

Improving Chemotherapy Scheduling at the BC Cancer Agency

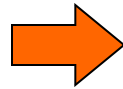
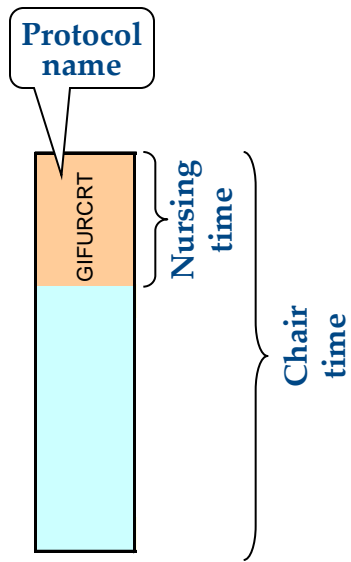
CIHR Team in
Operations Research for Improved Cancer Care

The Challenge

- Increasing Volumes of Chemotherapy Patients
 - New therapies
 - More cases
- Antiquated scheduling methodology
 - Burdensome on staff
 - Schedulers
 - Pharmacy
 - Inconvenient for patients
 - Most notified one day before treatment
- Goals
 - Increase time between notification and appointment
 - Simplify and automate process
 - Put changes into practice



Optimization Problem Description



Treatment slots

NURSE07				
Time	CHAIR25	CHAIR26	CHAIR27	CHAIR28
8:00				
8:15				
8:30				
8:45				
9:00				
9:15				
9:30				
9:45				
10:00				GUE P
10:15				
10:30				
10:45				
11:00	CTCH			
11:15				
11:30				
11:45				
12:00		UGIFFR B		
12:15	Break			
12:30				
12:45				BRAJ TR
13:00				
13:15				
13:30				
13:45				
14:00	Break			
14:15				
14:30				BRAJ DTFE C
14:45				
15:00	BRAJFEC			
15:15				
15:30				
15:45				
16:00		BRAJ TR		
16:15				
16:30				
16:45				
17:00				
17:15				
17:30				
17:45				
18:00				
18:15				
18:30				
18:45				

Start of shift

Prep time

Break

Lunch break

End of shift

A Daily Chemotherapy Schedule

Decision Variables

x_{ijk}^p = 1 if patient p is scheduled at treatment slot i in chair j of nurse k , 0 otherwise

$$x_{ijk}^p \in \{0,1\}$$



Auxiliary Variables

Θ_k = 1 if nurse k has patients scheduled, 0 otherwise

Ω_{jk} = 1 if chair j of nurse k has patients scheduled, 0 otherwise

Λ = maximum nurse workload

δ_k^+ = shortfall in number of patients with respect to second part of the shift for nurse k

δ_k^- = shortfall in number of patients with respect to first part of the shift for nurse k

$$\Theta_k, \Omega_k \in \{0,1\}$$

$$\Lambda, \delta_k^+, \delta_k^- \geq 0$$



Parameters

ξ^p : chair time for patient p

v^p : nurse time for patient p

χ^p : complexity for patient p

Π_k : maximum number of patients to be assigned to nurse k

Ξ_k : maximum chair time to be assigned to nurse k

N_k : maximum nurse time to be assigned to nurse k

X_k : maximum complexity to be assigned to nurse k

Γ_k : maximum number of patients for nurse k that can start treatment simultaneously (nursing constraint)

Ψ : maximum number of patients for all nurses that can start treatment simultaneously (pharmacy constraint)



Constraints

- All patients need to be scheduled

$$\sum_{ijk} x_{ijk}^p = 1 \quad \forall p$$

- At most one patient can be scheduled in a given chair at each treatment slot

$$\sum_p \sum_{i-\xi^p \leq \hat{i} \leq i} x_{ijk}^p \leq 1 \quad \forall i, j, k$$

- At most one patient receiving nursing care in any of the chairs of each nurse

$$\sum_p \sum_{i-v^p \leq \hat{i} \leq i} \sum_j x_{ijk}^p \leq 1 \quad \forall i, k$$



Constraints

- Maximum scheduled:

$$\sum_{p,ij} x_{ijk}^p \leq \Pi_k \quad \forall k \quad \text{number of patients}$$

$$\sum_{p,ij} x_{ijk}^p \cdot \xi^p \leq \Xi_k \quad \forall k \quad \text{chair time}$$

$$\sum_{p,ij} x_{ijk}^p \cdot \nu^p \leq \mathbf{N}_k \quad \forall k \quad \text{nurse time}$$

$$\sum_{p,ij} x_{ijk}^p \cdot \chi^p \leq \mathbf{X}_k \quad \forall k \quad \text{complexity per nurse}$$

- Maximum number of patients to start treatment simultaneously (same slot)

$$\sum_{p,j} x_{ijk}^p \leq \Gamma_k \quad \forall i, k \quad \text{per nurse}$$

$$\sum_{p,j,k} x_{ijk}^p \leq \Psi \quad \forall i \quad \text{overall}$$



Constraints

- Definition of maximum nurse workload in terms of:
(only one of the following active at a time)

$$\sum_{p,ij} x_{ijk}^p \leq \Lambda \quad \forall k \quad \text{number of patients}$$

$$\sum_{p,ij} x_{ijk}^p \cdot \xi^p \leq \Lambda \quad \forall k \quad \text{chair time}$$

$$\sum_{p,ij} x_{ijk}^p \cdot v^p \leq \Lambda \quad \forall k \quad \text{nurse time}$$

$$\sum_{p,ij} x_{ijk}^p \cdot \chi^p \leq \Lambda \quad \forall k \quad \text{complexity}$$



Constraints

- Relationship between scheduling variables and indicators per nurse

$$x_{ijk}^p \leq \Theta_k \quad \forall p, i, j, k$$

- Relationship between scheduling variables and indicators per chair-nurse

$$x_{ijk}^p \leq \Omega_k \quad \forall p, i, j, k$$

- Balance between number of patients in first and second part of nursing shift

$$\sum_{(p,ij) \in AM} x_{ijk}^p + \delta_k^+ = \sum_{(p,ij) \in PM} x_{ijk}^p + \delta_k^- \quad \forall k$$



Objective Function

$$\text{Min } \Phi + \sum_k (\delta_k^+ + \delta_k^-)$$

Where Φ can be chosen as:

- Maximum nurse workload (defined as number of patients, chair time, nurse time or complexity)

$$\Phi = \Lambda$$

- Number of nurses scheduled

$$\Phi = \sum_k \Theta_k$$

- Number of chairs used

$$\Phi = \sum_{jk} \Omega_{jk}$$



The Model in Numbers

- Typical scenario:
 - 40 to 50 patients to be scheduled
 - 8-9 nurses (8-hr shift; 6-hr of effective treatment)
 - 4 chairs per nurse
 - 11-hr workday (8:00 to 19:00) divided in 15' slots
- Resolution:
 - Decision variables: over 100,000 (most binary)
 - Constraints: over 40,000
 - Solution time: ~1-5' to optimality
(30" for gap < 5%)
 - Modeling platform: GAMS/CPLEX
 - Database platform: MS Access
 - Tool platform: VBA

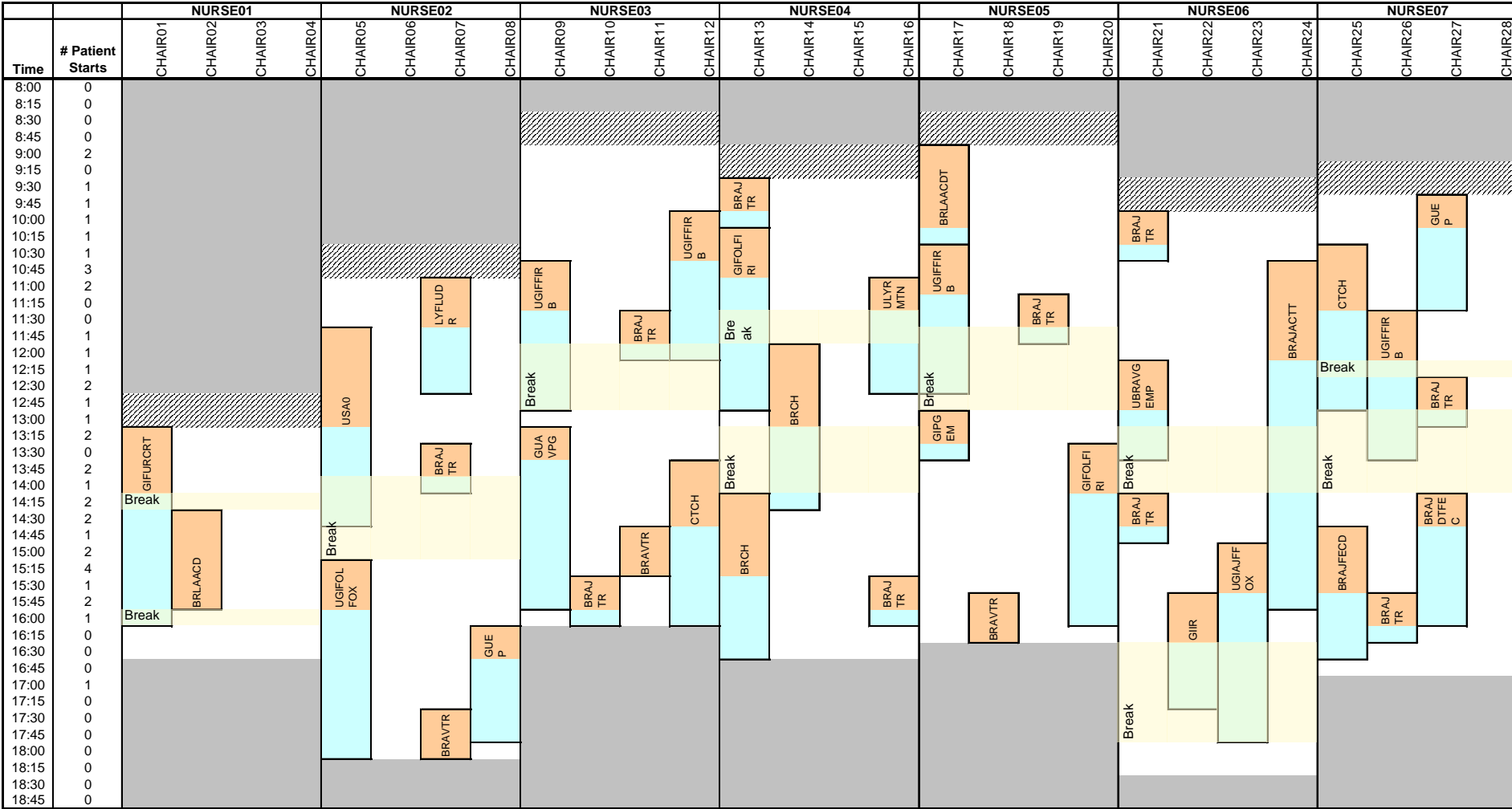


Output Report – Nursing Schedule

Time	# Patient Starts	Nurse						
		NURSE01	NURSE02	NURSE03	NURSE04	NURSE05	NURSE06	NURSE07
8:00	0							
8:15	0							
8:30	0							
8:45	0							
9:00	2							
9:15	0							
9:30	1							
9:45	1							
10:00	1				BRAJTR (30min)	BRLAACDT (75min)		
10:15	1			UGIFFIRB (45min)			BRAJTR (30min)	GUEP (30min)
10:30	1				GIFOLFIRI (45min)			
10:45	3					UGIFFIRB (45min)		
11:00	2		LYFLUDR (45min)	UGIFFIRB (45min)	ULYRMTN (30min)			CTCH (60min)
11:15	0					BRAJTR (30min)	BRAJACTT (90min)	
11:30	0			BRAJTR (30min)	Break			UGIFFIRB (45min)
11:45	1							
12:00	1		USA0 (90min)					
12:15	1			Break				
12:30	2				BRCH (75min)	Break	UBRAVGEMP (45min)	BRAJTR (30min)
12:45	1							
13:00	1							
13:15	2					GIPGEM (30min)		
13:30	0	GIFURCRT (60min)		GUAVPG (30min)				
13:45	2		BRAJTR (30min)			GIFOLFIRI (45min)	Break	Break
14:00	1			CTCH (60min)	Break			
14:15	2	Break						
14:30	2						BRAJTR (30min)	BRAJDTFEC (30min)
14:45	1		Break		BRCH (75min)			
15:00	2	BRLAACD (90min)		BRAVTR (45min)				
15:15	4						UGIAJFFOX (45min)	BRAJFEC (60min)
15:30	1		UGIFOLFOX (45min)					
15:45	2			BRAJTR (30min)	BRAJTR (30min)			
16:00	1	Break				BRAVTR (45min)	GIIR (45min)	BRAJTR (30min)
16:15	0							
16:30	0		GUEP (30min)					
16:45	0							
17:00	1							
17:15	0							
17:30	0						Break	
17:45	0		BRAVTR (45min)					
18:00	0							
18:15	0							
18:30	0							
18:45	0							

# Patients	40	2	6	7	6	6	6	7
Total Time	39:0	3:0	6:0	6:15	5:45	6:15	6:0	5:45
Booked Time	30:45	2:30	4:45	4:45	4:45	4:30	4:45	4:45
% Booked	79%	83%	79%	76%	83%	72%	79%	83%
Chair Time	72:15	4:30	11:0	12:0	11:0	8:45	13:0	12:0

Output Report – Chair Schedule



# Patients	1	1	0	0	2	0	3	1	2	1	2	2	3	1	0	2	3	1	1	1	3	1	1	1	2	2	3	0
Nursing time	1:00	1:30	0	0	2:15	0	2:00	0:30	1:15	0:30	1:15	1:45	2:30	1:15	0	1:00	2:30	0:45	0:30	0:45	1:45	0:45	0:45	1:30	2:00	1:15	1:30	0
Chair time	3:00	1:30	0	0	6:00	0	3:15	1:45	5:00	0:45	1:30	4:45	6:00	2:30	0	2:30	4:30	0:45	0:45	2:45	3:00	1:45	3:00	5:15	4:30	3:00	4:30	0

Scheduling Tool Concept

- Visual interface for managers to review and modify schedule
- Initial schedule loaded from optimization model
- Patients can be re-scheduled across nurses
 - Constraints are checked “on the fly” and warnings/error messages reported to user
 - Workload stats are updated after every change
 - Web-based platform



Discussion

- Implementation plan being developed
- Daily optimization model
 - Requires expert involvement
 - Must interface with system
 - Inputs
 - Outputs
 - Standalone tool
- Ignores variability
- Many inputs are arbitrary now



Overall Concluding Comments

Concluding Remarks

- Just touched the tip of the iceberg of potential applications
- Many challenging optimization (OR) problems arise in healthcare
- They can significantly effect practice both at the operational and strategic levels
- They offer great research potential
- Often solutions cannot be delivered easily so guidelines are necessary
- Researchers must be cognizant of needs of staff and work collaboratively to develop applications

