

# **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:



Right lung contusion



- 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

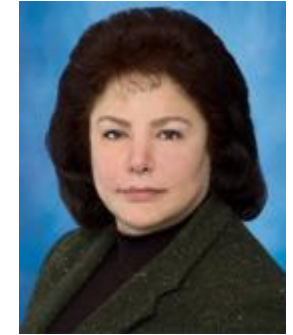
- Site Visit every 3 years, by external reviewers assigned by the American College of Surgeons-Committee on Trauma (ACS-COT)
- Extensive hospital data must be provided
- 24-Hour Availability by Physicians and specialty care staff
- Expertise to treat severely injured patients
- Few institutions have 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



DEPARTMENT OF  
SURGERY

# ACUTE CARE SURGERY

A DIVISION OF GENERAL SURGERY AT THE UNIVERSITY OF MICHIGAN



CENTER FOR  
HEALTHCARE ENGINEERING & PATIENT SAFETY  
UNIVERSITY OF MICHIGAN

# 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)

3. Unit Coverage

2. Maximum Consecutive Work Weeks e.g. <4

1. Attending Assignment

4. Valid Unit Pairs

Unit	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
TBICU	Annette	Daisy	Esther	Esther	Houston	Daisy	Isaac
BURN	Annette	Fiona	Daisy	Daisy	Esther	Daisy	Fiona
ACS1	Bob/Clark	Annette	Annette	Annette	Daisy	Isaac	Greg
ASC2	Daisy	Greg	Bob	Bob	Isaac	Fiona	Isaac
SICU	Annette	Bob	Clark	Fiona	Greg	Houston	Clark

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)

Nights	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1		Caroline	Caroline	Annette	Dennis	Esther	Dennis
Week 2	Caroline	Annette	Caroline	Bob	Caroline	Annette	Bob
Week 3	Bob	Dennis	Caroline	Esther	Annette	Bob	Annette
Week 4	Dennis	Bob	Caroline	Bob	Esther	Dennis	Esther

Units	Week 1	Week 2	Week 3
TBICU	Dennis	Caroline	Caroline
BURN	Annette	Dennis	Sarah
ACS1	Dennis	Bob	Annette
ASC2	Esther	Annette	Bob
SICU	Bob	Esther	Dennis

- 8. ACS1 Friday Assignments
- 1. Nights Coverage e.g. Bob Week 2 Friday
- 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
- 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

$A$ : set of attending surgeons

$U$ : set of units

$W$ : 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**

$$x_{au_1w} + x_{au_2w} \leq p_{u_1u_2} + 1 \quad \forall a \in A, w \in W, \\ u_1, u_2 \in U \text{ s.t. } u_1 > u_2$$

**Attending Assignment**

$$\sum_{u \in U} x_{auw} \leq 2 \quad \forall a \in A, w \in W$$

**Preassignments**

$$x_{a_y u_y w_y} = 1 \quad \forall y \in Y^x$$

**Prohibitions**

$$x_{a_n u_n w_n} = 0 \quad \forall n \in N^x$$

# 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**

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

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

$$\sum_{i=w}^{w+max} z_{ai} \leq max \quad \forall a \in A, w = 1, \dots, numWeeks - max$$

# THE DAY CALL SCHEDULING FORMULATION (KRISTINE)

**Week Off Requests Denied**

$$\mathbb{D}^T = \sum_{a \in A} \sum_{w \in V_a} z_{aw}$$

$$lb \leq \mathbb{D}^T \leq ub$$

$$\mathbb{D}^M \geq \sum_{w \in V_a} z_{aw}$$

$$\forall a \in A$$

$$lb \leq \mathbb{D}^M \leq ub$$



# THE NIGHT CALL SCHEDULING FORMULATION (KRISTINE)

## Sets

$A$ : set of attending surgeons

$D$ : 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)

**Unit Coverage**

$$\sum_{a \in A} y_{ad} = 1 \quad \forall d \in D$$

**No Consecutive Assignments**

$$\sum_{i=d}^{d+1} y_{ai} \leq 1 \quad \forall d = 1, \dots, numDays - 1$$

**Maximum Assignments in 7-Day-Period**

$$\sum_{i=d}^{d+6} y_{ai} \leq 2 \quad \forall d = 1, \dots, numDays - 6$$

**Preassignments**

$$y_{a_{(p)}d_{(p)}} = 1 \quad \forall p \in P$$

**Prohibitions**

$$y_{a_{(n)}d_{(n)}} = 0 \quad \forall n \in N$$

# 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**

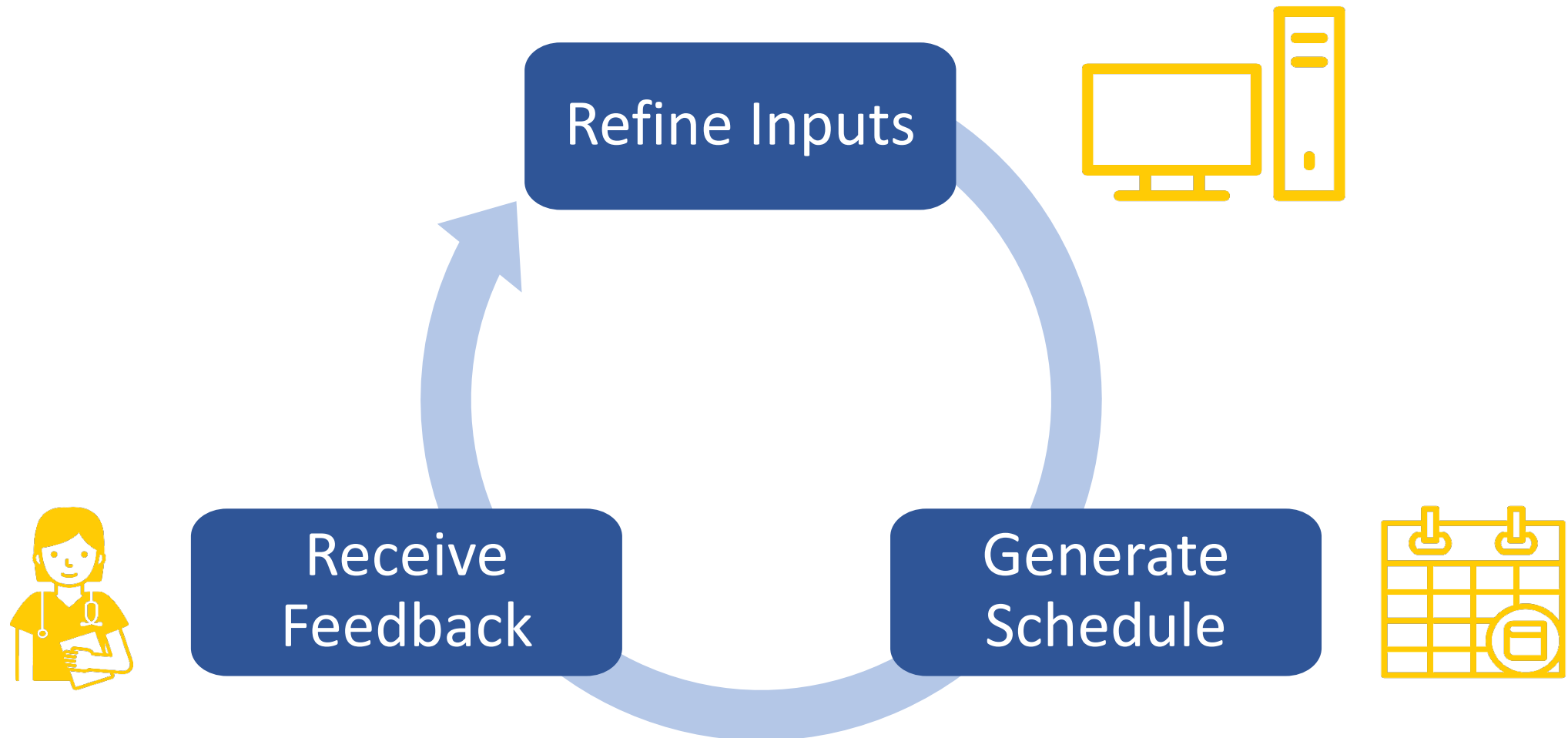
$$lb_a \leq \sum_{d \in D} y_{ad} \leq ub_a \quad \forall a \in A$$

**Sunday Assignments**

$$y_{ad_w} \leq s_{aw} \quad \forall a \in A, w \in W$$

# WHAT MAKES THIS PROBLEM CHALLENGING (RAGHU)

# HOW WE SOLVE IT (HANNAH)



# HOW WE SOLVE IT (HANNAH)

Multi-criteria optimization in practice...

## Day Call Schedule



## Night Call Schedule



# 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

# HOW WE SOLVE IT (HANNAH)

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)