Operations Research: Decision Support Tools to Reduce Wait Times

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Outline

- Brief intro to Operations Research
- Queueing Theory
  - Examples and Limitations
- Simulation Modeling
  - Continuous models (System Dynamics)
  - Discrete Event models
- Mathematical Programming
  - Matching Capacity to Demand

Brief Intro to O.R.

- Started during WWII in UK
- Quantitative analysis: math, physics, stats
- Canadians involved from the start

Queueing Theory Primer

- Queues are everywhere: bank machines, grocery stores, airports, phone calls, elevators, EDs, etc.
- Basic idea:
  - Given average service and arrival rates
  - can calculate average wait time, expected queue size, utilization rate, and more
  - Several assumptions involved

Simple example

- Bank machine:
  - Average service rate:
    - 30 people/hour [2 minutes each]
  - Average arrival rate:
    - 15 people/hour [one every 4 minutes]
  - Utilization – 50%

Some Assumptions

- First come – first served
- Independent
  - Customs at airport?
  - Prescheduled appointments?
- Identically distributed
  - Different times of day?
- Service rate is *faster* than the arrival rate
- Everyone is served – no "reneging"

Three Types of Health Queues

1. Short term: "Daily" problem
   - *Average* service rate faster than arrival rate
2. Long term: "Monthly" problem
   - *Average* service rate ***equals*** arrival rate
   - Queue size never changes!
3. Catastrophe: Queue grows out of control
   - *Average* arrival rate faster than service rate!

Problem #1

- Queueing theory formulae only apply to the short term problem!
- Assumes that the "server" has some idle time
- Otherwise, impossible to predict queue characteristics!

Solution?

- If you want no idle time, you must have:
  - A buffer of people on the wait list
  - Arrival rate = Service rate
- Occasionally, you may need to provide additional capacity to reduce the wait list
- Of course, you must know the arrival rate!

Problem #2

- For the long term problem, in most situations, we have little or no knowledge of Arrival volumes!
- Wait lists are hiding in doctors' offices

Problem #3

- For the short term problem, in most situations, we have little or no knowledge of service rates!
- We know what was ***booked***, but typically, no one records how long appointments actually took.

Problem #4

- Even if the average demand is equal to the average capacity, if there is variation queues will form because unmet demand is carried forward, but unfilled capacity is lost.

Problem #5

- There are perverse incentives for having a queue:
  - it keeps a service busy and apparently essential to the service
  - waiting list initiatives are awarded to services with queues

Have you ever counted them?

- Nuclear Medicine at William Osler
- Endocrinology at the Cleveland Clinc

CPOE at Sunnybrook

- Computerised Physician Order Entry
  - In-patient medication orders
- Question: How many computer terminals should be allocated to each ward?
- "Docs should never have to wait for a computer"

CPOE at Sunnybrook

- compare expected waiting time and resulting clinician "ill-will" with the cost of purchasing additional workstations;
- A maximum acceptable waiting time used to calculate the minimum number of workstation
- A combination of the two approaches

Prioritized Waitlist

- Priorities make the average worse!
  - Basic rule in scheduling: SPT – doing "Shortest Process Time" jobs first will minimize the average waiting time.
  - Adding priorities (e.g., in the ED) often means that the short ones go last.
  - Some priorities are medically necessary – but should be used with caution!

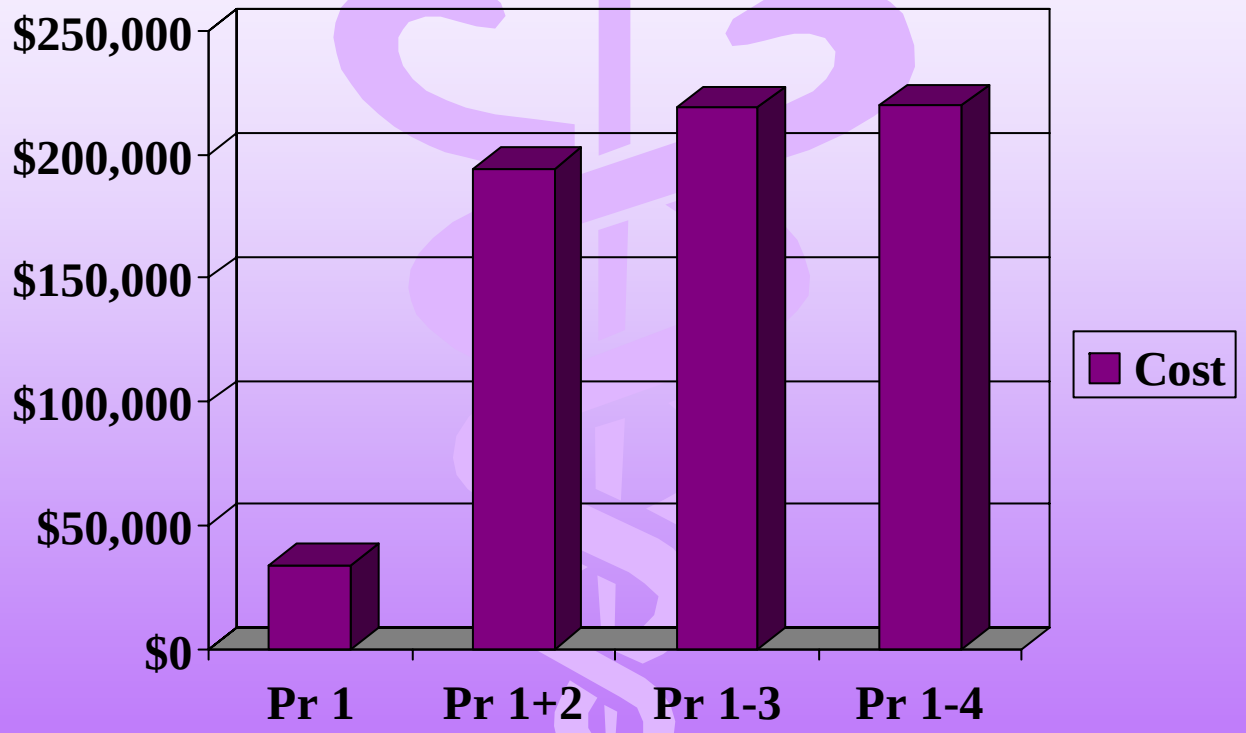
Simcoe County CCAC

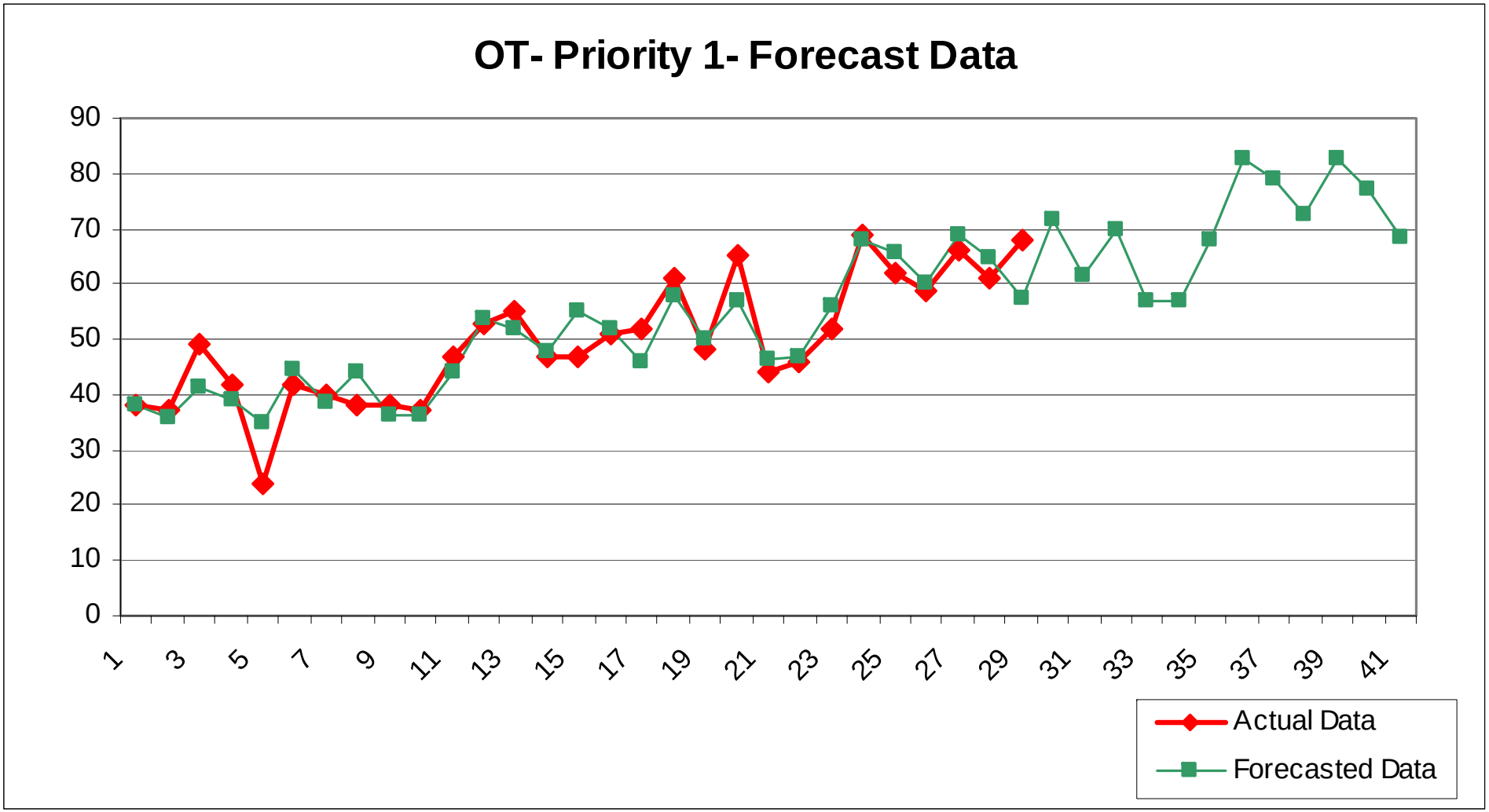
- Services
  - Nursing
  - Therapies
  - Personal Support
    - Meals, bathing, dressing, cleaning, living skills ...
  - Placement Services
    - 21 Long term care facilities – 1,763 beds

Simcoe County CCAC

- Therapies
  - Occupational therapy (OT)
  - Physiotherapy (PT)
  - Diet/Nutrition (NUT)
  - Speech pathology (SP)
  - Social work (SW)

Total Cost to Clear Wait List




OT- Priority 1- Forecast Data
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
Actual Data
Forecasted Data

Estimating Waiting Time

- Queueing Theory: Given the customer arrival rate 🖱, and the system service rate 💻, we can analytically compute a number of statistics (expected wait time, expected number of patients waiting, etc.) for each service.
- This can be extended to multiple priority queues

Monthly Arrival & Service Rates

Service	Priority 1 (λ_1)	Priority 2 (λ_2)	Priority 3 (λ_3)	Total (λ)	Service Rate (μ)
NUT	33.58	11.29	2.97	47.84	42.06
OT	40.42	33.00	9.25	82.67	89.38
PT	139.75	55.78	5.92	201.45	169.31
SP	4.25	4.33	0.81	9.39	15.68
SW	16.5	18.29	7.5	42.29	36.06

Decision Support Tools

- Model 1: Given limits on the queue for each priority (maximum acceptable wait times) compute the minimum service level required.
- Model 2: Given a fixed service level ($$), compute the expected wait times.

Network of Queues

- Many queues involve a sequence of wait lists:
  - ED ► ICU ► Ward ► ALC ► LTC
  - GP ► Surgeon ► Lab ► Surgeon ► OR ► etc
- Each one is a queue – each has an arrival rate and service rate/LOS
- We typically don't know arrival or service rate for many parts
- Analysis is more complex (computer simulation)

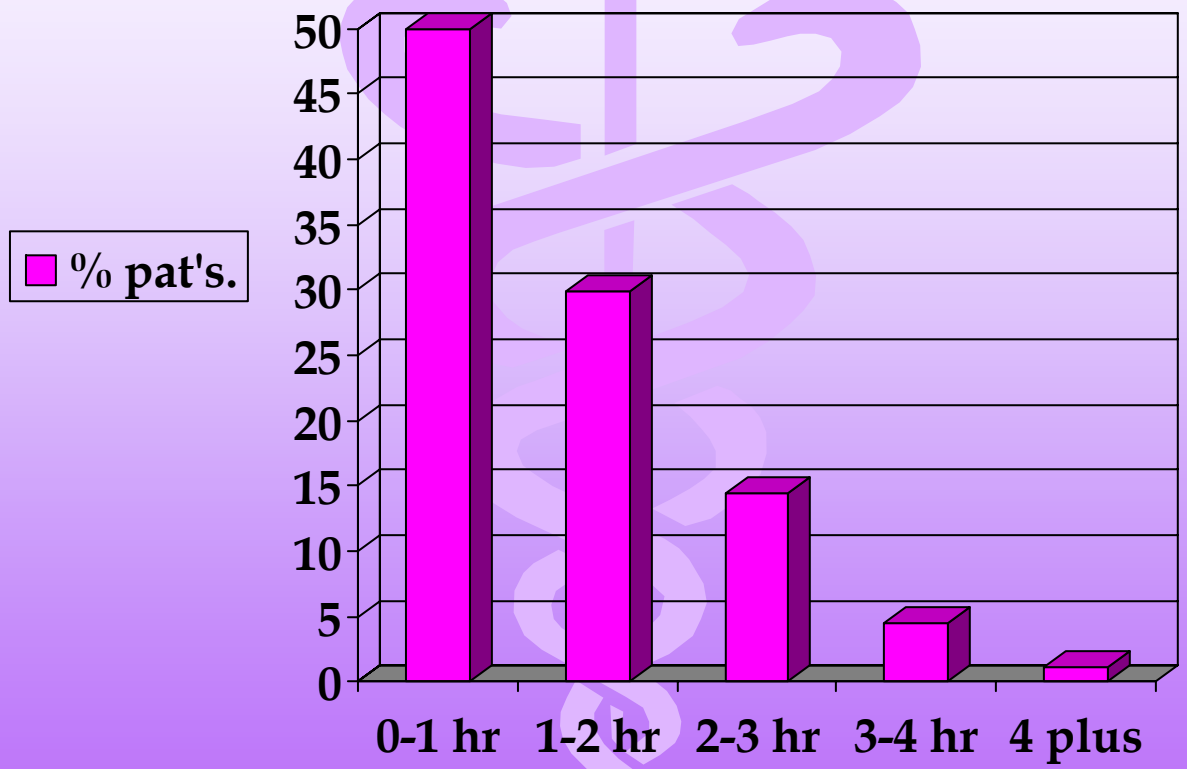
Hospital Patient Simulation

- 1989: Nursing Crisis in Ontario
- Ont. Min. of Health & Five Hospitals
- Prof. Linda O'Brien-Pallas (Nursing)
- 1995: Efficient Use of Resources!
- "What if?" Simulation tool

CHEO: Emergency Room

- Children's Hospital of Eastern Ontario: Ottawa 1993
- Paediatric Teaching Hospital
- 50,000 patient visits per year in the ER

CHEO: Waiting Times (1993)



CHEO: Emergency Room

- 20 % of patients wait over two hours
- Eleven suggestions by staff
- Simulation used to evaluate scenarios
- Fast track clinic
- New Casualty Officer
- Staggered start times

Generalized Simulation of Ontario Emergency Departments: Toward a Better Understanding of Patient Length-of-Stay: The CROWDED study

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[4]Sunnybrook and Women's College Health Sciences Centre

Background

- ED overcrowding and waiting - major problem
- Most analysis based on LOS data
- A few simulation models - typically model LOS
- Does not help us analyze improvements
- Wanted to understand what happens in an ED

CIHR & SSHRC funding

- ***CROWDED*** study: ***Causes and Relationships of Overcrowding and Waiting in Different Emergency Departments***
- Two full time research assistants for one year
- One full time PhD student: Dominic Fernandes
- Cross section of hospitals in type & geography
  - 3 rural, 4 community and 3 teaching from each geographic area of Ontario

The Hospital Partners

- Academic
  - Kingston General
  - Sunnybrook & Women's
  - London HSC
- Rural
  - Quinte Health Corp
  - Stevenson Memorial
  - South Muskoka
- Community
  - Royal Victoria - Barrie
  - Sudbury Regional
  - Markham-Stouffville
  - Windsor Regional

Models for Assessment of Blood Product Shortages: Likelihood and Consequences

Somayeh Sadat, Renata Kopach, Daniel Frances

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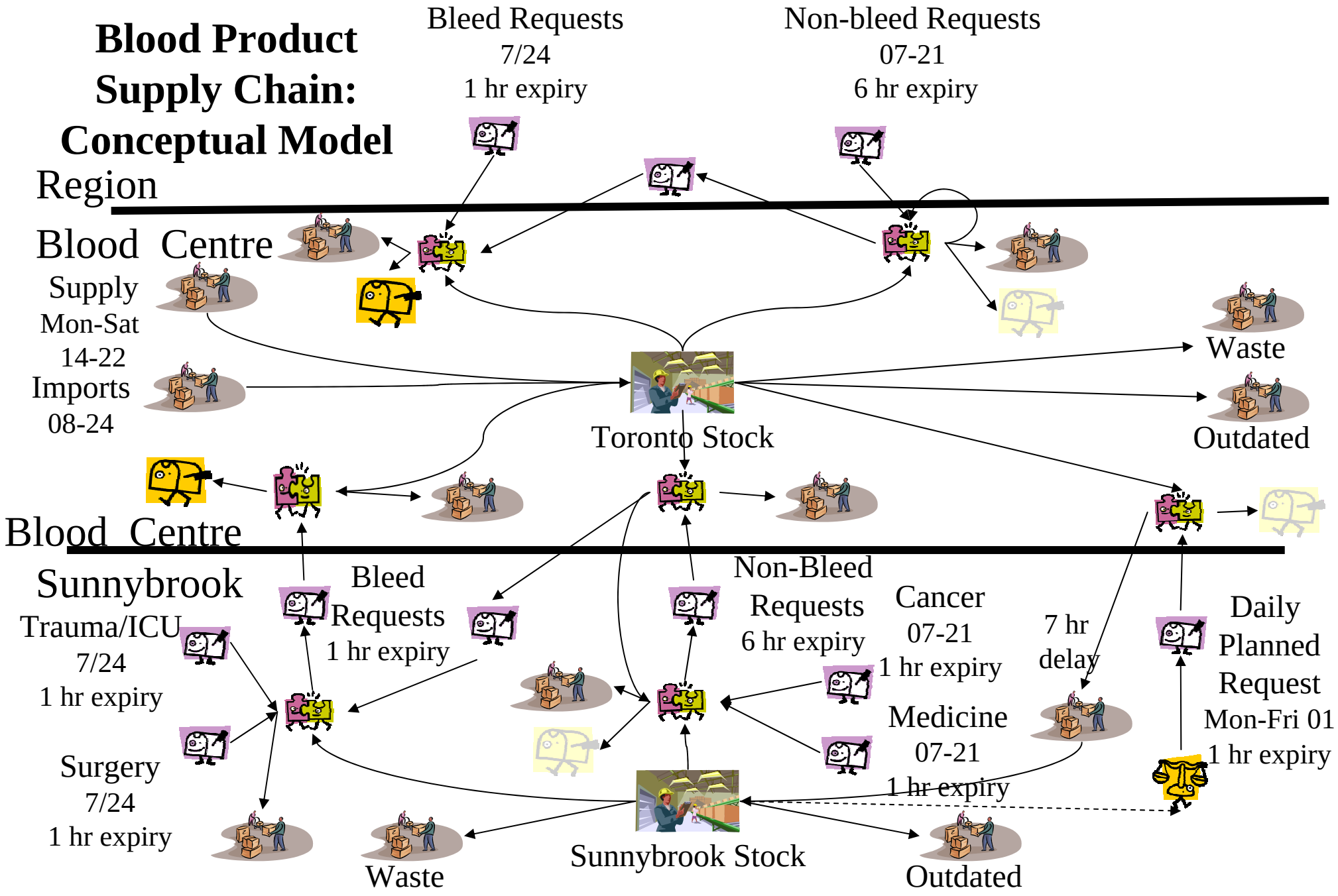
Rational

Need to quantify the incidence and medical consequences of blood products shortages

***Taking into account*:**

- **Uncertain supply and demand**
- **Product outdates and wastes**
- **Transit time in rural areas**

Blood Product Supply Chain: Conceptual Model



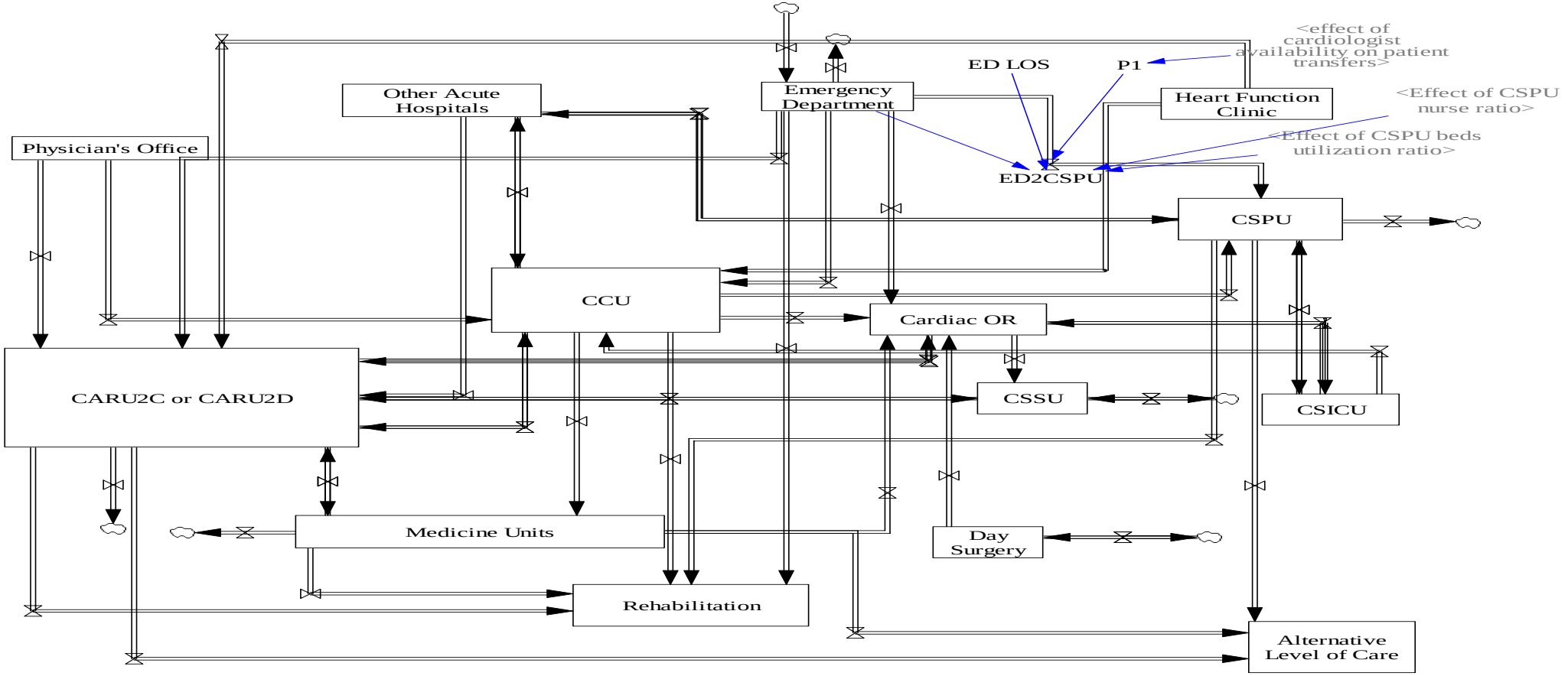
System Dynamics Simulation for Cardiac Resource Allocation at Trillium Health Center

Somayeh Sadat, Caroline Chan, Michael Carter

Cardiology at Trillium

- Community Hospital which also serves as the regional cardiac care centre for communities west of Toronto, Ontario
- Conducts 10% of all cardiac procedures in Ontario
- Performs more than 7,000 cardiac surgeries annually
- Performs unique procedure: beating heart surgery

Cardiac Patient Flow at Trillium



Mathematical Programming: Strategic Hospital Planning Model

- Mid 1990's – 3 year cuts of 18%
- John Blake Ph.D. thesis - Mt. Sinai Hosp
- Understand relationship between revenues, costs, resources.
- Mathematical model
- Goal Programming formulation

Problem Statement

- Identify a case mix for physicians that:
  - Enables the hospital to break even.
  - Provides physicians with a stable income.
  - Allows physicians, as much as is possible, to perform their target mix of cases.

Two Goal Programming Models

- Volume model:
  - Fix the cost of each CMG
  - Determine the case mix that meets targets
- Cost model:
  - Fix the case mix (volume) for each CMG (at current levels)
  - Determine the cost reductions necessary to meet targets

Project Results

- Used during 1996 (plan for 11% cut)
- Intuition at hospital:
  - Retain clinically important services (oncology)
  - Eliminate “unimportant” services (dental, ENT, ophthalmology)
- Model recommendations:
  - ***increase*** dental/eye/ENT
  - ***decrease*** thoracic, oncology
- Thoracic surgery was eliminated in 1997

Western Canada Wait List Project

- Wait lists are anecdotal!
- Plus, every doc has his/her own priority
- WCWL has developed standard priority instruments
- But, how will that help reduce wait times?
- Need to develop models of resources to predict impact on wait times.

Cardiac Care Network of Ontario

- Currently fund 110 surgeries per 100,000 pop.
- What would happen to wait lists if they funded 120? 130?
- Developing simulation model with CCNO and ICES (Jack Tu)

Readings

- "Operations Research and Health Care: A Handbook of Methods and Applications Series", *Kluwer International Series in Operations Research and Management Science*, Vol. 70, Brandeau, Margaret L.; Sainfort, Francois; Pierskalla, William P. (Eds.) 2004, 872 p.