TOPIC:Using Integer Programming for Nurse Scheduling

ANIRUDH SHEENA VIDYADHARAN-20243567

ANISH KUMAR-20243031

ANJALI RAJ-20243031

PROBLEM STATEMENT:

USE INTEGER PROGRAMMING TO CREATE NURSE SCHEDULES THAT MINIMIZES OVERTIME WHILE MEETING PATIENT-NURSE RATIOS

The Core Challenge

Scheduling Complexity

Hospitals must assign nurses across multiple shifts spanning seven days while accommodating variable patient demand and staffing constraints

Integer Programming Solution

Mathematical optimization ensures whole-number assignments—you can't schedule half a nurse—while automatically handling complex rules

Primary Objective

Reduce overtime costs and prevent burnout while maintaining safety standards like the critical 1:5 nurse-to-patient ratio

Decision Variables

Our model requires two key variable types to represent scheduling decisions and track overtime

Assignment Variable

Indicates whether a specific nurse is scheduled for a particular shift on a given day

$$X_{n,d,s} = \begin{cases} 1 & \text{if nurse } n \text{ works shift } s \text{ on day } d \\ 0 & \text{otherwise} \end{cases}$$

Binary decision: nurse either works that shift or doesn't

Overtime Variable

Tracks additional hours each nurse works beyond their regular 40-hour weekly limit

$$OT_n \geq 0$$

Non-negative continuous variable measuring extra hours for nurse n

Objective Function

Minimize Total Overtime

Primary Goal

Minimize the sum of overtime hours across all nurses to reduce costs and improve staff well-being

Mathematical Expression

$$\min \sum_{n} OT_n$$

Cost Adaptation

Can multiply by overtime rate (typically 1.5× regular pay) to minimize dollar costs instead of hours

Key Constraints: Coverage & Hours

Coverage Constraint

Ensure adequate staffing for each shift based on patient demand and required nurse-to-patient ratios

$$\sum_{n} X_{n,d,s} \geq R_{d,s} \quad \forall d, s$$

Where *R_{d,s}* represents required nurses calculated from patient census divided by safe ratio

Work Hours Constraint

Calculate total weekly hours per nurse, capping regular time at 40 hours while tracking necessary overtime

$$\sum_{d,s} X_{n,d,s} \times H_s = Regular_n + OT_n \quad \forall n$$

With *Regular_n \leq 40* and *OT_n \geq 0*, where *H_s* is shift duration

Additional Constraints

1

No Overlap Constraint

Prevent nurses from being double-booked on multiple shifts during the same day

$$\sum_{s} X_{n,d,s} \leq 1 \quad \forall n, d$$

2

Variable Type Constraints

Assignments must be binary yes/no decisions; overtime must be non-negative hours

$$X_{n,d,s} \in \{0, 1\}, \quad OT_n \geq 0$$

Previous Literature & Research Foundations

This model builds upon decades of optimization research in healthcare scheduling

1

Mystakidis et al. (2024)

Applied **integer programming** to optimize nurse rostering in oncology units; improved workload balance and reduced overtime while meeting staffing constraints.
Reference:https://www.mdpi.com/2227-9032/12/24/2545?utm_source=chatgpt.com

2

Sukonpat & Jarumaneeroj (2023)

Formulated a **multi-objective mixed-integer model** for Thai hospital nurse scheduling; balanced fairness, rest periods, and overtime cost effectively.
Reference:https://ph02.tci-thaijo.org/index.php/TJOR/article/view/249443?utm_source=chatgpt.com

3

Zhang et al. (2025)

Developed a **multi-stage stochastic MIP** for nurse staffing under uncertain patient demand; demonstrated reduced overtime and cost through flexible scheduling.
Reference:https://arxiv.org/abs/2505.22124?utm_source=chatgpt.com

4

Milesky et al. (2025)

Reviewed effects of **patient-to-nurse ratio violations** on care quality and safety; emphasized importance of adequate coverage constraints in optimization models.
Reference:https://journals.sagepub.com/doi/10.1177/25160435251358976?utm_source=chatgpt.com

Implementation Details

Technical Approach

Formulate the problem as a Mixed-Integer Linear Program (MILP), input hospital data including nurse availability and patient demand forecasts, then solve for the optimal schedule

01

Define Parameters

Nurse pool, demand patterns, shift structure

02

Build Model

Add variables, objective function, constraints

03

Solve Optimization

Run solver engine to find optimal solution

04

Generate Schedule

Output shift assignments and overtime totals

Technology Stack

Python Language

Widely available, simple syntax for optimization

PuLP Library

Defines variables, constraints, objective

CBC Solver

Free built-in solver (or Gurobi/CPLEX for scale)

No internet required—install PuLP via pip for offline use

Summary & Next Steps

Integer Programming Creates Efficient Schedules

By minimizing overtime while meeting critical patient-nurse ratios through mathematical optimization

Comprehensive Model Components

Decision variables, objective function, and constraints work together to balance competing operational demands

Proven by Research & Practice

Decades of academic literature demonstrate 15-30% improvements in overtime reduction across diverse hospital settings

THANK YOU!