Multi-criteria Objective Functions In A Real-World Clinical Provider Scheduling Problem

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CHEPS

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Rx

A prescription to address system complexity in healthcare

INNOVATING HEALTHCARE DELIVERY

FOSTERING LEARNING

BUILDING COMMUNITY

POSITIVE IMPACT THROUGH...

Research
Education
Implementation
Outreach
Dissemination

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Department of Trauma/Acute Care (Division of Acute Care Surgery)
Department of Pediatrics
Department of General Medicine

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HEALTHCARE PROVIDER SCHEDULING

- Typically, assigning from a fixed group of people to a fixed group of (recurring) shifts
- Heterogeneous workforce with different skills
- Shifts that require different skills
- Trade-off between different rules:
  - Patient care: patient coverage, continuity of care
  - Training/trainee experience: training opportunities, resident wellness

CHALLENGES

There is not a single, clear objective function

Various objectives:

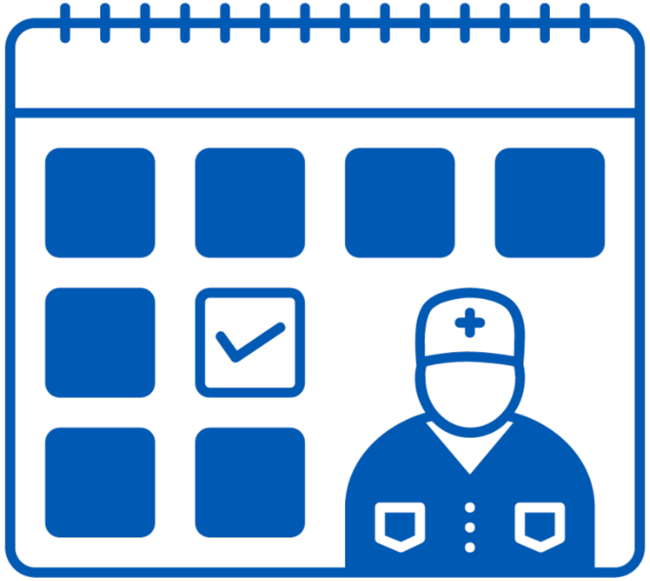
- Provider preferences
- Patient continuity of care
- Rest and well being
- Educational / training needs

TRADITIONAL APPROACHES

- Hierarchical Optimization (need well-defined hierarchy)
- Weighted Sum (need pre-determined reasonable weights)
- Goal Programming
- …

- In our experience, those approaches are not fully sufficient for our healthcare provider scheduling problem

Trauma Attending Call Service Scheduling Problem



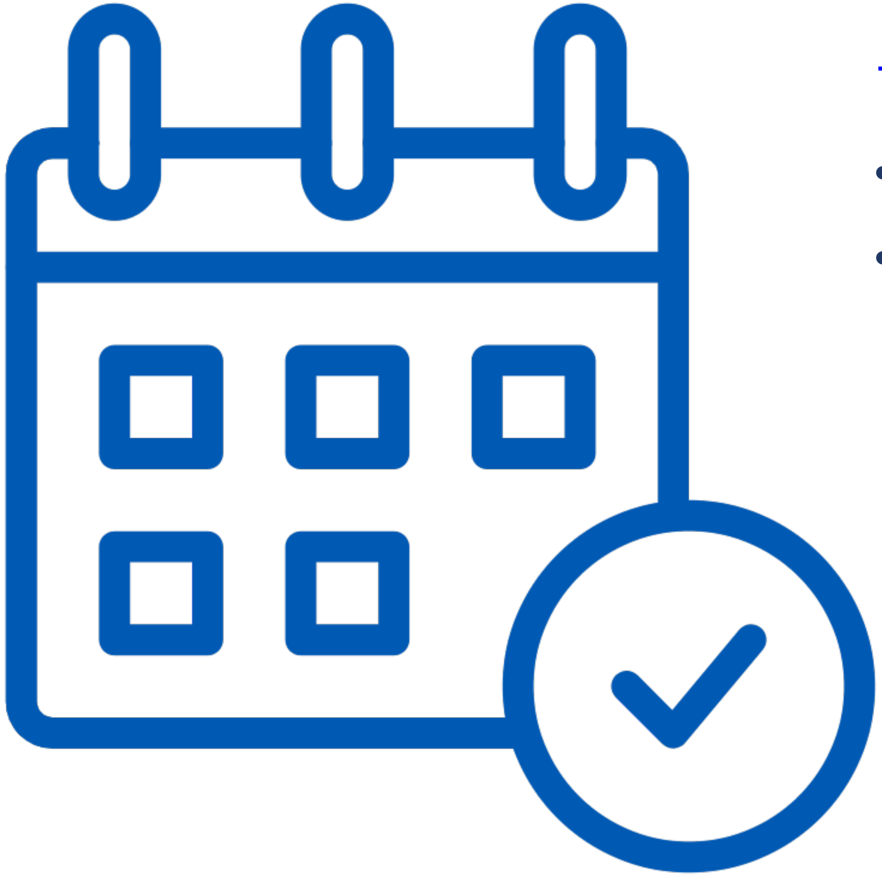
DIVISION OF ACUTE CARE SURGERY IN MICHIGAN MEDICINE

- The Division of Acute Care Surgery at Michigan Medicine provides care for major trauma and burn patients, as well as the management of emergency surgery and critical care services.
- There are 5 units to which the attendings (doctors) are assigned to within the division:
  - Trauma & Burns Intensive Care Unit (**TBICU**): treats patients with serious trauma and burn injuries
  - Surgical Intensive Care Unit (**SICU**): responsible for patients with a variety of critical care surgical issues
  - Acute Care Surgery (**ACS1**, **ACS2**): treats trauma patients with less severe injuries
  - **Burns**: treats patients with severe burn injuries

SCHEDULING REQUIREMENTS

- Assign specific attendings for the Division of Acute Care Surgery to specific units each week for a 6-month (26 weeks) period based on rules to create the day call schedule
- Some basic rules:
  1. Each unit must have exactly 1 attending assigned each week
  2. Attendings cannot be assigned to more than 2 units in each week(with some exceptions)
  3. Attendings cannot work consecutively for more than 2 weeks
  4. Pre-determined assignments which must be implemented

  ...



METRICS

- How do we evaluate a given schedule?
- Four metrics:
  - ✓ Minimize the total number of denied days off requests
  - ✓ Minimize the maximum number of days off request denied among all attendings
  - ✓ Minimize the total number of exceedances on the consecutive days off allowances
  - ✓ Minimize the total number of denied external schedule requests

PROBLEM SCALE

- Binary Decision variables
- $X_{auw} = 1$ if Attending **a** is assigned to Unit **u** on Week **w**
- How many feasible solutions? (A = 15, U = 5, W = 26)
- $2^{AUW} = 2^{1950} \approx 10^{587}$
- Consider constraints:
- Each time slot (u, w) can be assigned to at most one attending
- => $A^{UW} = 15^{130} \approx 10^{152}$
- Each attending can only do one service during the same week
- => $\left(P_U^A\right)^W = \left(\frac{A!}{(A-U)!}\right)^W = \left(\frac{15!}{10!}\right)^{26} \approx 10^{144}$

METRIC EQUIVALENT SOLUTIONS

- 4 dimensional metrics vector (A, B, C, D)
- (7, 2, 14, 0) is a metric vector of some feasible solutions
- First, we add constraints to fix all metric values
- The algorithm will find the next “equivalent” feasible solution by excluding the incumbent solution from the feasible region and solve the new optimization problem
- Loop until the problem become infeasible
- There could be more than 30,000 such equivalent solutions

PARETO OPTIMAL SOLUTIONS

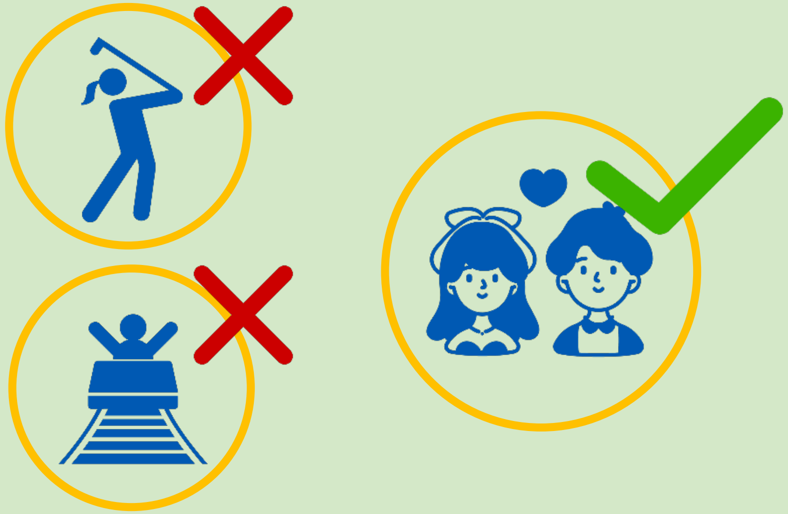
- How many Pareto optimal metric vectors?
- We applied a recursive algorithm to generate the complete Pareto frontier
- It yielded 53 distinct Pareto optimal vectors

"NON-COMMODITY" METRICS

- Some metrics are "non-commodity"
- The scheduler might have preferences on some optimal (or even non-optimal) solutions over other solutions with the same (or better) objective values.
- The minimum number of total denied days off may be the same in different solutions, but it could be denying a different person taking those days off for different reasons

SOME EXAMPLES

One "optimal" solution may grant someone a day off to go play golf but deny someone else a day off to attend their sister's wedding.



The scheduler might prefer a non-optimal solution which denies someone a day off for golf and a day off to ride rollercoasters in order to ensure someone is able to attend their sister's wedding.

WORK IN PROGRESS

- Currently this metric is calculated as
- $A = A_1 + A_2 + \cdots = N$
- Binary auxiliary variable $A_i = 1$ if the **i**-th request is denied.

$$\sum_{i \in R; A_i = 1} A_i \leq N - 1$$

- We got less than 100 (most time less than 20) different schedules with the same Pareto optimal metric values but with different denied requests.

Thank you!