Disclosures

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None
Presentation outline

1. Background
2. Model
3. Practical implementation
4. Conclusions
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Medical training pathway

Undergraduate Student → Medical Student → Resident → (Fellow) → Attending Physician

Responsibility

Resident

Post-medical school physician trainee

Patient care provider under attending physician supervision
Medical training pathway

Undergraduate Student → Medical Student → Resident → Attending Physician

Responsibility

Focus

Developing internal medicine clinical skills vs Seeking early subspecialization
Roles/responsibilities of CMRs

Chief Medical Resident
Impact of residency schedules

- clinical and administrative workflow
- patient access, care quality, safety, and satisfaction
- training quality and burnout rates
Two years ago, we knew three things:

1) We were likely unnecessarily impacting our residents’ (and patients’) lives in a negative way.
2) There had to be a better way to advocate for residents and meet their needs.
3) We needed a lot of help if we were ever going to get there.
Partner programs

Pediatrics [ Peds ]
Medicine-Pediatrics [ MP ]
Internal Medicine [ IM ]
Dept. of Surgery [ 12 programs ]
Research objective

Develop a decision support system to enable **fast construction** while simultaneously **improving quality** of annual rotation schedules
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4. Conclusions
Model

Minimize:
- Ranked resident requests denied
- Ranked administrative preferences denied
- Seasonal (interview, graduation) conflicts
- Burnout sequences
- Undesirable activity assignments
- Ambulatory credit variability

Subject to:
- Basic assignment rules
- Rotation duration
- Service coverage demands
- Resident education requirements
- Service spacing and sequencing
- Resident pairings
- Prohibitions and pre-assignments
Model parameters

Sets

\( R \): set of residents
\( S \): set of services
\( T \): set of time periods
\( A \): set of activities

Decision variables

\[ x_{rst} = \begin{cases} 1, & \text{if assigning resident } r \text{ to service } s \text{ during time period } t \\ 0, & \text{otherwise} \end{cases} \]

\[ y_{rat} = \begin{cases} 1, & \text{if assigning resident } r \text{ to begin activity } a \text{ during time period } t \\ 0, & \text{otherwise} \end{cases} \]
Constraints

Basic assignment
\[ \sum_{s \in S} x_{rst} = 1, \quad \forall r \in R, t \in T \]

Rotation duration
\[ x_{rst} - \sum_{a \in A: s(a)=s} \sum_{p \in [\max(0,t-d_a+1),t]} y_{rap} = 0, \quad \forall r \in R, s \in S, t \in T \]

Service coverage
\[ L \leq \sum_{r \in R'} \sum_{s \in S'} \sum_{t \in T'} x_{rst} \leq U, \quad \forall (R', S', T') \in C \]

Resident education
\[ \lambda \leq \sum_{s \in S'} \sum_{t \in T'} x_{rst} \leq \mu, \quad \forall e \in E, (S', T') \in e \]

Service spacing
\[ y_{rAt} + \sum_{i=t+d_A}^{t-1} y_{rBi} \leq 1, \quad \forall t \in \{0, \ldots, |T| - 1 - d_A\} \]

Service sequencing
\[ 0 \leq \sum_{i=0}^{t-1} \sum_{s \in A^*} x_{rsi} - x_{r\beta t}, \quad \forall t \in \{1, \ldots, |T| - 1\} \]

Resident pairings
\[ \sum_{r \in R_1^g} \sum_{s \in S_1^g} \sum_{t \in T_1^g} x_{rst} + \sum_{u \in R_2^g} \sum_{v \in S_2^g} \sum_{w \in T_2^g} x_{uvw} = 0, \quad \forall g \in G \]

Pre-assignments
\[ x_{rn_sn} = 1, \quad \forall n \in N \]

Prohibitions
\[ x_{ro_so} = 0, \quad \forall o \in O \]
Objective function

Important to consider numerous metrics, but no obvious objective function

- Ranked resident requests denied
- Ranked administrative preferences denied
- Seasonal (interview, graduation) conflicts
- Burnout sequences
- Undesirable activity assignments
- Ambulatory credit variability

Options:
1. Optimize weighted sum of metrics
2. Optimize metrics hierarchically
3. Something else?
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Implementation process

1. Formulate
2. Encode
3. Load
4. Solve
5. Review
Encode the model in C++, using CPLEX 12.4

Design robust input file formats to match potential needs

Gather rules and requests for the respective partner programs
Dept. of Surgery model

175 residents  73 services
12 time periods  74 activities

Total Variables  208,543
Total Constraints  59,385
Integrated Solve Time  < 1 min
Peds – MP – IM model

- Pediatrics [ Peds ]
- Medicine-Pediatrics [ MP ]
- Internal Medicine [ IM ]

245 residents
24 time periods
107 services
122 activities

Total Variables 1,346,520
Total Constraints 1,992,897
Integrated Solve Time 1 – 24 hrs
Sequential scheduling

Schedule Peds (w/ MP pre-assignments)

- **Peds Solve Time**: < 1 min
- **MP Solve Time**: < 1 min

Schedule MP only

Schedule IM (w/ MP pre-assignments)

- **IM Solve Time**: > 30 min
Decoupled senior/intern schedules

Senior Solve Time: 10 – 20 min

IM Solve Time: > 30 min

Intern Solve Time: < 5 min
Two-stage scheduling

**Stage 1**
Aggregate similar services with composite educational requirements and service demands

**Stage 2**
Decompose aggregated services and apply individualized requirements and service demands

**Stage 1 Solve Time** 5 – 20 min

**Stage 2 Solve Time** < 5 min
Warm-starting solver

1. Add subset of constraints to model
2. Solve model
3. Generate MIP warm start file
4. Repeat steps 1-3 until all constraints have been incorporated
Minimize iterative changes

After hierarchically optimizing metrics, minimize changes from previous draft

Reduces number of individual resident schedules that must be reviewed each iteration
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Summary

Facilitating coordinated scheduling for two separate groups of interdependent programs

Afforded leadership greater specificity of scheduling needs compared to manual construction

Improved stakeholder satisfaction regarding measures of schedule quality

Enabled rapid construction via algorithmic strategies
## Ongoing work

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Investigating impact of specific rules (and rule categories)</th>
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<tbody>
<tr>
<td>Engines</td>
<td>Exploring whether modifications to CPLEX default settings, use of Gurobi, etc. improve solve time</td>
</tr>
<tr>
<td>Processes</td>
<td>Streamlining administrative, input, iteration, and revision mechanisms</td>
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</tbody>
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Challenges and opportunities

Challenges

• Each program is unique
• Mathematical complexity
• Ill-defined objective function and shifting / competing preferences

Opportunities

• Many benefits to close collaboration
• Blending of practical / theoretical research
• Standardization and developing deep knowledge of problem domain
• Key focus: Impact in practice
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