Addressing Multi-criteria Objective Functions in Healthcare Provider Scheduling Projects: A Case Study in Scheduling Trauma Attendings

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THE TEAM, THE TEAM, THE TEAM (AMY)
DIVISION OF ACUTE CARE SURGERY!

- What are we?
- Who are we?
- What do we do?
- Our Services
- Our Programs
- Our Awesome Staff!
Our services of care
24 X 7:

- TBICU: Trauma Burn ICU
- ACS-1: Emergency surgery and Trauma
- ACS-2: Emergency surgery and Trauma
- SICU: Surgical ICU
- Burn
- New Consults/Admissions
What it takes to be an adult designated LEVEL ONE TRAUMA AND BURN VERIFIED CENTER

- Site Visit every 3 years, by external reviewers assigned by the American College of Surgeons-Committee on Trauma (ACS-COT)
- Extensive hospital data must be provided
- 24-Hour Availability by Physicians and specialty care staff
- Expertise to treat severely injured patients
- Few institutions have achieved the Level 1 Trauma Center verification for both adults & children, a fact that demonstrates our longstanding commitment to providing the best & most responsive resources for the treatment of trauma.
THE DAY CALL SCHEDULING PROBLEM (DANIEL)

Task:
• Scheduling an attending to a unit in a week
• 5 units, 26 weeks, and 15 attendings
# The Day Call Scheduling Problem (Daniel)

1. Attending Assignment
2. Maximum Consecutive Work Weeks e.g. <4
3. Unit Coverage
4. Valid Unit Pairs

<table>
<thead>
<tr>
<th>Unit</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBICU</td>
<td>Annette</td>
<td>Daisy</td>
<td>Esther</td>
<td>Esther</td>
<td>Houston</td>
<td>Daisy</td>
<td>Isaac</td>
</tr>
<tr>
<td>BURN</td>
<td>Annette</td>
<td>Fiona</td>
<td>Daisy</td>
<td>Daisy</td>
<td>Esther</td>
<td>Daisy</td>
<td>Fiona</td>
</tr>
<tr>
<td>ACS1</td>
<td>Bob/Clark</td>
<td>Annette</td>
<td>Annette</td>
<td>Annette</td>
<td>Daisy</td>
<td>Isaac</td>
<td>Greg</td>
</tr>
<tr>
<td>ASC2</td>
<td>Daisy</td>
<td>Greg</td>
<td>Bob</td>
<td>Bob</td>
<td>Isaac</td>
<td>Fiona</td>
<td>Isaac</td>
</tr>
<tr>
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<td>Clark</td>
<td>Fiona</td>
<td>Greg</td>
<td>Houston</td>
<td>Clark</td>
</tr>
</tbody>
</table>

5. Bounds on Attendings’ Total Unit Assignments e.g. Greg $3 < x < 8$
6. Bounds on Attendings’ Individual Unit Assignments e.g. Annette ACS1 $1 < x < 3$
THE DAY CALL SCHEDULING PROBLEM (DANIEL)

• Metrics:
  • Changes to External Schedule Requests
  • Weeks Off Requests Denied
  • Exceedances of Target Maximum Number of Consecutive Weeks Off
THE NIGHT CALL SCHEDULING PROBLEM (DANIEL)

Task:
• Scheduling an attending to a date
• 182 days and 15 attendings
# The Night Call Scheduling Problem (Daniel)

<table>
<thead>
<tr>
<th>Nights</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td></td>
<td>Caroline</td>
<td>Caroline</td>
<td>Annette</td>
<td>Dennis</td>
<td>Esther</td>
<td>Dennis</td>
</tr>
<tr>
<td>Week 2</td>
<td>Caroline</td>
<td>Annette</td>
<td>Caroline</td>
<td>Bob</td>
<td>Caroline</td>
<td>Annette</td>
<td>Bob</td>
</tr>
<tr>
<td>Week 3</td>
<td>Bob</td>
<td>Dennis</td>
<td>Caroline</td>
<td>Esther</td>
<td>Annette</td>
<td>Bob</td>
<td>Annette</td>
</tr>
<tr>
<td>Week 4</td>
<td>Dennis</td>
<td>Bob</td>
<td>Caroline</td>
<td>Bob</td>
<td>Esther</td>
<td>Dennis</td>
<td>Esther</td>
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<td>Dennis</td>
<td>Sarah</td>
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<tr>
<td>ACS1</td>
<td>Dennis</td>
<td>Bob</td>
<td>Annette</td>
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<td>Bob</td>
</tr>
<tr>
<td>SICU</td>
<td>Bob</td>
<td>Esther</td>
<td>Dennis</td>
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</table>

1. Nights Coverage  
2. No Consecutive Assignments  
3. Maximum Assignments in 7-Day-Period  
4. Bounds on Attendings’ Total Assignments e.g. Bob 2 < x < 4  
5. Bounds on Attendings’ Monthly Assignments e.g. Bob 1 < x < 3  
6. Sunday Assignments  
7. Granted Time Off Requests e.g. Esther Week 3  
8. ACS1 Friday Assignments e.g. Bob Week 2 Friday  
9. ACS2 Saturday Assignments  
10. ACS1 Sunday Assignments
THE NIGHT CALL SCHEDULING PROBLEM (DANIEL)

Metrics:
• Nights Off Requests Denied
• Assignments Outside of Preferences
THE DAY CALL SCHEDULING FORMULATION (KRISTINE)

Sets

\[ A : \text{set of attending surgeons} \]
\[ U : \text{set of units} \]
\[ W : \text{set of weeks in planning horizon} \]

Decision variables

\[ x_{auw} = \begin{cases} 
1 & \text{if assigning attending } a \text{ to unit } u \text{ on week } w \\
0 & \text{otherwise} 
\end{cases} \]

\[ \forall a \in A, u \in U, w \in W \]
THE DAY CALL SCHEDULING FORMULATION (KRISTINE)

Unit Coverage
\[ \sum_{a \in A} x_{auw} = 1 \quad \forall \ u \in U, w \in W \]

Valid Unit Pairs
\[ x_{au_1w} + x_{au_2w} \leq p_{u_1u_2} + 1 \quad \forall \ a \in A, w \in W, u_1, u_2 \in U \ s.t. u_1 > u_2 \]

Attending Assignment
\[ \sum_{u \in U} x_{auw} \leq 2 \quad \forall \ a \in A, w \in W \]

Preassignments
\[ x_{ayuw_y} = 1 \quad \forall \ y \in Y^x \]

Prohibitions
\[ x_{anun_w} = 0 \quad \forall \ n \in N^x \]
THE DAY CALL SCHEDULING FORMULATION (KRISTINE)

Bounds on Attendings’ *Individual* Unit Assignments

\[ lb_{au} \leq \sum_{w \in W} x_{auw} \leq ub_{au} \quad \forall \ a \in A, u \in U \]

Bounds on Attendings’ *Total* Unit Assignments

\[ lb_a \leq \sum_{u \in U} \sum_{w \in W} x_{auw} \leq ub_a \quad \forall \ a \in A \]

Maximum Consecutive Work Weeks

\[ z_{aw} \geq x_{auw} \quad \forall a \in A, u \in U, w \in W \]

\[ z_{aw} \leq \sum_{u \in U} x_{auw} \quad \forall a \in A, w \in W \]

\[ \sum_{i=w}^{w+\text{max}} z_{ai} \leq \text{max} \quad \forall \ a \in A, \quad w = 1, \ldots, \text{numWeeks} - \text{max} \]
The Day Call Scheduling Formulation (Kristine)

Week Off Requests Denied

\[ D^T = \sum_{a \in A} \sum_{w \in V_a} z_{aw} \]

\[ lb \leq D^T \leq ub \]

\[ D^M \geq \sum_{w \in V_a} z_{aw} \quad \forall a \in A \]

\[ lb \leq D^M \leq ub \]
THE NIGHT CALL SCHEDULING FORMULATION (KRISTINE)

Sets

\[ A : \text{set of attending surgeons} \]
\[ D : \text{set of dates in planning horizon} \]

Decision variables

\[ y_{ad} = \begin{cases} 1 & \text{if assigning attending } a \text{ on date } d \\ 0 & \text{otherwise} \end{cases} \]

\[ \forall a \in A, d \in D \]
# The Night Call Scheduling Formulation (Kristine)

<table>
<thead>
<tr>
<th>Category</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Coverage</strong></td>
<td>( \sum_{a \in A} y_{ad} = 1 \quad \forall \ d \in D )</td>
</tr>
<tr>
<td><strong>No Consecutive Assignments</strong></td>
<td>( \sum_{i=d}^{d+1} y_{ai} \leq 1 \quad \forall \ d = 1, \ldots, numDays - 1 )</td>
</tr>
<tr>
<td><strong>Maximum Assignments in 7-Day-Period</strong></td>
<td>( \sum_{i=d}^{d+6} y_{ai} \leq 2 \quad \forall \ d = 1, \ldots, numDays - 6 )</td>
</tr>
<tr>
<td><strong>Preassignments</strong></td>
<td>( y_{a(p)d(p)} = 1 \quad \forall \ p \in P )</td>
</tr>
<tr>
<td><strong>Prohibitions</strong></td>
<td>( y_{a(n)d(n)} = 0 \quad \forall \ n \in N )</td>
</tr>
</tbody>
</table>
THE NIGHT CALL SCHEDULING FORMULATION (KRISTINE)

 Bounds on Attendings’ Monthly Assignments

\[ lb_{am} \leq \sum_{d \in D_m} y_{ad} \leq ub_{am} \quad \forall \ a \in A, m \in M \]

 Bounds on Attendings’ Total Assignments

\[ lb_a \leq \sum_{d \in D} y_{ad} \leq ub_a \quad \forall \ a \in A \]

 Sunday Assignments

\[ y_{adw} \leq s_{aw} \quad \forall a \in A, w \in W \]
WHAT MAKES THIS PROBLEM CHALLENGING  (RAGHU)
HOW WE SOLVE IT (HANNAH)

1. Refine Inputs
2. Receive Feedback
3. Generate Schedule
HOW WE SOLVE IT (HANNAH)

Multi-criteria optimization in practice…

Day Call Schedule

- Spacing
- Time Off Requests
- Changes to Schedule Requests

Night Call Schedule

- Preferences
- Consistent Monthly Bounds
- Overall Equity
HOW WE SOLVE IT (HANNAH)

Unforeseen challenges and schedule conflicts…

Day Call Schedule
  • Translation of time off requests
  • External schedule requests denied time off requests

Night Call Schedule
  • Preferences denied by weekend assignments
Results…

Day Call Schedule
- 108 of 110 time off requests granted
- 52 of 52 external schedule requests granted

Night Call Schedule
- 152 of 182 assignments within preferences
- 108 of 108 time off requests granted
CLOSING THOUGHTS (RAGHU)