Applications of Computer Simulation Modeling for Health Care Process Management

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Overview of Presentation

- Computer Simulation Modelling
- CHEO ED – Ottawa
- Hamilton Cardiac Surgery
- System Dynamics: Toronto Western and Ottawa Hospital ED
- Some Challenges
Computer Simulation

• Many packages available
• MedModel, Simul8 and Arena
• Illustrate with MedModel
• Patients arrive randomly
• Arrival rate varies over the day
• Wait for triage, MD, RN, labs, etc.
• Add resources, increase rates, “What if?”
- Location Statistics examples:
- Crit exam1: 76.02% util.;
- Crit exam1: avg. time: 59.71 min.
- Avg. time in waiting room: 107.6 min.
Resource Statistics

- MD: 73.5% util.
- RN: 27.55% util

- Also find the avg. time per patient in the ED: 113.11 min
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
Cardiac Surgery Simulation

• Hamilton Health Sciences
• Opening fourth cardiac OR in Spring 2006
• How should OR time be allocated?
• How many beds are required in ICU/ward?
• “What if?” Simulation tool
Surgery Grouping

Cardiac Surgery 2002-2004
N>4000

No Redo/Combined
- CABG
- VALVE
- COTHR
- CONGD

Redo/Combined
- CABG
- 1,2,3 TVR, AVR
- CONGD COTHR

- CABG
- 4,5,6,7 MVR

- CAVLV
- AORTA

- CABG
- VALVE
- AORTA

- CAVLV
- COTHR
Cardiac Surgery 2002-2004

- **Intermediate**
  - 322 mins
  - n=281
  - 359

- **In-btwn**
  - 284 mins
  - n=890
  - 313

- **Minor**
  - 244 mins
  - n=1016
  - 266

- **Major 1**
  - 353 mins
  - n=116

- **Major 2**
  - 431 mins
  - n=60
Surgery Duration Distribution

Minor
246 mins
n=1530

In-btwn
285 mins
n=1789

Intermediate
337 mins
n=499

Major
461 mins
n=220
Performance Indicators

– Number of cases completed/year

– Cancellation rates
  • Lack of ICU/ ward bed
  • Out of scheduled time
  • More urgent case took precedent

– Operating room utilization
  • Under-utilization (hours/week)
  • Overtime (hours/week)

– Ward bed utilization (ICU & CSU)
Which procedures should be booked together?

11 hour OR

Undertime & Overtime (hour/day)

Undertime

Overtime

Total Cancellations (Cases/year)

Combinations

1 major + 1 minor
1 intermediate + 1 in-between
1 intermediate + 1 minor
2 in-between
1 in-between + 1 minor

Which procedures should be booked together?
Planning ICU and Ward Capacity

![Bar chart showing ICU cancellations and CSU over exceedance of 30 beds per week.]

- **Unit/year**
- **Weekdays:** Mon, Tue, Wed, Thu, Fri, Sat, Sun
- **ICU cancel (# cancellations)**
- **CSU over (# days exceeded 30 beds)**
General Internal Medicine Resource Allocation at Toronto Western Hospital: A System Dynamics Approach

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A System Dynamics Approach

The ED and GIM units at TWH are functioning over capacity, struggling daily to cope. Decisions that affect the whole hospital are made in silos.

TWH needs a way to explore the interactions of ED & GIM with each other, other departments within the hospital, and with the outside world.

Objectives

Gain a better understanding of the influence GIM has on the ED.

Explore the impact of hospital policy on ED-GIM patient flow.

Redesign policies to better allocate resources.
GIM Patient Flow

“Stocks” are where patients accumulate

Patient flow

“Valves” control the rate of inflow and outflow

Source or sink (stocks outside model boundary)
Current Situation

Delay 62 min

LOS 9.1 hrs

Delay 27.9 hrs

LOS 26.2 days

Delay 9.4 days

LOS 7.5 days

LOS 15.7 days

Death

Home
Questions for the Model to Consider

I’d be interested in knowing how much we’d need to decrease patient LOS to impact ED waiting times.

I’m interested in the bed question. E.g. If we add an additional 12 beds, what is the impact on flow?

If we’re able to cut down the time it takes to:
- Identify a patient as needing to go to inpatient Rehab/CCC (ALC facility)
- Complete and send off applications
- Match patients to available ALC beds quicker

What is the impact to GIM LOS, ALC days, etc.?

How is LOS affected if:
- 5 additional (or any #) of patients are discharged on Friday
- All patients are discharged before 3pm weekdays
- ED patients move directly to floors and do not spend time in ED.

I’d be interested in knowing how much we’d need to decrease patient LOS to impact ED waiting times.
Using System Dynamics, we can model the effect of:

- ED waiting room occupancy on rates of patients who leave without being seen
- ED bed occupancy on ED waiting room LOS
- GIM bed occupancy on GIM LOS in ED
- ALC days on GIM occupancy
- Hour of day and day of week trends in GIM discharge...how does this affect the ED?
- Changes in the GIM patient population (diagnosis, discharge destination, etc)
Objectives

• Help hospital decision makers make more informed decisions by providing insights into the system.

• Explore relationships between resource levels and bottlenecks in patient flow

• determine best allocation of scarce resources (nurses, beds, etc.) to meet objectives (eg., shorter LOS in ED)
The Ottawa Hospital
ED Patient Flows

Rate adjusted by:
- hour of day
- season

ED bed type depends on:
- pt. severity (CTAS) which is dependent on age

Rates at which pts. get ED bed depends on:
- Time of day
- # of pts. in waiting room

ED LoS depends on:
- Area
- If consult needed

Inpt. los depends on:
- Service
- Discharge destination

Admission rate depends on admitting services’:
- Nurse to patient ratio
- Nursing shift in
Model Validation

Model Accuracy: ED LOS

% deviation: 
(real los – model los) 
real los

e.g.:
corridor, no consult c-no):
real: 5.3 hrs
model: 4.6 hrs
Hence, model has 12% deviation from real

Note: Summer results (June, July, August, 2003) are noticeably different. SARS effect
Scenario Testing

The model can help answer the following questions:

How will wait times change in the ED if inpatients are directly admitted without a visit from a consult?

What will happen if we add/reduce # of GM beds? GS beds?

If adding a nurse, which service should one be added to in order to have greatest impact on ED los?

What will happen to ED LoS if there is a x% increase in patients 90 years old or older?
Generalized Simulation of Ontario Emergency Departments: The CROWDED study

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Background

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

- Evaluation of alternatives (e.g., CTAS 4, 5)
- Best practices
- Identify bottlenecks
- Impact on wait times of:
  - faster consults
  - improved MRI process
  - additional nurses, doctors, treatment rooms, etc.
  - reduction in average time to admit
Opportunities (cont.)

- Evaluate various policy scenarios:
  - Alternate staff schedules
  - Focused care-areas (e.g., for Cardiac).
  - Impact of changing demographics (e.g., study role of non-emergent pts on LOS)
  - Analysis of Fast Track clinic option
• CROWDED study: *Causes and Relationships of Overcrowding and Waiting in Different Emergency Depts.*

• 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
Generalized Model

• Build ten individual ED models
• Use components to build a general model
• Design an interface to allow user to create their own model
Data Collection

• Three visits to each hospital:
  – pre-visit: three days
  – two data collection visits: seven days each

• Followed individual patients and tracked around 60 different processes
  – included triage, nurse- and physician-assessments, lab and imaging activities, consults and disposition
  – Patient data include presenting problem, diagnosis, mode of arrival, age, sex, and disposition
Data Analysis

- Approx. 2200 patients tracked
- Data is being used:
  - for process time distributions
  - to determine patient pathways
- Approximately 25 patient-types identified
  ~90% of pts.
- Pareto Rule: 80% of patients fall under 20% of possible diagnoses
MD-Tracking

- MD-activity characteristics will be used to define resource availability in simulation model.
- Different trends can be observed among hospital types.
Challenges

- Doctors are hard to track (multi-tasking)
- Missing data (long LOS; trauma)
- Layout issues
- Off-site fast-track clinic
- Wait time before triage
- Unplanned critical events (SARS, Norwalk)
- Preemption
- Administrative issues (suspicion, turnover)
Conclusions

• Simulation is a powerful tool for analyzing emergency departments

• It is not as simple as it looks: Most of my projects took over a year
  – I wrote a book chapter on Challenges

• It is worth the time and effort
Readings

  Chapter 8: Carter & Blake “Using Simulation in an Acute Care Hospital: Easier Said Than Done”