

Applications of Operations Research in Healthcare at the University of Michigan Health System

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Epstein Institute Seminar Series
University of Southern California
March 12, 2013



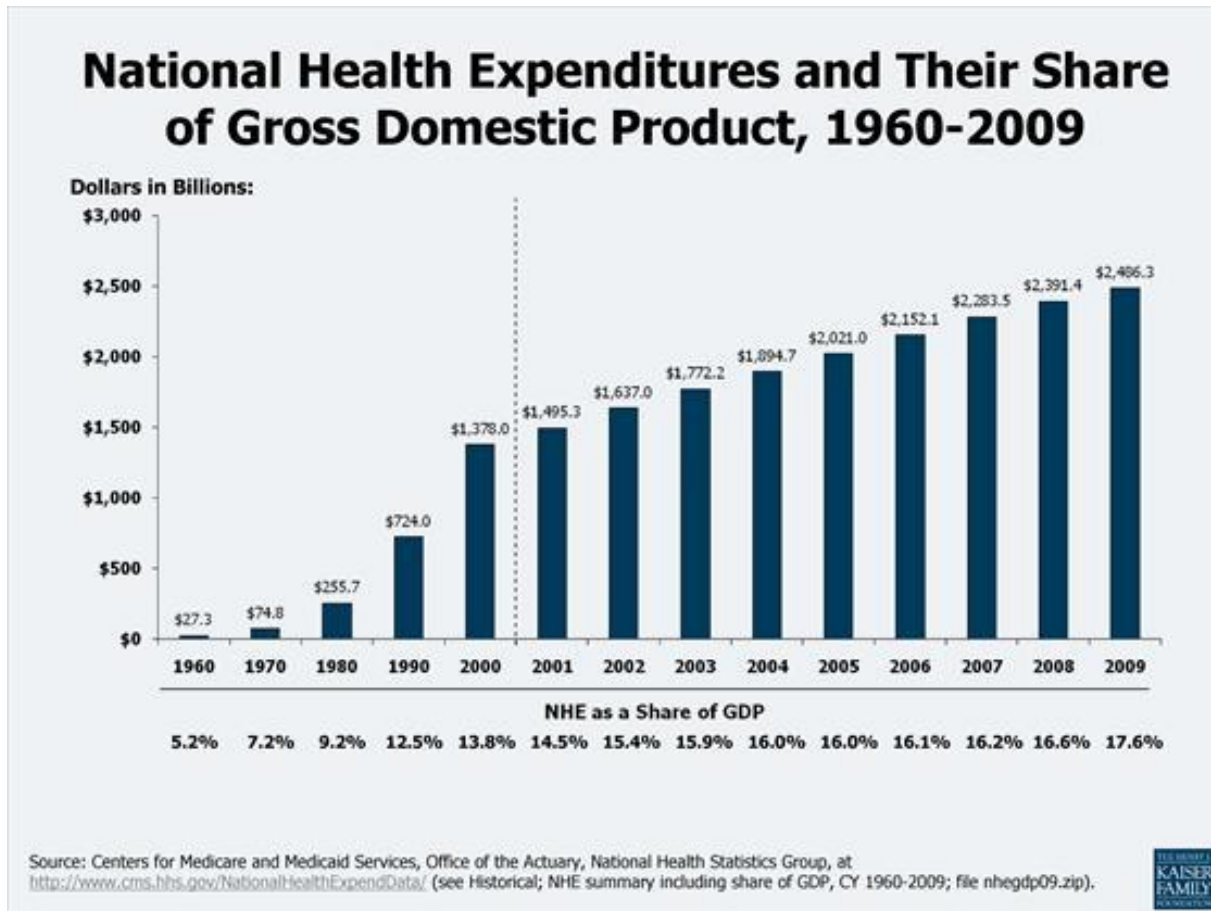
Outline

- Need for and challenges of using OR tools to solve healthcare problems
- Brief introduction to the UM Center for Healthcare Engineering and Patient Safety (*CHEPS*)
- Almost-traditional use of math programming in healthcare
- Educating healthcare providers
- Importance of data visualization



Scope and Scale of the Problem

- 17% of US GDP



IOM Goals

- 2005 seminal report issued jointly by IOM and NAE:
- Six major goals for the U.S. healthcare system:
 - Safe
 - Effective
 - Timely
 - Patient-centered
 - Efficient
 - Equitable
- Importance of “a vigorous new partnership” between engineering and healthcare to overcome the challenges that prevent us from reaching these goals



OR/MS Opportunities for Impact

- Why is this partnership important?
 - Systems perspective
 - OR/MS ability to translate complex real-world problems into mathematical models that can be analyzed and optimized
 - Use of data to drive decisions



Broadening the Scope

- Understand problem domain
- Identify specific problem
- Gather data
- **Build models**
- **Build algorithms**
- Analyze results
- Implement solutions
- Maintain solutions



Key Challenges

- Language and cultural barriers
- Access to data and privacy issues
- Conflicting and ill-defined objectives
- Complexity and enormity of system



Introduction to CHEPS

- University of Michigan Center for Healthcare Engineering and Patient Safety
- Initiated by the deans of Medicine and Engineering
- Focus on facilitating deep collaborations between engineering and healthcare researchers and providers (including SPH, Nursing, Pharmacy, etc.)



Introduction to CHEPS, cont.

- Initiatives
 - Research
 - Implementation
 - Education



Scheduling Pediatric Emergency Medicine Residents at UMHS



Acknowledgements

- Ongoing collaboration with many talented contributors
 - Winter 2013 Team
 - UMHS Chief Resident: Dr. Micah Long
 - Students: Young-Chae Hong, Ariella Rose, Elizabeth Perelstein
 - Fall 2012 Team
 - UMHS Chief Resident: Dr. Micah Long
 - Students: Young-Chae Hong, Mindy Alberty
 - Spring/Summer 2012 Team
 - UMHS Chief Resident: Dr. Micah Long
 - Students: Young-Chae Hong, Boying Liu, Tara Lynn O’Gara, Mindy Alberty



What is medical residency?

- Transition period between medical school and fully independent/unsupervised practice
 - Four years of med school
 - First year of residency – “Intern”
 - Two more years of residency
 - Possibly one or two additional years as “Chief Resident”
 - Possibly more years as a “Fellow”
- During all of this time, providing patient care (albeit with the oversight of a more senior “attending” physician –supervision decreases over time)



What is medical residency?

- A key issue: Dual role of residency
 - Learning experience: Residency (and Fellowship) are parts of the medical education training process
 - Patient care: Residents/Fellows provide a significant amount of the patient care in teaching hospitals and the associated clinical system
- A typical resident might engage in all of the following activities:
 - “Continuity clinics”
 - Shifts on service
 - Seminars, formal educational activities
 - Research



Inherent Time Conflicts

- How to schedule residents' time
 - Need adequate patient coverage with a limited pool of residents
 - Need adequate training opportunities
 - Need adequate rest – fatigue increases risk of error
 - Need to address resident satisfaction, personal life
- Not just quantity of hours but pattern
 - Continuity of care
 - Sleep issues (especially associated with overnight shifts)
 - Opportunities for different medical experiences



What is the general problem?

- **Given a set of residents to be trained and a set of shifts to be covered, build a schedule that satisfies all patient care, educational, and other requirements**



What is our specific problem?

- Assigning residents to shifts to cover the pediatric emergency department in Mott Children's Hospital at UMHS
- Eight overlapping shifts per day
- Month-long schedule (but conflicting *switch dates* depending on the resident)
- Approximately 15 residents per month, coming from four or five different residency programs



What are the rules?

- Patient care requirements:
 - 8 overlapping shifts every day of the month
 - Every shift has to have exactly one resident assigned
 - Exceptions: 10a – 7p and 12p – 9p shift coverage is optional
 - Not *all* of these shifts can be left uncovered for the entire month
 - Ideally one of the two “flex shifts” should be covered each day
 - Certain shifts cannot be assigned to an intern
 - Certain overlapping pairs of shifts require a Peds resident on at least one of the two shifts
 - ...



What are the rules?

- Resident availability
 - Senior residents switch on the first of the month
 - Interns switch on the 27th of the preceding month
 - Pre-assigned vacation time must be respected
 - Continuity clinics/post CC
 - Some shifts are pre-assigned to certain residents/programs
 - 10-hour rule
 - First and last shifts must recognize boundaries of other rotations
 - ...



What was the current state?

- Schedules typically built by Chief Residents
- Limited decision support
- No formal training
- Hard to satisfy all rules
- Unlikely to make everyone happy



Why is it hard to schedule manually?

	6		1		4		5	
		8	3		5	6		
2								1
8			4		7			6
		6				3		
7			9		1			4
5								2
		7	2		6	9		
	4		5		8		7	

- The more squares you fill in, the fewer choices you have left for what is valid
- Once you make a mistake, you might not know it for a long time
- Once you realize something is wrong, it can be very hard to back track and correct
- If a requirement changes, you have to start from scratch



Why is it getting even harder?

- Number of residents is set and fixed externally (i.e. a program can't independently increase the number of residents to increase staffing)
- ACGME (American College of Graduate Medical Education) limits the amount of duty hours, patterns and frequency of time off, etc.
 - Have made some major increase to limitations in the past
 - Current talk about further tightening of restrictions
- This means there is not a lot of slack in the system, and it's likely to get worse



How do we solve it?

- Mixed integer programming approach
 - $x_{r,s,d} = 1$ if resident r is assigned to shift s on day d , else 0
- Feasibility constraints are straightforward to model
- Run time using C++ and CPLEX on a standard PC is minimal (a few seconds at most)
- Finding a schedule that satisfies the rules is already progress over what exists (especially given time required)
- But not all feasible schedules are equally good



How to “optimize”?

- No one clear objective function, but many important metrics
 - Equity across residents
 - Number of shifts
 - Number of night shifts
 - General quality of schedule
 - “Bad sleep patterns”
 - Personal requests
 - Post-continuity clinic calls
 - Flex shift coverage
 - Transition shift coverage



How to “optimize”?

- We could treat this as a multi-criteria objective function, assign weights to normalize, and solve
 - Weights are hard to find
 - Convergence can slow dramatically
- Is “optimal” the right goal???
 - Is this an engineering construct that we’re imposing inappropriately?



How to “optimize”?

- Our approach:
 - Set boundaries on the metrics
 - Define as hard constraints
 - Search for a feasible solution
 - If found, review and decide what to tighten next
 - If not found, loosen the boundaries
 - Repeat until satisfied



How is it working?

- Remarkably well!
- Schedule is of higher quality than manual schedules (dramatically)
- Chief Resident time requirement is much decreased
- “Buffer” to allocations of favoritism
- Ability to smoothly and quickly recover from data errors and last-minute changes
- “Unbelievable – this was literally a life saver. Amazing job – I’m very thankful.”



Where do we go next?

- Research
 - When infeasible, why?
 - More complex sleep patterns, cross-resident requirements/request, cross-day requirements/requests
 - Generalization
- Practice
 - Make operational/sustainable/affordable for Peds Emergency Medicine at UM
 - Expand to other programs' Peds Emergency Medicine service
 - Expand to other Peds services (e.g. NICU scheduling)
 - Expand to other fields of residency (eg psych, surgery...)



Transplant Surgery Training: Merging Scheduled Shifts with Random Surgical Opportunities



Acknowledgements

- Ryan Chen, William Pozehl
- Professor Mark Daskin, Professor Jacob Seagull
- Dr. Rishi Reddy, Dr. Andrea Obi, Jennifer Chung
- SURE summer team



Motivation for Computer Simulation

- Cardio thoracic surgeons don't always think about probability the way engineers do
- Policy makers limiting work hours don't always think about probability the way engineers do
- Policy makers setting training certification levels don't always think about probability the way engineers do



Motivation for Computer Simulation

- Motivating question:
 - If you have, on average, 40 transplants per year...
 - If you have four residents...
 - If each resident is on call every fourth night...
 - What is the probability that each resident gets 10 transplants over the course of the year?



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 - If you have four residents...
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 - What is the probability that each resident gets 10 transplants over the course of the year?
 - Hint: It's not 1!



Description of Computer Simulation

- A way to demonstrate these probabilistic issues to people not used to thinking about probability
- A way to analyze policy questions
- A way to evaluate alternative scheduling paradigms



Demo



Pediatric Asthma Patients Presenting at the ED: Patient Flow Issues



Pediatric Asthma in the ED

- What happens to children presenting at the ED with asthma?
- Downside of treating in ED
- Downside of treating in inpatient ward
- Long term goal of project
- Short term impact of visualization



Pediatric Asthma in the ED

		Relationship between respiratory patient arrival to and discharge from the ED																							Total Patients:	5732
Total:		282	197	177	141	161	123	119	117	159	210	273	273	293	311	256	240	261	290	320	315	302	334	306	272	
23		0	0	0	0	0	0	0	0	0	2	0	2	3	2	9	2	10	22	38	58	87	89	26	1	351
22		0	0	0	0	0	0	0	0	0	0	0	2	3	5	10	12	16	42	67	73	62	33	0	0	325
21		0	0	0	0	0	0	0	0	0	0	1	5	4	8	10	22	30	63	78	65	9	0	0	0	295
20		0	0	0	0	0	0	0	0	2	2	6	5	9	16	28	41	69	74	60	23	0	0	0	0	335
19		0	0	0	0	1	0	0	2	2	3	4	9	12	28	38	52	54	48	22	0	0	0	1	0	276
18		1	0	0	0	1	0	0	3	1	4	5	17	29	46	68	58	53	16	2	0	0	0	0	1	305
17		0	0	0	2	1	2	2	1	3	5	21	20	38	55	59	32	12	0	0	0	1	0	0	1	255
16		1	0	2	0	0	1	1	3	8	16	23	43	63	74	26	10	0	0	0	0	0	0	1	0	272
15		0	1	0	0	3	0	2	4	12	16	49	62	61	61	6	0	1	0	1	0	0	1	0	0	280
14		1	0	1	1	6	5	4	3	12	23	46	57	59	9	0	0	1	3	1	1	2	1	0	0	236
13		1	0	2	2	4	9	7	6	14	22	62	32	8	1	0	0	0	0	1	1	0	0	1	0	173
12		4	2	2	2	4	3	11	10	16	52	42	18	1	0	0	1	1	1	0	0	1	2	3	3	179
11		1	1	4	3	3	10	14	13	23	41	14	0	0	0	0	0	0	1	1	0	1	1	1	2	133
10		5	1	5	3	10	8	17	27	47	24	0	0	0	0	0	0	1	0	2	2	3	5	1	161	
9		2	4	2	10	16	17	11	28	19	0	0	0	0	0	0	0	1	0	0	2	1	2	5	1	121
8		10	6	11	15	10	16	27	17	0	0	0	0	0	0	0	1	0	2	2	1	3	2	4	5	132
7		8	11	16	21	31	27	20	0	0	0	0	0	0	0	0	0	2	1	1	1	2	7	10	158	
6		22	21	32	28	32	23	3	0	0	0	0	2	0	0	0	0	2	0	2	2	8	8	11	196	
5		30	30	29	35	35	1	0	0	0	0	0	0	2	0	0	0	0	1	3	6	9	12	10	203	
4		36	46	45	19	4	0	0	0	0	0	0	0	0	0	0	0	0	4	5	5	4	18	33	219	
3		67	57	23	0	0	1	0	0	0	0	0	0	0	0	0	1	0	3	7	11	18	42	41	271	
2		58	17	3	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3	11	17	35	42	66	254	
Discharge	1	34	0	0	0	0	0	0	0	0	0	0	1	1	0	1	2	3	6	9	23	31	58	56	60	285
Hour	0	1	0	0	0	0	0	0	0	0	0	0	0	4	1	6	9	7	26	36	61	66	74	26	317	
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
		Arrival Hour																								

Pediatric Asthma in the ED

		Matrix of Admit (to Inpatient) Hour vs Discharge (from Inpatient) Hour, for Respiratory Patients																			Total # of patients				1536
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Discharge Hour of Admitted Patients from Hospital (JUST Respiratory Patients)	23	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0
	22	0	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0
	21	1	3	0	2	0	1	1	0	1	0	0	0	1	0	0	0	0	1	3	0	0	0	1	0
	20	0	3	2	2	0	0	0	1	2	0	0	0	2	0	1	1	0	2	3	1	2	2	4	0
	19	4	6	0	4	6	3	1	4	2	1	0	1	1	1	1	2	2	4	6	4	7	6	1	3
	18	7	7	2	3	2	3	3	3	3	1	3	0	0	2	4	1	11	6	1	7	7	3	6	4
	17	8	3	5	9	5	3	4	4	4	2	1	4	5	5	4	4	10	7	11	7	5	12	7	12
	16	13	6	9	6	3	1	7	5	3	1	3	1	6	3	6	8	8	7	11	4	18	11	8	11
	15	7	9	7	5	3	4	3	3	3	4	3	2	3	7	7	10	10	5	16	8	7	14	3	12
	14	15	11	7	8	9	3	4	6	2	4	3	3	6	3	9	13	19	15	10	11	12	12	8	16
	13	9	10	9	9	5	6	6	5	5	0	3	3	7	2	7	15	13	14	15	20	19	9	12	8
	12	10	6	5	6	4	9	5	1	5	4	2	0	3	6	5	12	13	15	11	13	13	13	7	9
	11	9	4	6	7	3	3	3	1	1	3	1	3	1	4	3	8	8	3	8	7	6	3	9	8
	10	3	3	4	1	2	1	3	4	3	1	1	1	1	2	5	6	6	6	2	5	5	1	3	4
	9	1	1	2	2	0	0	1	1	0	0	0	2	1	0	1	3	2	1	1	0	3	2	1	1
	8	1	0	1	0	1	2	1	3	0	0	2	0	2	3	0	2	1	0	1	1	0	1	2	1
	7	0	1	0	0	0	0	0	0	2	0	1	0	0	0	0	0	2	1	1	1	1	2	1	0
	6	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1
	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	3	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2	0	0	0	0
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
		Admit hour of admitted patients to Inpatient (JUST Respiratory Patients)																							
total patients each hr:		90	76	60	66	44	41	44	41	37	23	23	20	41	38	56	86	106	90	102	91	105	92	74	90



What have we learned?

- The math is often the easiest part
- You need to invest time (a LOT of time!) to tackle real problems in healthcare
- It's not always optimal to look for optimal
- Doctors don't talk or think like engineers
- Engineers don't talk or think like doctors
- Relationships are invaluable and can be the basis of a long, productive line of collaborative research
- The interesting math problems will come but don't let that drive your work



Questions and Discussion

