Optimization of a Weekly Nurse Schedule in a Healthcare Center

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1. INTRODUCTION

In healthcare, nurse scheduling is essential for operational efficiency, requiring the balance of the need for constant patient care with nurse availability and preferences [1]. We employed a linear programming (LP) approach [2] to maximize nurse preferences, subject to 6 constraints:

1. each nurse can work a maximum of 5 shifts per week
2. daily demand has to be met
3. nurses are not allowed to work more than 3 consecutive days
4. nurses cannot work the whole weekend
5. nurses cannot work more than 1 shift per day
6. nurses can work only if they are available

2. METHODOLOGY

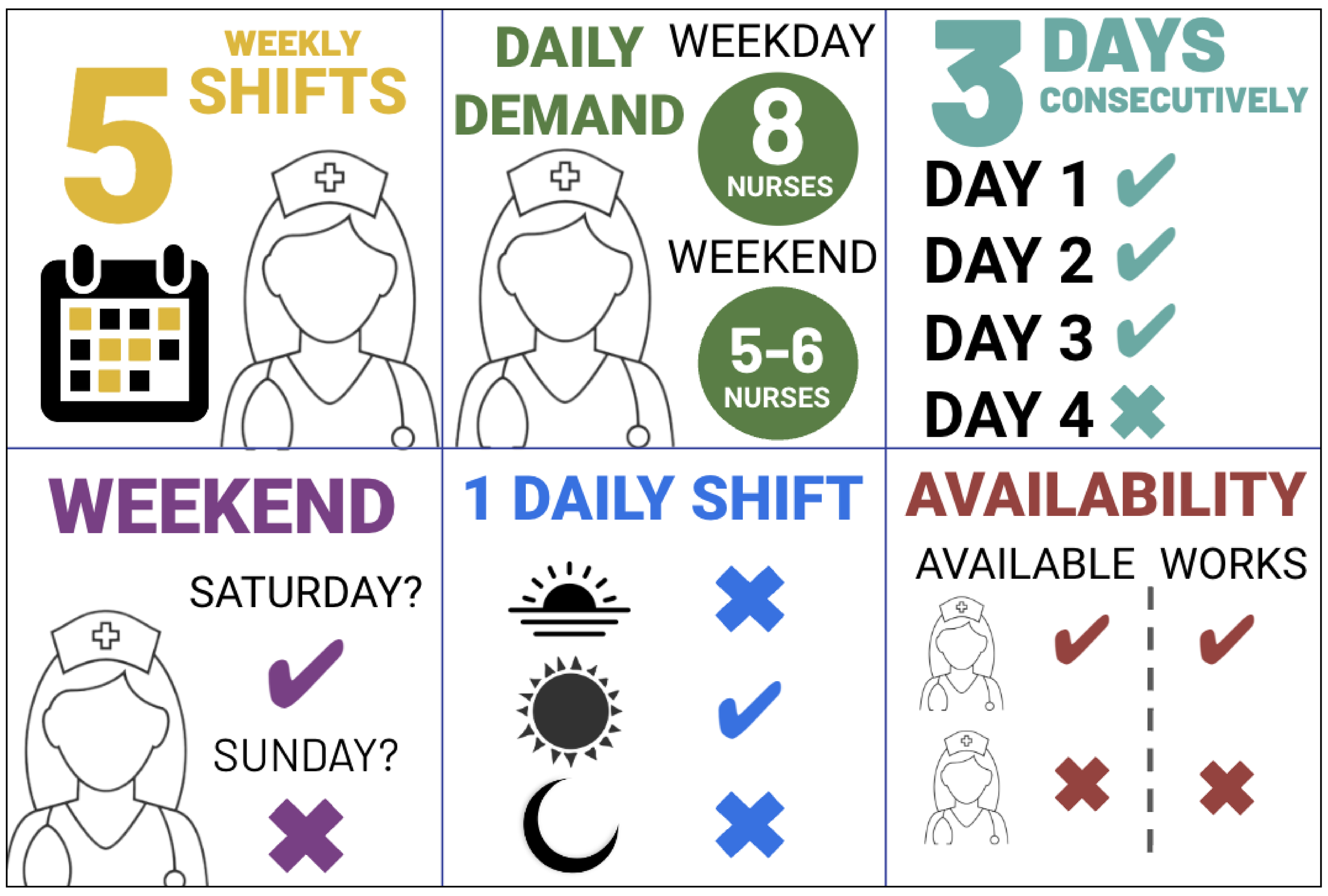
The problem adapted itself to straightoward LP formulation.
We used the binary decision variable x_{ijk}. $i = 1, \ldots, 36$ represents the 36 nurses, $j = 1, \ldots, 7$ represents the 7 days of the week, and $k = 1, 2, 3$ represents the 3 shifts (morning, afternoon, and night), where:

$$x_{ijk} = \begin{cases} 1 & \text{if nurse } i \text{ works on day } j \text{ in shift } k, \\ 0 & \text{otherwise.} \end{cases}$$

p_{ijk} represents the preference nurse i has to work shift k on day j, and a_{ij} represents whether nurse i is available on day j.

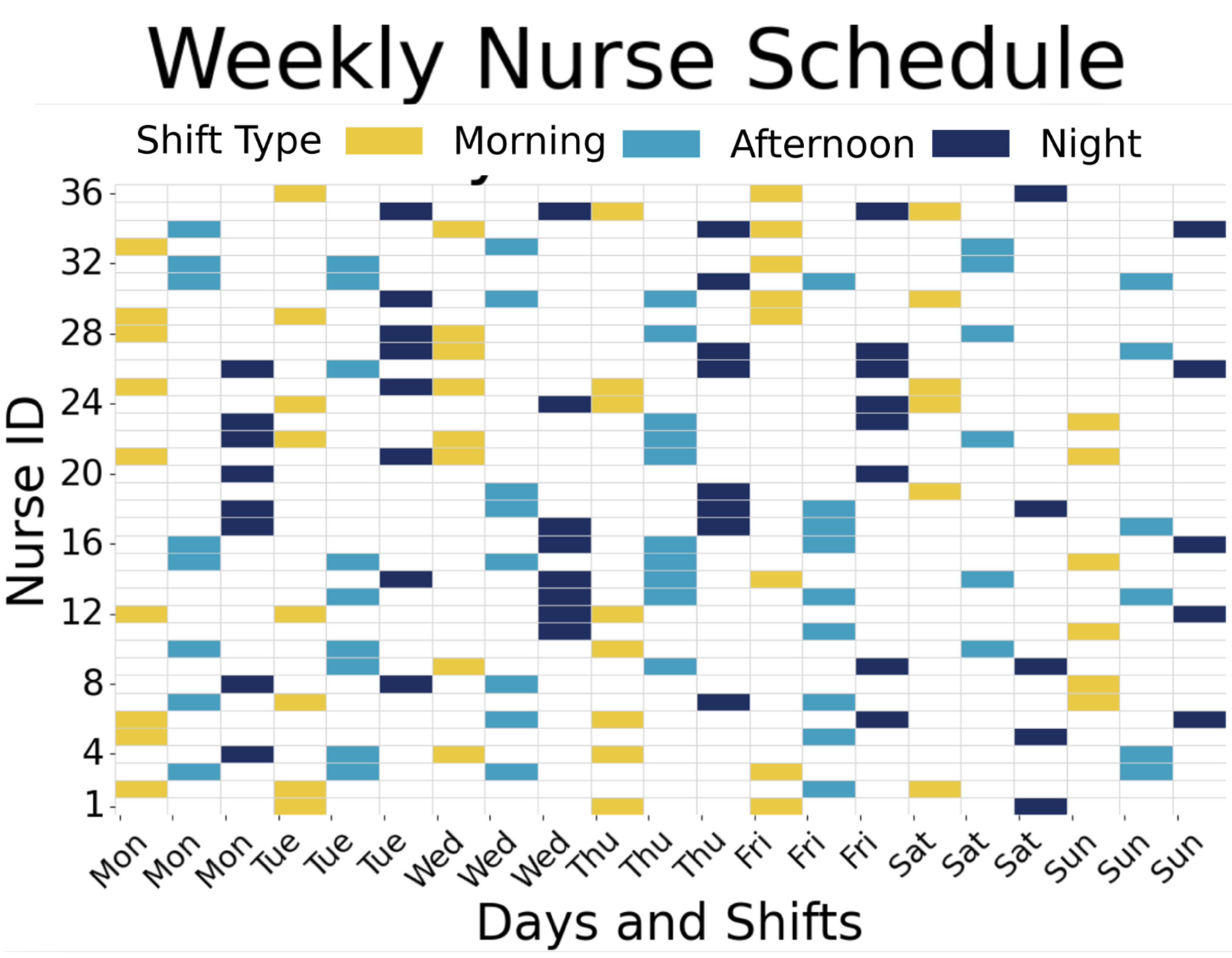
The LP problem can be formulated as:

$$\begin{aligned}
\text{maximize} \quad & \sum_{k=1}^{3}\sum_{j=1}^{7}\sum_{i=1}^{36} p_{ijk}x_{ijk} \\
\text{subject to} \quad & \sum_{k=1}^{3}\sum_{j=1}^{7} x_{ijk} \leq 5, \quad i = 1, \ldots, 36, \\
& \sum_{i=1}^{36} x_{ijk} \geq d_{jk}, \quad j = 1, \ldots, 7, \quad k = 1, 2, 3, \\
& \sum_{k=1}^{3}\sum_{j=j_0}^{j_0+3} x_{ijk} \leq 3, \quad i = 1, \ldots, 36, \quad j_0 = 1, 2, 3, 4, \\
& \sum_{k=1}^{3}\sum_{j=6}^{7} x_{ijk} \leq 1, \quad i = 1, \ldots, 36, \\
& \sum_{k=1}^{3} x_{ijk} \leq 1, \quad i = 1, \ldots, 36, \quad j = 1, \ldots, 7, \\
& \sum_{k=1}^{3} x_{ijk} \leq a_{ij}, \quad i = 1, \ldots, 36, \quad j = 1, \ldots, 7, \\
& x_{ijk} \in \{0, 1\}, \quad i = 1, \ldots, 36, j = 1, \ldots, 7, k = 1, 2, 3
\end{aligned}$$



3. RESULTS

After modeling the LP problem in Python using the LP library Pyomo [3], and using data given from the client about the preferences p_{ijk} and availabilities a_{ij} for each nurse, we created a Gantt chart [4].



- Nurses can identify their weekly schedule by finding their Nurse ID on the y-axis and checking which shifts they are working on the x-axis.
- The model selected 159 shifts in total.
  - 144 correspond to the nurses' highest preferences, 15 correspond to the second highest preferences, and 0 correspond to the third preferences.

4. CONCLUSIONS

- We successfully maximized nurse shift preferences with respect to scheduling constraints using an LP approach.
- Some key considerations were not taken into account. For example:
  - **Schedule flexibility**: holidays, sick days, emergencies are not taken into account. The schedule assumes constant nurse availability.
  - **Shift quantity imbalance**: Nurses work different numbers of shifts, causing resentment if all nurses get paid equally.
    - The model could be improved by adding a constraint stating every nurse must work the same number of shifts.
    - The hospital could implement a pay-per-shift system to promote fairness.

5. REFERENCES

[1] Jaumard, Brigitte, et al. "A Generalized Linear Programming Model for Nurse Scheduling." European Journal of Operational Research, vol. 107, no. 1, 13 Jan. 2011, pp. 1–18.
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[4] Waskom, Michael. "Seaborn.Heatmap." Seaborn, seaborn.pydata.org/generated/seaborn.heatmap.html. Accessed 04 Oct. 2024.