Making Evidence-Informed Decisions in Health Care:

Input from Operations Research

(a different type of "OR")

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What is Operations Research?

- A systematic way of thinking about management and decision making
- Involves building data-driven mathematical and computer models of complex processes to help quantify cost-benefit tradeoffs under uncertainty
- OR helps managers make tough decisions, solve critical problems, and shape important policy
- OR methods address both long term planning and day to day operational challenges
- "The Science of Better Decision Making"

History of OR

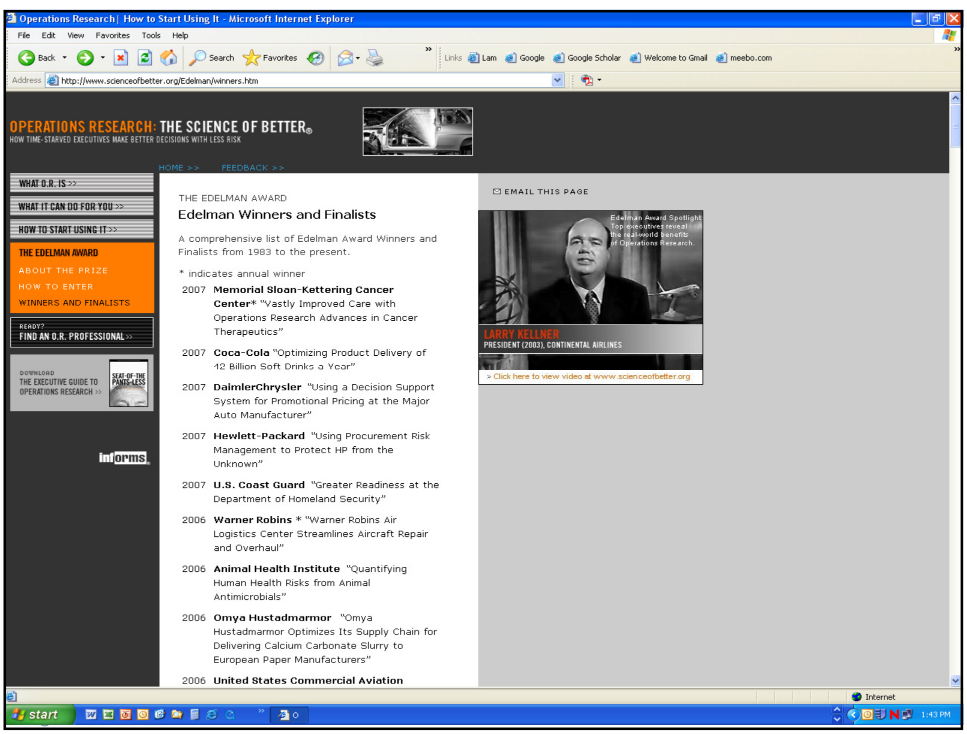
- Developed during World War II
  - To find the most effective utilization of military resources by using quantitative techniques
    - deploying radar
    - searching for enemy submarines
    - getting supplies where they were most needed
- Expanded post-war
  - Manufacturing products more efficiently
  - Scheduling equipment maintenance
  - Inventory planning
  - Transportation/logistics
  - Telecommunications
  - Service industries (health care, call centers)

Examples Outside of Health Care

- What is the most efficient way to route FedEx trucks to make deliveries?
- How much inventory should WalMart reorder each month?
- How can Disneyworld reduce the average time customers wait in lines?
- How should an airline schedule its pilots and flight attendants? How many seats should they sell at the different price points?

Operations Research in Health Care

- OR has been increasingly applied to health care in the last 10-15 years.
  - Rising % of GDP attributable to health care
  - More treatment options available
- Examples
  - How should nurses/physicians/diagnostic exams/ surgeries be scheduled? How many beds should there be in the ER?
  - Where should ambulance bases be located?
  - How should resources be allocated to control ID outbreaks? Who should be vaccinated, quarantined?
  - What is the optimal time to initiate HIV therapy?



Local Health Care OR Projects

- Assessment of porter operations for the Vancouver Coastal Health Authority and Providence Health Care
- Improving patient throughput at BC Children's Hospital
- Improving surgical patient flow at Royal Jubilee Hospital
- Residential care capacity planning for Vancouver Island Health Authority
- Reducing patient wait times at the BCCA ambulatory care unit
- Strategic scheduling of radiation therapists at the BCCA

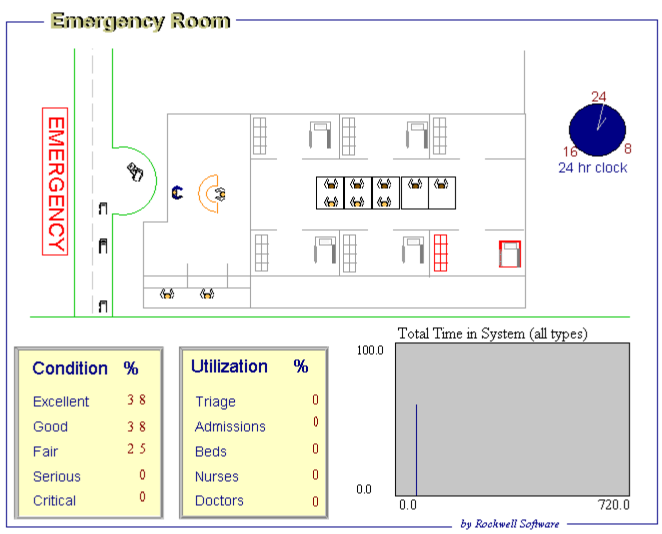
Operations Research and Urology

- Optimal time to switch from neoadjuvant hormone therapy to radiation therapy for treating prostate cancer (Lavieri et al.)
- Deciding between watchful waiting and radical prostatectomy (Kattan et al., Fleming et al.)
- Determining good prostate cancer screening policies (Cantor et al., Krahn et al.)
- Optimal placement of radioactive seeds to treat prostate cancer with brachytherapy (Lee et al.)
- Optimal control of a paired-kidney exchange program (Zenios et al., Gentry et al.)
- Optimal allocation of kidneys to patients on the waiting list (Su et al., Zenios et al.)

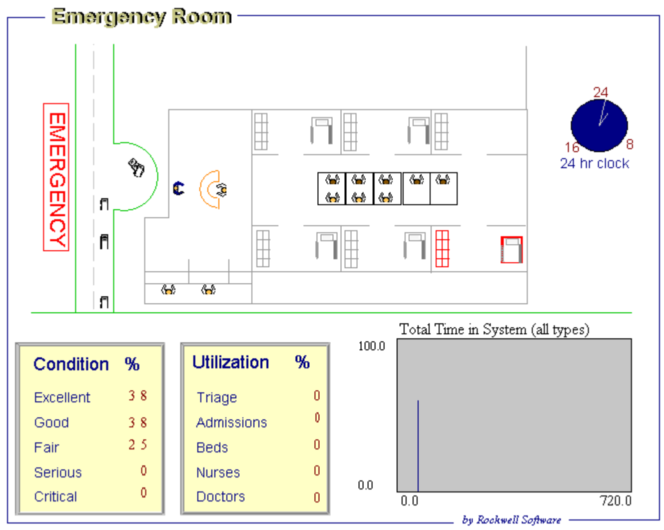
Simulation Modeling

- Widely used operations research tool for analyzing complex processes in which variability has a significant effect
- Allows one to test potential changes to a process in a computer model, prior to making any real policy changes (“What if” analysis tool)
- Useful when testing various changes to the real process may be too expensive, time consuming, or risky to take a trial-and-error approach
- Examples
  - Resource planning in health care facilities
  - Ambulance location
  - Organ allocation policies

Example: Emergency Room Simulation



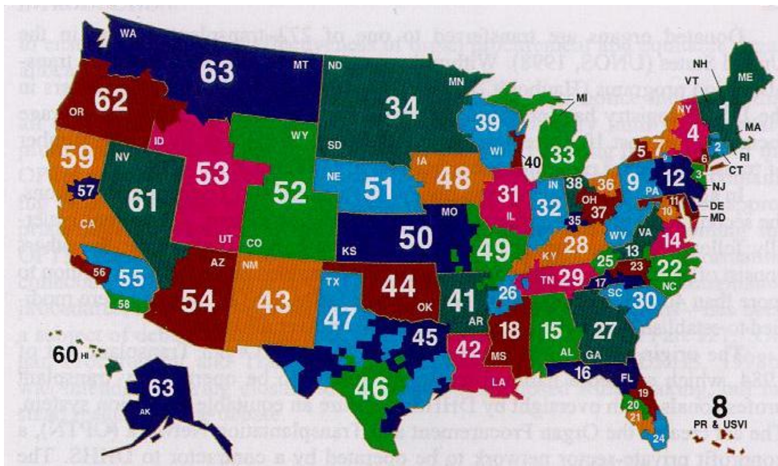
Example: Emergency Room Simulation



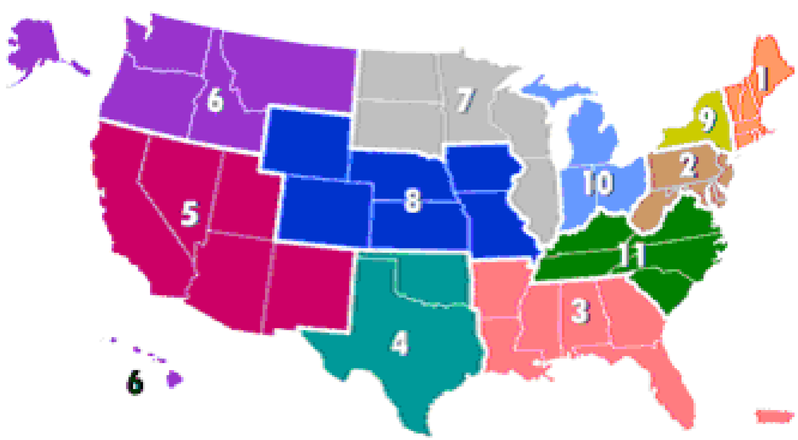
Simulating ESLD and the Liver Allocation Process

- Problem: Mismatch between supply and demand—approx. 16,000 patients with ESLD are waiting for a liver donation in the US
- Liver transplantation is the only viable therapy for these patients
- Therefore, cadaveric liver allocation policy has major implications for health outcomes
  - This is a contentious issue which tries to balance notions of efficiency with equity
- A randomized controlled trial is not feasible in this context
- Simulation provides a rigorous means to provide biologically based estimates of policy changes on patient outcomes
  - E.g., average waiting time for a transplant, deaths while waiting, average post-transplant survival time, etc.

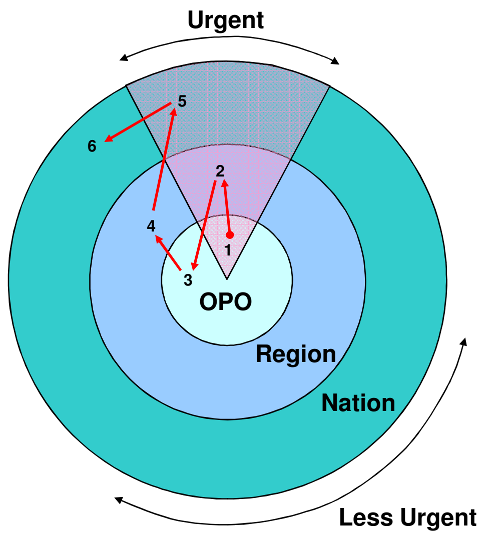
US Organ Procurement Organizations



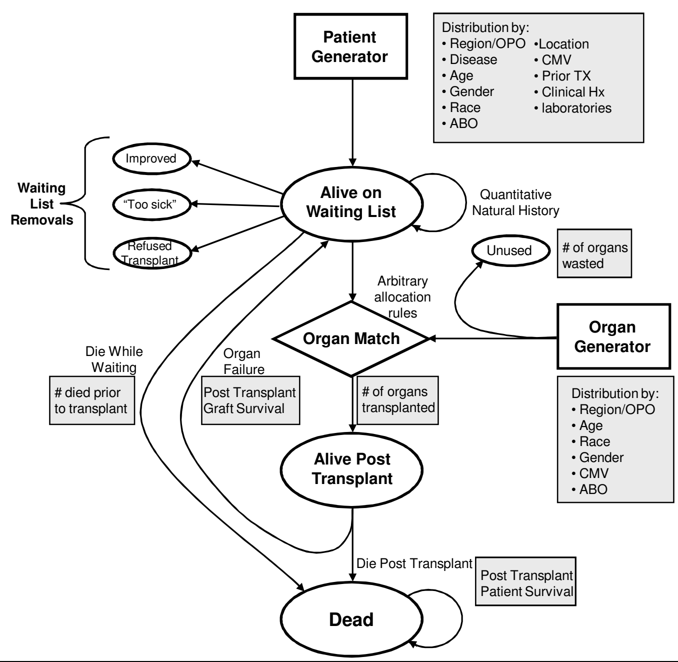
Organ Regions



Allocation Policy



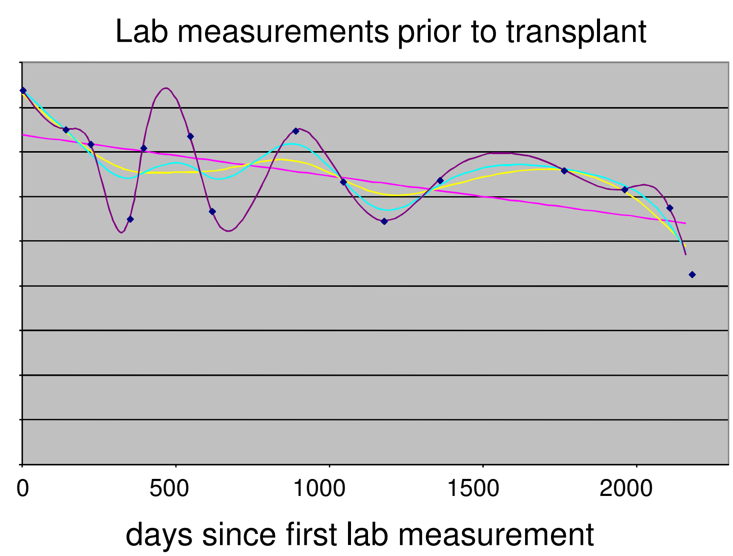
Model Structure



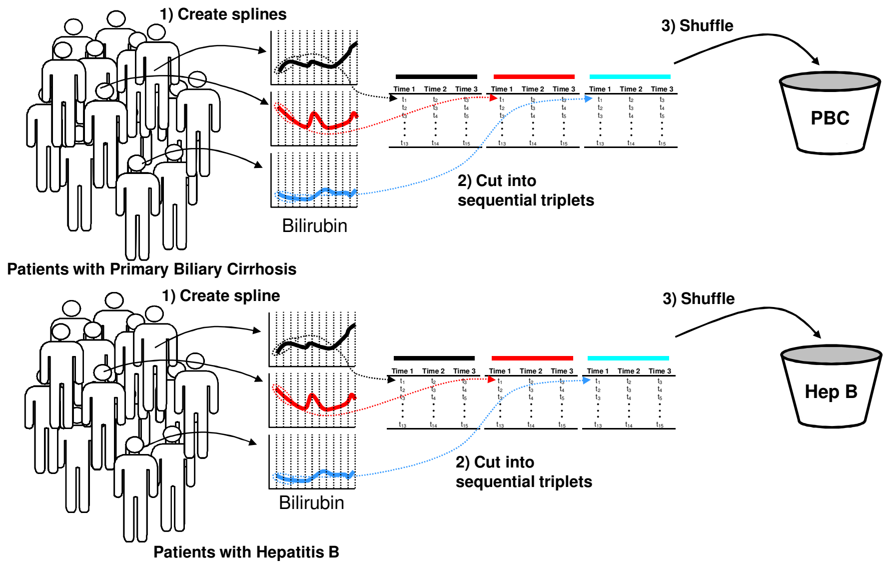
Natural History Modeling

- We want to update a patient's health periodically in the model (e.g., every month)
- However, real laboratory data are not taken at regular intervals:
  - More data when patient is sick (over-sampled)
  - Less data when patient is healthy (under-sampled)
- We estimate laboratory data in between using cubic splines

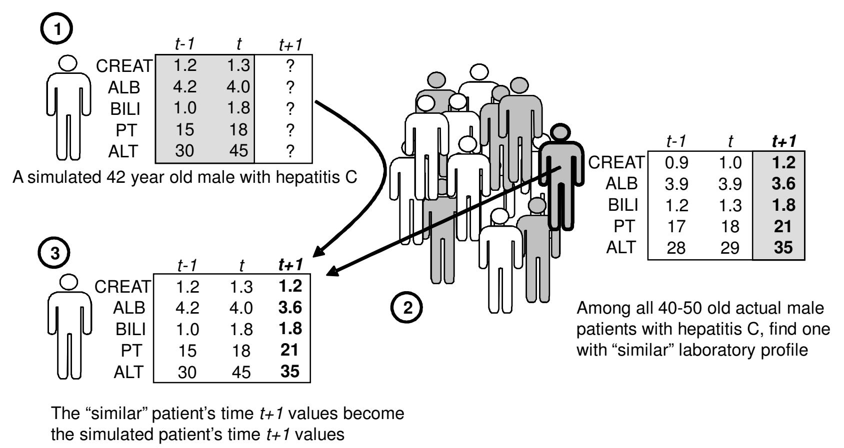
Natural History Modeling



Simulating Natural History



Simulating Natural History



	t-1	t	t+1
CREAT	1.2	1.3	?
ALB	4.2	4.0	?
BILI	1.0	1.8	?
PT	15	18	?
ALT	30	45	?

A simulated 42 year old male with hepatitis C

	t-1	t	t+1
CREAT	0.9	1.0	**1.2**
ALB	3.9	3.9	**3.6**
BILI	1.2	1.3	**1.8**
PT	17	18	**21**
ALT	28	29	**35**

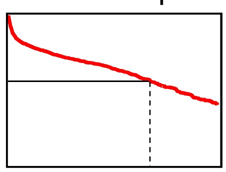
Among all 40-50 old actual male patients with hepatitis C, find one with "similar" laboratory profile

	t-1	t	t+1
CREAT	1.2	1.3	**1.2**
ALB	4.2	4.0	**3.6**
BILI	1.0	1.8	**1.8**
PT	15	18	**21**
ALT	30	45	**35**

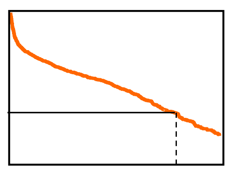
The "similar" patient's time *t+1* values become the simulated patient's time *t+1* values

Modeling Post-Transplant Survival

- After transplantation, model considers one of two possibilities for the patient
  - Patient dies after some time
  - Patient needs to relist for a new transplant after some time
- Used data from sample of ~17,000 transplants to develop Cox proportional hazards models
  - factors in patient and donor clinical variates at the time of transplantation to create survival curves for transplanted liver and patient



Patient Survival



Liver Survival

If Patient Survival > Liver Survival, patient is relisted at time of liver failure

If Patient Survival < Liver Survival, patient dies at survival time

Model Validation

- Face validity: National Clinical Oversight Committee to check that model assumptions were reasonable
- Validated components along the way: natural history and post-tx survival
- Putting it all together:

Variable		1992	1993	1994	1995	1996
Number of transplants	Model	2614	2947	3129	3470	3567
	Actual	2599	2946	3124	3460	3583
Number waiting	Model	1903	2809	3838	5365	7203
	Actual	1880	2548	3544	5072	6795
Deaths while waiting	Model	516	567	671	835	1000
	Actual	473	514	589	754	919
Waiting time (median)	Model	124	175	242	345	n/a
	Actual	142	193	217	316	n/a

Testing Alternative Policies

Outcome measure	4 Status Regional	4 Status National	MELD Regional	MELD National
Patients relisted	1622	1947	1670	1985
Deaths while waiting	3589	3169	3612	3149
1 year patient survival	0.84	0.82	0.84	0.82
1 year graft survival	0.78	0.75	0.78	0.75
Median wait time (days)	252	346	181	284
Mean survival (years)	9.51	9.63	9.32	9.46
Mean survival (QALYS)	6.65	6.56	6.67	6.65

Questions We Can Explore

- What if we changed the way in which OPOs are grouped into regions?
- What if we offered the liver to the patient that has the most to gain from this particular liver (i.e., expected lifetime), rather than the sickest patient?
- What is the cost effectiveness of these different allocation policies?

Liver Model Data

Model Component	Sample Size	Source
Disease progression module	1,997	Clinical records of patients awaiting liver transplantation at the University of Pittsburgh Medical Center (UPMC)
Relisted patient characteristics	655	Clinical records of patients relisted for transplant at UPMC
Patient generator	36,651	Candidate registry from the United Network for Organ Sharing (UNOS)
Survival estimation module	17,044	Liver transplant registry data from UNOS
Organ generator	17,044	Donor organ registry from UNOS
Quality-of-life module	95	Prospective evaluation of a cohort of patients awaiting liver transplantation at UPMC

Research Under Way

- Optimal path planning for laparoscopic surgery
  - The exact location of some critical structures is unknown during the course of surgery
    - Pre-op imaging helps surgeons have a good idea of where things should be, but there is uncertainty in precise boundaries
    - Also, patient may be physically oriented differently in surgery compared to scan, so organs may be in slightly different position
  - The location uncertainty makes it challenging to reach a target organ (e.g., kidney for nephrectomy) safely and efficiently
  - How can initial location uncertainty be combined with information gathered along the way to suggest which direction to cut into next?

Research Under Way

- Reevaluating the living donor process
  - Both potential recipients and donors go through several tests to determine suitability.
  - Are all of these needed?
  - Should the sequence be different?
  - How can we reduce the turnaround time from patient referral to living donor transplant?
  - When should the potential donors begin their evaluations?

Lean Principles and Health Care

- Lean thinking grew out of management ideas at Toyota
  - Eliminate waste throughout the system
  - Spirit of continuous improvement
- Recent interest in applying these ideas to health care
  - To reduce unnecessary movements (of patients, physicians, nurses, documents)
  - To reduce medical errors (e.g., surgical checklists, better labeling of medications)
- Lean and OR
  - Lean principles may be applied initially to take a step back and see where clear efficiency gains may be realized
  - OR models may then be useful when the effects of changes are not so clear and require more analytics to help evaluate cost-benefit tradeoffs

Some Observations

- Major decisions about health care resources and patient treatment should not be made without careful analysis
- Operations research methods can significantly improve health care delivery
  - They provide a systematic way to think about complex processes and the possible downstream effects of different choices
  - Systems-level analyses
    - Staffing, scheduling, location decisions
  - Patient-level analyses
    - When and how to treat
- There is a growing interest in health care OR problems
  - They are challenging, can produce good basic and applied research, and most importantly can benefit society
- It is important that appropriate data are collected and saved over time so that valid models can be developed

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