Optimal Long Term Nurse Staffing Considering Absenteeism and Demand Uncertainty

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Effects of Increased Nursing Levels

On Patients
- Decreased patient mortality rates
- Shorter patient length of stay
- Decrease in medication errors
- Lower odds of several patient adverse events
- Higher nurse-reported quality of care

On Nurses
- Decrease in nurse burnout rates
- Increase in nurse satisfaction

On Costs
- Already 15% of hospital costs
Effects of Increased Nursing Levels

More nurses
Better for Patients & Nurses

More nurses
Higher cost; Already 15% Of Hospital Costs
High variability in census needs and nursing availability
How is nursing organized at UMHS

- **Flexible**
  - Temp nurses
  - $$$

- **Some Flexibility**
  - Pool nurses
  - $$

- **Inflexible**
  - Adult ICU
  - Pediatric ICU
  - Neonatal ICU
  - $$

**Temporal and Spatial Correlations**
Absenteism

- Nurses may not be able to provide care for patients due to:
  - Not being at work:
    - Paid Time Off
    - Unpaid Time Off
    - Conferences/Employee Development
  - Being at work:
    - Educational Commitments
    - Administrative Responsibilities

20% at UMHS
Determine UMHS nurse staffing levels to:

- Ensure patient demand is satisfied
- Minimize nurse staffing costs

While accounting for uncertain:

- Demand
- Nurse Absenteeism
Formulation: Sets

**J** Units in a pool

**S** Demand scenarios

**R_s** Realizations of absent nurses in scenario \( s \in S \)
Formulation: Parameters

Daily cost per nurse
• \( c_j \) unit \( j \in J \)
• \( d \) pool
• \( e \) temp.

Value of extra nurse: \( f \)

Probability
• \( q_s \) of demand scenario
• \( \Theta^r_s \) of absenteeism realization

\# of nurses needed in unit \( j \in J \) in scenario \( s \in S \): \( \eta_{js} \)

\# of absent nurses in realization \( r \in R_s \) from:
• \( a^r_{js} \) unit \( j \in J \)
• \( b^r_s \) pool
Formulation: Decision Variables

Long Term Decisions:
# of nurses to hire:
  - \( X_j \) unit \( j \in J \)
  - \( Y \) pool

Daily Decisions:
For unit \( j \in J \), scenario \( s \in S \), realization \( r \in R_s \)
  - \( Z^r_{js} \) # of pool nurses to allocate
  - \( W^r_{js} \) # temp nurses to hire
  - \( V^r_{js} \) # of extra nurses
Model Formulation

Min \( \sum_{j \in J} c_j X_j + dY + \sum_{s \in S} q_s \sum_{r \in R_s} \theta^r \left\{ e \sum_{j \in J} W^r_{js} - f \sum_{j \in J} V^r_{js} \right\} \)

Subject to:

Unit + pool + E\{Temp – Extra\} Cost

Unit – Unit Absenteeism + Pool Assignment + Temp – Extra \( \geq \) Needed

\[ \sum_{j \in J} X_j - a_j^r + Z_{js}^r + W_{js}^r - V_{js}^r \geq n_j s \ \forall \ j \in J; \ s \in S; \ r \in R_s \]

All pool nurses are either assigned to a unit or absent

Integrality and Non-Negativity Constraints
Example Results

- 4 Unit Pediatric Acute Care Pool
- 366 days in 2012

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>P(Absent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>$400</td>
<td>0.2</td>
</tr>
<tr>
<td>Pool</td>
<td>$425</td>
<td>0.2</td>
</tr>
<tr>
<td>Temp</td>
<td>$460</td>
<td>0</td>
</tr>
<tr>
<td>Extra</td>
<td>$200</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Genetic Algorithm Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop. Size</td>
<td>25</td>
</tr>
<tr>
<td>Max Generations</td>
<td>100,000</td>
</tr>
<tr>
<td>Max Generations w/out an improvement in the pop.</td>
<td>20,000</td>
</tr>
<tr>
<td>P(Mutation)</td>
<td>0.25</td>
</tr>
<tr>
<td>Reps/day</td>
<td>20</td>
</tr>
</tbody>
</table>
Sensitivity to $P(\text{Absent})$

The graph shows the sensitivity of the expected number of extra nurses required based on the probability of absenteeism ($P(\text{Absent})$). The x-axis represents the probability of absenteeism ranging from 0.00 to 0.20, while the y-axis represents the number of nurses. The expected number of extra nurses is shown for different units and pools, with varying colors and line markers. The base case is highlighted at $P(\text{Absent}) = 0.20$.
### Why Does This Happen?

<table>
<thead>
<tr>
<th>Unit</th>
<th>Nominal Cost</th>
<th>P(Absent)</th>
<th>Cost/Contact Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>$400</td>
<td>0.2</td>
<td>$500</td>
</tr>
<tr>
<td>Pool</td>
<td>$425</td>
<td>0.2</td>
<td>$531.25</td>
</tr>
<tr>
<td>Temp</td>
<td>$460</td>
<td>0.0</td>
<td>$460</td>
</tr>
</tbody>
</table>

**Unit and Pool nurses more $ per contact hour Why use them?**
... But Temp Nurses Are Not As Good

- Use UNIT w/ 8.7% temp penalty
- Use POOL w/ 17% temp penalty
Limit on the # of temp nurses that can be hired

\[ P\left( \sum_{j \in J} W_{js}^r > \tau; \forall s \in S; r \in R_s \right) \leq \alpha \]

\[ P(\text{use more than } \tau \text{ temps in any realization}) \leq \alpha \]
Chance Constraint Results

P(5 or more temp nurses needed) ≤ α

- No employees hired when Prob=1
- More hired as Prob goes down

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With current staffing costs and absenteeism rates, the “cost minimizing” solution does not use hospital based nurses.

Hospital based nurses are used if
- Penalty using temps is \( \geq 8.7\% \)
- Absenteeism rate \( \leq 70\% \) its current rate
- Account for limited availability of temp nurses
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Thank You!