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HEALTHCARE ENGINEERING & PATIENT SAFETY
UNIVERSITY OF MICHIGAN

A General Model for Medical Resident Rotation Scheduling

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Medical training pathway

Physicians who have completed medical school

Providers of patient care under the supervision of attending physicians

Annual rotation scheduling

Process of assigning residents to services to provide patient care and receive advanced training

Many residents (varying disciplines, seniority, educational requirements, personal needs)

Many services (varying difficulty, coverage requirements, preferred composition)

Problem statement

Ensuring adequate resident education and proper service coverage requires many training programs to integrate schedules

Coordinating long-term rotation schedules is a complex challenge

Traditionally, program leadership (chief residents and program directors) constructs the block schedule by hand

Practical challenges

Challenges of general scheduling problems

Plus challenges of personnel scheduling (preferences, retention, quality of life)

Plus challenges of educational requirements

Plus challenges of patient care

Research objective

Develop a decision support system to enable fast construction of high-quality rotation schedules while improving measures of quality

Quality ↑ **Time** ↓

Medical training at U-M

Case study

Three interdependent residency programs

Formulation

Sets

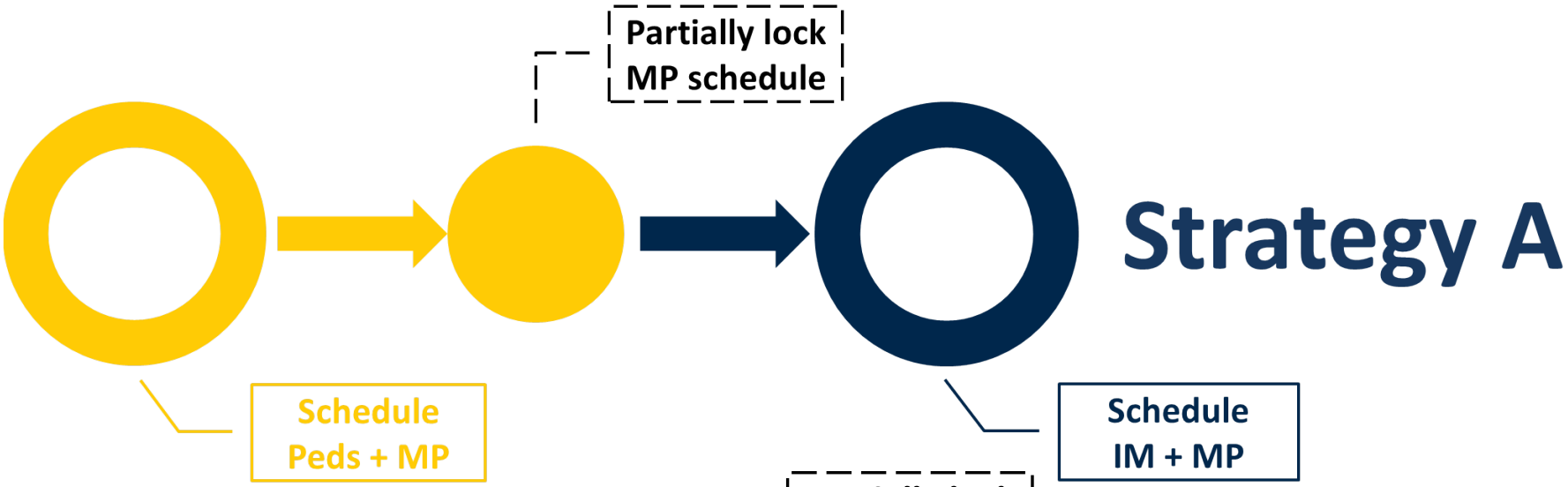
Parameters

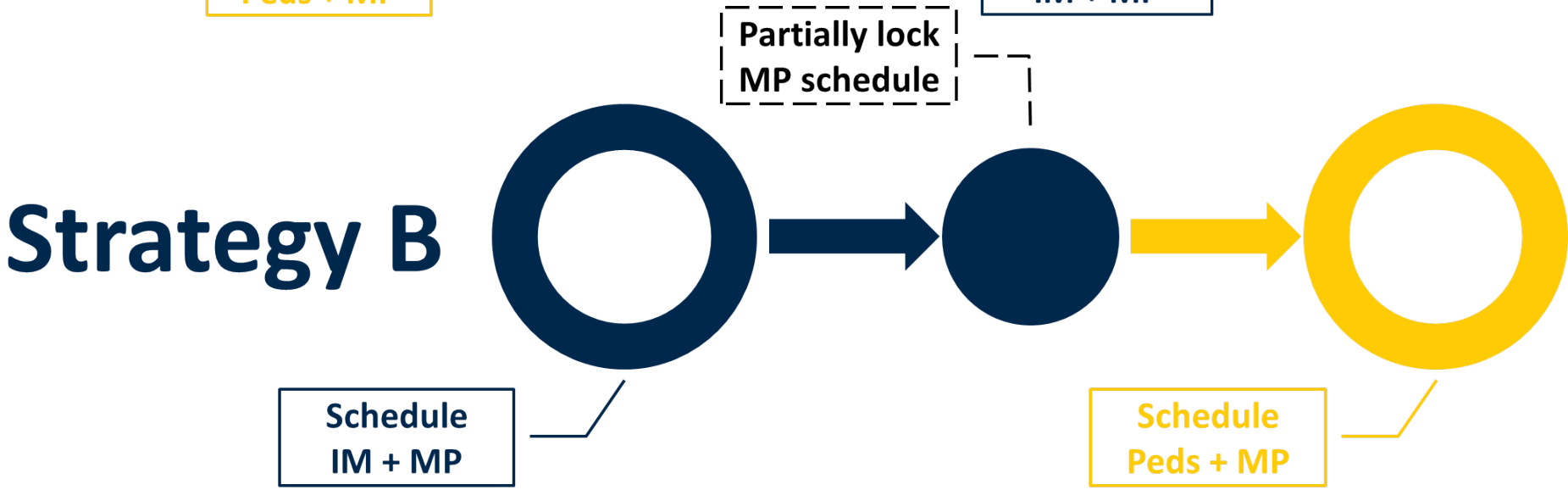
Design variable definition

Formulation

Constraints (all one page, refer to previous presentations for more detail)

Scheduling strategy





Impact

Facilitated concurrent scheduling of all 3 programs for first time

Enabled program leadership to more precisely specify scheduling needs compared to manual construction

Provided improved satisfaction (relative to prior years) regarding:

- vacation requests
- elective/research offerings
- fellowship interview and graduation conflicts
- schedule fairness
- pacing and challenging rotation sequences

Computational observations

Strategy A solves faster than Strategy B

Strategy B produces better quality than Strategy A

Lessons learned

Collaboration is key to getting the details right, buy-in, success of implementation

Variable definition key to **tractability**

Significant **real-world impact** on quality of schedules, resident satisfaction, and patient care

Next steps

Design new **modeling** approaches to better accommodate all three programs

Refine processes for **data acquisition**, interacting with the chiefs and program directors

Build tools to facilitate **schedule modifications** throughout the year

Ongoing work

Speed — Evaluating alternative formulations for impact on solve time

Quality — Implementing additional metrics based on leadership feedback

Efficiency — Streamlining administrative and schedule revision processes

Acknowledgements

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Thanks to the **students** who have built this tool

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HEALTH SYSTEM
UNIVERSITY OF MICHIGAN

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Questions and discussion

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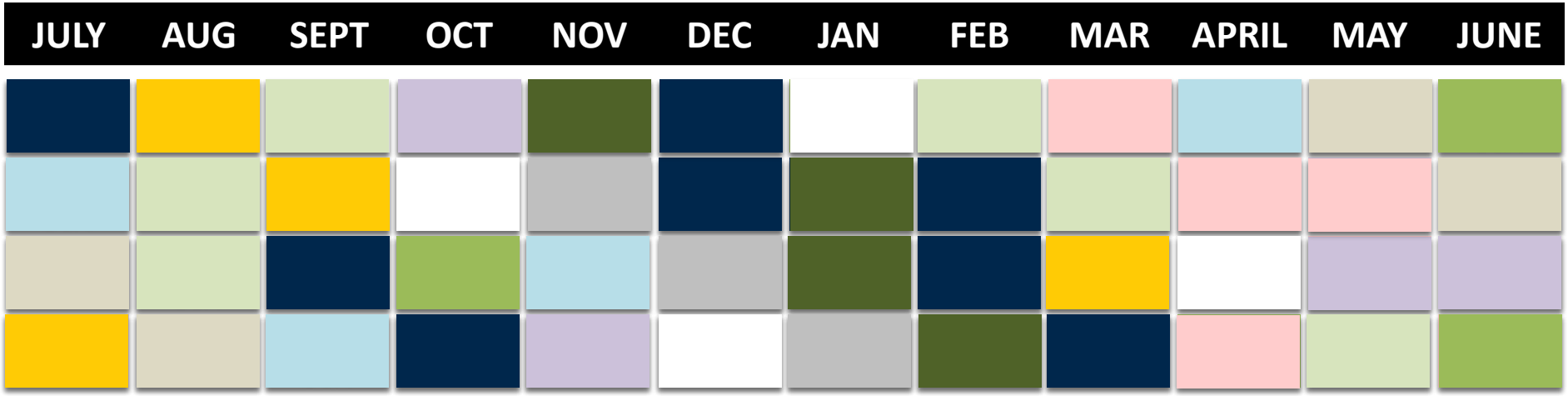
Traditional strategy

1. Build rotation templates
2. Adjust for coverage and educational needs
3. Renegotiate after reaching a dead-end



Pediatric block scheduling

Collaboration with the **Pediatric Residency Program** at the University of Michigan Health System

Program Size

3-year residency

22 residents per class

18 required services
+ electives + vacation

12 months, July – June

Scheduling Considerations

One service / resident / period

Service coverage needs

Resident education needs

Vacation periods

Consecutive hard rotation limits

Metrics and objective

No obvious objective but **numerous metrics** important to consider

Treat as **feasibility problem** with bounded metrics

$$\min \ 0$$

$$\mathbf{Ax} \leq \mathbf{b}$$

PBS model: phase I

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$$\mathbf{x}_{rsm} = \begin{cases} \mathbf{1}, & \text{if assigning resident } r \text{ to service } s \text{ during month } m \\ \mathbf{0}, & \text{otherwise} \end{cases}$$

2014-15

Constructed schedule for Pediatrics interns only

Total Variables:	**4,752**
Total Constraints:	**6,576**
Solve Time:	**< 20 sec**

PBS model: phase 1.5

2015-16

Constructed schedule for all Pediatrics residents

Total Variables: **14,256**
Total Constraints: **19,722**
Solve Time: **infeasible**

Problem: unequal senior coverage needs in 1st and 2nd halves of months

PBS model: phase 2

$$\mathbf{x}_{rpm} = \begin{cases} \mathbf{1}, & \text{if assigning resident } r \text{ to service pair } p \text{ during month } m \\ \mathbf{0}, & \text{otherwise} \end{cases}$$

where $p \in P$, $P :=$ the set of valid "service pairs", and $|P| = 64$

2015-16

Constructed schedule for all Pediatrics residents

Total Variables:	**50,688**
Total Constraints:	**64,722**
Solve Time:	**< 1 min**

Expanding our scope

Internal Medicine (IM) Residency Program

- 3-year program
- 44 residents per year

Medicine-Pediatrics (MP) Residency Program

- 4-year program
- 8 residents per year
- 3 months at a time on Pediatrics and Medicine

2016-17 Goal

build schedules for all in an **integrated model**

New features for IM and MP

Constraints

Service sequencing

Service spacing

Ad-hoc pre-assignments/prohibitions

Metrics

Graduation conflicts

Prioritized desires

Integrated model: phase 3

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2016-17

Constructed schedules for Pediatrics, MP and IM

236 residents
3,896 service pairs (95 services)
12 months

Total Variables:	**15,332,306**
Total Constraints:	**1,992,897**
Solve Time:	**8 – 48 hrs**

Integrated model: phase 4?

$$\mathbf{x}_{rsh} = \begin{cases} \mathbf{1}, & \text{if assigning resident } r \text{ to service } s \text{ during half month } h \\ \mathbf{0}, & \text{otherwise} \end{cases}$$

$$\mathrm{x}_{rsh} = \mathrm{x}_{rs(h+1)}, \qquad \forall\, r \in R, s \in F, h \in \{1,3,\dots,23\}$$

$$\mathrm{x}_{rsh} + \mathrm{x}_{r\delta(h+1)} \leq 1, \qquad \forall r \in R, s \in H, \delta \in D_s, h \in \{1,3,\dots,23\}$$

Must ensure valid month-long rotations