

# **TOPIC:Using Integer Programming for Nurse Scheduling**

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# **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	Mathematical Expression
Minimize the sum of overtime hours across all nurses to reduce costs and improve staff well-being	$\min \sum_n OT_n$
Cost Adaptation	Can multiply by overtime rate (typically 1.5x 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

## Mystakidis et al. (2024)

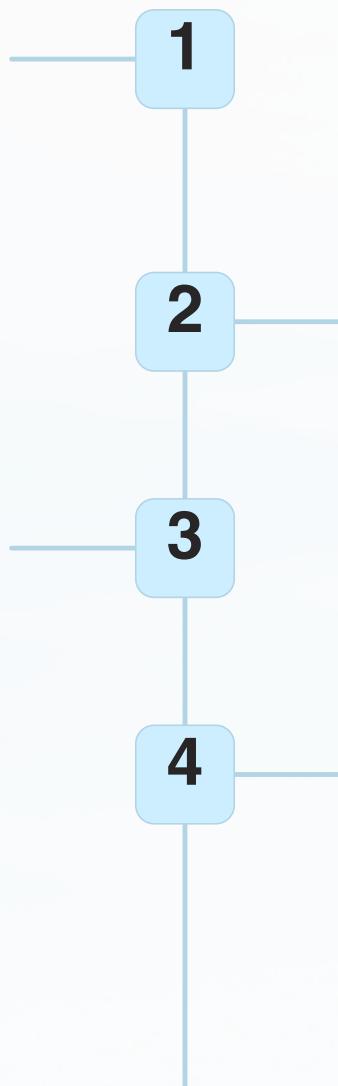
Applied **integer programming** to optimize nurse rostering in oncology units; improved workload balance and reduced overtime while meeting staffing constraints.

Reference:[https://www.mdpi.com/2227-9032/12/24/2545?utm\\_source=chatgpt.com](https://www.mdpi.com/2227-9032/12/24/2545?utm_source=chatgpt.com)

## 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](https://arxiv.org/abs/2505.22124?utm_source=chatgpt.com)



## 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](https://ph02.tci-thaijo.org/index.php/TJOR/article/view/249443?utm_source=chatgpt.com)

## 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](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!**