

Using Industrial Engineering and Other Tools to Improve Healthcare Delivery: Case Studies

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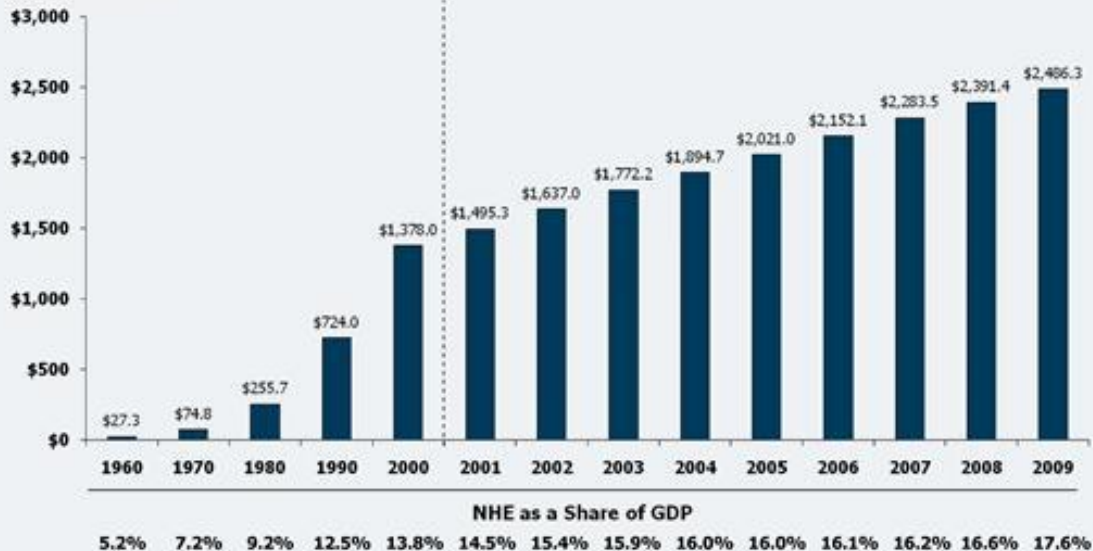


Motivation

- 17% of US GDP

National Health Expenditures and Their Share of Gross Domestic Product, 1960-2009

Dollars in Billions:

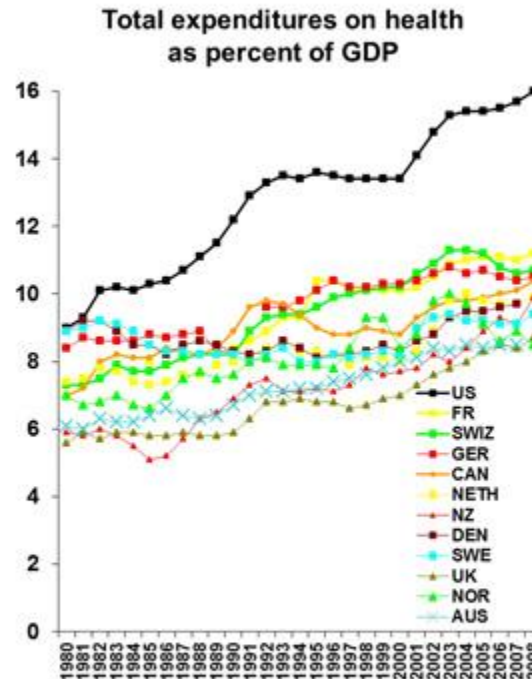
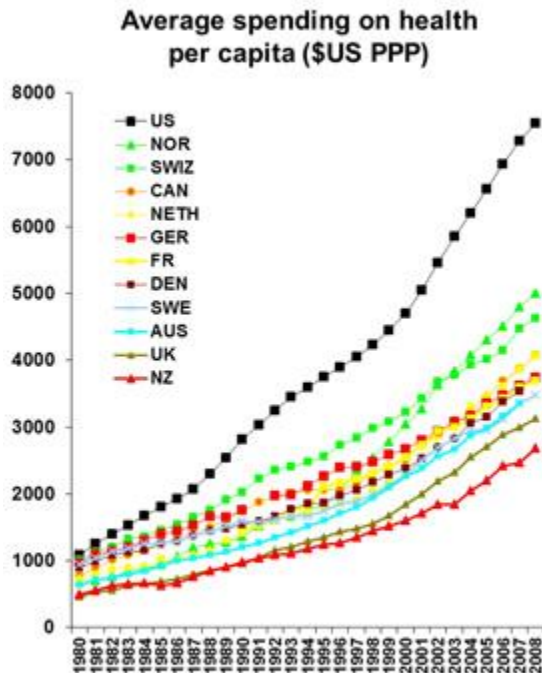


Source: Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group, at <http://www.cms.hhs.gov/NationalHealthExpendData/> (see Historical; NHE summary including share of GDP, CY 1960-2009; file nhegdp09.zip).



Motivation

International Comparison of Spending on Health, 1980–2008



Source: OECD Health Data 2010 (Oct. 2010).



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



Really Interesting OR Problems

- Merging large amounts of population data with very limited patient-specific data
 - Prediction
 - Classification
- Planning for expensive, capacity-constrained resources with planned and emergent demand streams
- Optimization under ill-defined objective functions



But the OR is the easy part

- The hardest challenges in healthcare are not mathematical
 - Communication
 - Culture
 - Competing objective criteria
 - Competing decision makers/constituents
 - Autonomous decision makers
 - Understanding the briar patch of healthcare finance



Re-Engineering the US Healthcare System

- Systems-based approach
- Quantitative, analytical, and evidence-based
- Descriptive modeling, prescriptive modeling, and policy implications
- Collaboration, collaboration, collaboration!!!



SCHEDULING PEDIATRIC EMERGENCY DEPARTMENT RESIDENTS



Acknowledgements

- Ongoing collaboration with many talented contributors
 - Winter 2014 Team
 - UMHS Chief Resident: Dr. Jenny Zank
 - Students: Young-Chae Hong, Elizabeth Perelstein, Zak VerShure, Peter Mayoros, Josh Wollman
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 - UMHS Chief Resident: Dr. Micah Long
 - Students: Young-Chae Hong, Mindy Alberty
 - And beyond...



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



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



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



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- Dr. Rishi Reddy, Dr. Andrea Obi, Dr. Jennifer Chung
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- SURE research 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
- **We are failing to adequately train transplant surgeons in a timely manner – may lead to shortage of surgeons very soon – conflict between ACGME and UNOS**



$$4 \times 10 \neq 40???$$

- 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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 - 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



Key Take-Aways

- Language is important ... for both sides! (“stochastic”, “mediastenoscopy”)
- Educating our partners is important
- Potential for policy impact as well as operations
- A little technical skill can go a long way
- Ground work for bigger, more “interesting” problems



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--CRLT

--SURE



QUESTIONS, COMMENTS AND DISCUSSION

