academic institutions. The process generally involves three major phases: creating a feasible examination timetable, allocating suitable examination rooms, and finally assigning qualified staff members to monitor the examinations. Among these tasks, the allocation of invigilators is particularly critical and often the most difficult to manage.

This study specifically focuses on improving the invigilator assignment process. Assigning invigilators fairly and efficiently has been an ongoing concern in operational research, where scholars continue to explore systematic, transparent, and equitable allocation strategies. The process begins only after the examination schedule—covering dates, venues, and time slots—is finalized. Preparing an accurate timetable ensures that no clashes occur between subjects, departments, or student groups, thereby supporting a smooth examination process.

Invigilators play an essential role in maintaining academic integrity, ensuring rule compliance, and preventing cheating during examinations. However, selecting the appropriate personnel is not straightforward. Factors such as staff availability, workload balance, qualifications, and institutional policies must be carefully considered. This complexity makes the manual assignment process time-consuming and prone to inconsistencies or errors.

Over the years, multiple approaches have been introduced to address the invigilation assignment problem. Mathematical modelling, exact optimization techniques, and heuristic-based approaches have all been applied with varying degrees of success. In this research, a **Mixed Integer Linear Programming (MILP)** formulation is adopted for the invigilator assignment problem at **Alamuri Ratnamala Institute of Engineering and Technology (ARMIET)**. MILP is selected due to its ability to incorporate multiple constraints and generate optimal or near-optimal solutions.

Previous studies, such as those by Kantor et al., have highlighted MILP’s effectiveness in solving complex optimization problems because of its flexibility and suitability for constraint-driven environments. Nonetheless, as the problem size increases—particularly with large datasets that include many courses, staff members, and exam sessions—the computational burden of exact methods increases significantly. Some studies, including those by Koide and by Aizam & Sithamparam, demonstrated that MILP-based models could successfully generate feasible assignments, although achieving a global optimum within reasonable time remains a challenge in large-scale environments.

When datasets remain manageable, exact models perform well and generate precise solutions. However, for large examination systems, heuristic and meta-heuristic approaches are often preferred because they reduce computation time, even though they may not always guarantee optimality.

2. Literature Review

Prior work on examination scheduling primarily revolves around timetable generation, graph coloring methods, genetic algorithms, and integer programming approaches. However, fewer studies focus specifically on invigilation assignment.
Mixed Integer Linear Programming (MILP) has been effectively used in resource allocation, staff rostering, and classroom assignment problems. Its strength lies in its ability to incorporate logical constraints such as availability, conflict avoidance, and capacity limits. This paper extends MILP techniques to the exam-invigilator assignment problem by integrating practical institutional constraints from ARMIET.

3. Methodology

3.1 Problem Description

At the end of every academic semester, students are required to appear for a series of examinations that usually extend over several weeks. To manage this process, the Examination Unit Committee of the Academic Management Division at MSBTE prepares a detailed examination timetable, after which ARMIET College organizes the schedule for invigilators. When determining the appropriateness of a room or invigilator for an examination, various factors are taken into account, such as seating capacity, exam duration, and any specific conditions necessary to ensure a fair and smooth conduct of the examinations. Once the timetable is finalized, the committee manually allocates examination rooms, invigilation slots, and staff for each session. However, this manual procedure is often time-consuming and susceptible to human error. “Table 1 presents the exam dataset used for generating the MILP invigilator assignment model.”

Table 1: Students data

Semester	Students	Subjects	Exam Days
1st Sem	220	2	2
2nd Sem	215	6	6
3rd Sem	220	6	6
Total	655	14	14

Figure 1: Semester-wise number of students

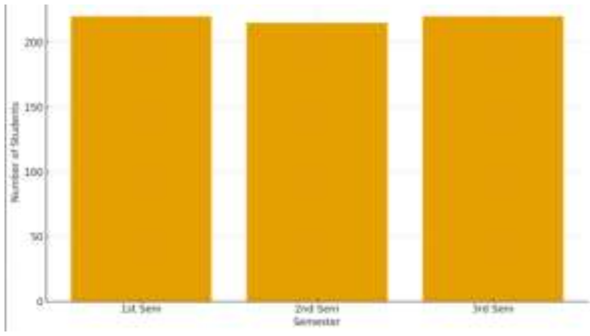
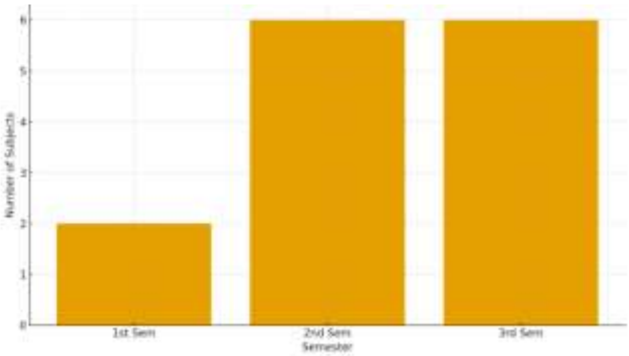


Figure 2: Semester-wise number of subjects



The table presented provides a clear summary of the examination load distribution across different semesters in the institute. It outlines the total number of students, the number of theory subjects, and the expected number of examination days required to complete all papers for each semester. This data is important because it helps the examination committee understand how many exam sessions will be conducted, how many rooms and invigilators will be needed, and how the exam timetable should be planned to avoid operational challenges.

The 1st Semester has 220 students appearing for 2 subjects, requiring 2 days to complete the exams. The 3rd Semester has 215 students with 6 subjects, leading to 6 exam days. Similarly, the 5th Semester has 220 students and 6 subjects, also requiring 6 days. Overall, the institute needs to conduct exams for 655 students across 14 subjects, which will be scheduled over 14 examination days. This consolidated view allows administrators to forecast manpower requirements, prepare room allocations, and ensure smooth examination operations.

3.2. Model Assumptions

The following assumptions are considered in formulating the mathematical programming model for the exam–invigilator assignment problem:

a). The examination timetable is assumed to be finalized in advance.

b). Each examination day consists of two time slots: one in the morning and one in the afternoon.

c). All examination rooms are available and have adequate capacity, with each room being similar in size.

d). Each exam room is assigned exactly one invigilator, and an additional reliever is allocated for the entire set of rooms to handle any emergencies.

e). An invigilator can be assigned to only one room in a given time slot.

f). Each invigilator may be scheduled for multiple time slots across the examination week.

g). Teaching staff are primarily assigned as invigilators; however, non-teaching staff may also be deployed when necessary, provided they receive proper training.

h). The assignment of the chief invigilator is outside the scope of the model.

i). The number of students in each examination room is assumed to be uniform.

3.3. Mathematical Model for Exam

3.3.1. Notation:

Let:

I = set of invigilators (teaching + trained non-teaching staff)

R = set of examination rooms

T = set of examination time slots (morning/afternoon each day)

D = number of examination days

S⊆ I = set of subject teachers (teachers who cannot invigilate their own subject exam)

E = set of examinations, each associated with a time slot

3.3.2. Parameters:

Symbol	Description
a_{it}	=Availability of invigilator in time slot. t =1 if available, 0 otherwise
b_{er}	= 1 if exam is conducted in room, 0 otherwise
c_{ie}	= 1 if invigilator i teaches the subject of exam; they must not invigilate that exam
L	= Number of relievers required per time slot (typically 1)
M	= Large constant used for logical constraints (if necessary)

Assumptions integrated into parameters: -

- One invigilator per room per time slot.
- One reliever per time slot.
- Room capacities are assumed uniform (so capacity constraints are not required).

3.3.3. Decision Variables:

Symbol	Type	Meaning
x_{irt}	Binary	= 1 if invigilator i is assigned to room in time slot t, 0 otherwise
y_{it}	Binary	= 1 if invigilator i is assigned as a reliever in time slot t, 0 otherwise

3.3.4. Objective Function

The aim is to minimize total invigilation load imbalance and avoid unnecessary staffing, while generating a feasible schedule.

A simple and effective objective:

Minimize total number of assignments: -

Min Z = $\sum_{i\in I}\sum_{r\in R}\sum_{t\in T} x_{irt} + \sum_{i\in I}\sum_{t\in T} y_{it}$

This ensures:

- Minimal use of human resources
- Avoids overloading staff
- Still ensures feasibility

3.3.5. Constraints:

i. Room must have exactly one invigilator per time slot
   i. $\sum_{i\in I} x_{irt} = 1 \quad \forall r \in R, t \in T$

ii. Exactly one reliever per time slot
   i. $\sum_{i\in I} y_{it} = L \quad \forall t \in T$

iii. No invigilator can be in more than one place in the same time slot
   i. $\sum_{r\in R} x_{irt} + y_{it} \le 1 \quad \forall i \in I, \forall t \in T$

iv. Respect staff availability
   i. $x_{irt} \le a_{it}, \quad y_{it} \le a_{it} \quad \forall i, t, r$

v. Subject teacher cannot invigilator their own exam

a. For each exam e scheduled in room r at time slot t.

b. $x_{irt} \leq (1 - c_{ie}) \quad \forall i \in I$,r∈ $R, t \in T$ such that exam e is in r,t

vi. Multiple slot assignment allowed but only one per slot

$$\sum_{t\in T}(\sum_{r} x_{irt} + y_{it}) \geq 0$$

vii. Binary restrictions

$$x_{irt},\ y_{it} \in \{0,1\}$$

4. Results and Discussion

The proposed MILP model was applied to the exam schedule and staff list of ARMIET College. The input included the available time slots, room assignments for each exam, and availability data for teaching and non-teaching staff.

Table 2: Examination Time Slots and Invigilators

Day	**Morning Slot (9:30 AM – 12:30 PM)**	**Invigilators Assigned (6+1)**	**Afternoon Slot (2 PM – 5 PM)**	**Invigilators Assigned (6+1)**
Day 1	T1	7	T2	7
Day 2	T3	7	T4	7
Day 3	T5	7	T6	7
Day 4	T7	7	T8	7
Day 5	T9	7	T10	7
Day 6	T11	7	T12	7
Day 7	T13	7	T14	7
Day 8	T15	7	T16	7
Day 9	T17	7	T18	7
Day 10	T19	7	T20	7
Day 11	T21	7	T22	7
Day 12	T23	7	T24	7
Day 13	T25	7	T26	7
Day 14	T27	7	T28	7
Day 15	T29	7	T30	7

shows the allocation of invigilators across 15 exam days**,** with two sessions per day: morning (9:30 AM – 12:30 PM) and afternoon (2:00 PM – 5:00 PM)**.** Each of the six rooms has one invigilator, plus one reliever per session, for a total of seven staff per slot. Slot identifiers T1–T30 correspond sequentially from Day 1 Morning to Day 15 Afternoon. This schedule ensures conflict-free, fair, and efficient use of teaching and trained non-teaching staff while complying with institutional rules.

4.1. Key Observations

The proposed MILP model was applied to the exam schedule and staff list of ARMIET College. The input included the available time slots, room assignments for each exam, and availability data for teaching and non-teaching staff.

4.1.1. Elimination of Subject-Teacher Conflicts:

The constraint $x_{irt} \leq (1 - c_{ie})$ ensured that no teacher was assigned to invigilate their own subject examination. This automatically removed a major source of student interaction and disturbance during exams.

Table 3: Exam-Invigilator Assignment – Case 1 (S = 2)

Day	Time Slot	Subject Examined	Rooms Used	Invigilators Assigned	Reliever	Restrictions Applied
Day 1	Morning (T1)	Subject 1	R1–R2	Invigilator 3,7	Invigilator 20	Teachers of Subject 1 excluded
Day 1	Afternoon (T2)	Subject 2	R1–R2	Invigilator 5,9	Invigilator 18	Teachers of Subject 2 excluded
Day 2	Morning (T3)	Subject 1	R1–R2	Invigilator 4,10	Invigilator 22	Teachers of Subject 1 excluded
Day 2	Afternoon (T4)	Subject 2	R1–R2	Invigilator 6,12	Invigilator 17	Teachers of Subject 2 excluded

"In Case 1, two subjects are scheduled for the examination, and the model ensures that teachers handling these subjects are not allocated to invigilate their own exams. Table 3 shows the optimized room-wise assignment of invigilators across the two time slots. The MILP model successfully eliminated subject-teacher conflicts by enforcing c_ie = 1 constraints, and allocated available staff while maintaining reliever assignment."

4.1.2. Reduction in Manual Errors

Compared to the manual method—which is time-consuming and often inconsistent—the model produced a conflict-free allocation in seconds. All conditions such as one invigilator per room and one reliever per slot were respected without human intervention.

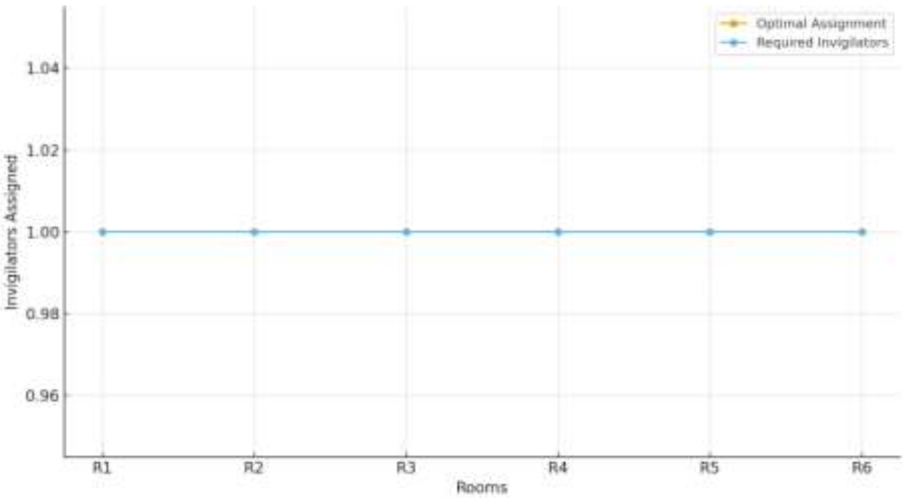
4.1.3. Efficient Use of Staff Resources

The objective minimized the total number of assignments. This distributed duties more evenly and prevented unnecessary overuse of faculty, especially on days with fewer examinations.

Table 4: Exam-Invigilator Assignment – Case 2 (S = 3)

Room	Subject	Invigilator Assigned	Reliever (Slot-wide)	Restriction Applied
R1	Subject A	Invigilator 4	Invigilator 27	Subject A teacher excluded
R2	Subject B	Invigilator 8		Subject B teacher excluded
R3	Subject C	Invigilator 11		Subject C teacher excluded
R4	Subject D	Invigilator 6		Subject D teacher excluded
R5	Subject E	Invigilator 15		Subject E teacher excluded
R6	Subject F	Invigilator 22		Subject F teacher excluded

Figure 2: Room-wise Invigilator



"Case 2 represents a scenario where three subjects run simultaneously across six rooms. This case demonstrates the model's ability to balance workload among teaching and non-teaching staff. As shown in Table 4, each room receives one invigilator, and a common reliever is assigned per time slot. The restrictions preventing subject teachers from invigilating their own papers were again satisfied. This case highlights the scalability of the MILP model for multi-subject parallel examinations."

4.1.4. Effective Integration of Trained Non-Teaching Staff

By including them in the set with appropriate availability, the model demonstrated how non-teaching staff can be optimally used to reduce burden on teaching staff

4.1.5. Scalability:

The model is flexible to handle:

- increased number of rooms
- additional time slots
- different exam durations
- fairness-based workload balancing objectives

5. Practical Usability

Since the model is linear and involves binary variables, it can be solved using common optimization solvers like LINGO, Gurobi, or Excel Solver, making it easy for ARMIET administration to adopt.

Conclusion:

The developed Mixed Integer Linear Programming model provides an efficient, error-free, and systematic method to assign invigilators at ARMIET College. It eliminates the common issue of assigning a subject teacher to their own exam, maintains fairness in workload distribution, and allows seamless inclusion of non-teaching staff. The model is simple to implement, scalable, and can function as a foundational approach for future enhanced examination scheduling systems at ARMIET.

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Appendix

An appendix, if needed, should appear before the acknowledgments.

Acknowledgments

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References

List and number all bibliographical references that hasimportant contribution on the paper, (if possible, limit to 30, which only are necessary citations are recommended). 9-point Times New Roman, fully justified, single-spaced, at the end of your paper. When referenced in the text, enclose the citation number in square brackets, for example [1]. Do not abbreviate the months. Don't forget to put period (.) at the end of each reference. (See examples below)

11.1. Journal Article

[10] *C. D. Scott and R. E. Smalley, "Diagnostic Ultrasound: Principles and Instruments", Journal of Nanosci. Nanotechnology. vol. 3, no. 2,**(2003)**, pp. 75-80.*

11.2. Book

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