Modeling Health Care from a Systems Perspective

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ISPOR Berlin
November 6, 2012

Outline

1. Introduce system dynamics modeling as a tool for modeling health systems
2. Describe basic elements of system models
3. Describe how this systems approach can be applied to inform health care delivery using osteoarthritis example.
Systems Thinking

- Thinking of the “big picture”
- Include the: dynamic, complex, interdependencies
- Feedback
- Balancing short term and long term perspectives

The systems viewpoint is generally oriented toward the long-term view. That’s why delays and feedback loops are so important. In the short term, you can often ignore them; they’re inconsequential. They only come back to haunt you in the long term. 

Senge

A Model of Systems Thinking

Figure adapted from Morecroft (2007)
System Dynamics (SD) Simulation

• “...simulation is an important element of successful learning laboratories to develop systems thinking and promote organizational learning.” Senge and Sterman (1992)
• Developed by Jay Forrester at MIT in 1950s
• SD is grounded in:
  – Nonlinear dynamics
  – Feedback control
  – Social sciences
• Toolkit (mapping, modeling and simulation)

Why System Dynamics Modelling for Planning Health Care Delivery?

“Health Care is a System…. and it is Dynamic”

• Balance demand, supply & delivery of services
• Consider resource constraints and impact on flow of patients through the system
  ▪ Population-level care delivery
  ▪ Capacity, patient flow, utilisation & wait times
  ▪ Captures changes projected over time
Examples of SD modeling Applications for Planning Health Care Delivery

- Examples of SD modeling applications:
  - Matters of national policy (e.g. WHO polio vaccine policy decisions, CDC for flu decisions)
  - Interaction of delivery systems and diseased populations (e.g. emergency department operations)
  - Health care policy reform (implementing new health systems)

- Homer and Hirsch, 2006

What is a System Dynamics Model?

Model system as series of stocks & flows

- Adapted from Sterman
Basic Elements of System Dynamics Models: Stocks and Flows

• **Stocks** – anywhere populations accumulate
  • Patients waiting, staff levels
• **Flows** – rates at which populations enter and depart; flows change the levels of stocks
  • Patients arriving/hour, staff leaving/month, capability/year
• **Rates** affected by state of the system

Stocks and flows can be directly translated into a system of integral and differential equations

Building a Decision Support Tool for Delivery of Health Services for Patients Hip and Knee Osteoarthritis (OA)
Project Objective

To create a decision-support tool for strategic service planning of care for hip & knee OA patients

- Evaluate health care quality and system performance
- Inform choices about health system interventions considering intended and unintended consequences
- Balance the tradeoffs between accessibility, effectiveness and efficiency across the continuum of care from OA onset – optimization...

Goal: Sustainable plan for OA care

Model Scope

- Hip and knee arthritis
- Disease progression, joint replacements and revisions
- Physician care, specialist care, surgery, pre- and post-surgical care
- Alberta population
- Long time horizon (decades)
Basic Elements of System Dynamics Models: Stocks and Flows

The naming of variables is arbitrary, but names should be meaningful and represent stocks and flows in the real system.

What this diagram says: The stock of People Without Hip and Knee Arthritis increases with the flow Births and decreases with the flows Developing Arthritis and Deaths. The flow Developing Arthritis is influenced by age, gender, obesity and other factors.

How is the model relevant to health care decision making?

• Key applications of the SD OA model
  – Identify variance in flows, resource use and costs to highlight areas where the source of variance should be explored as an opportunity to improve care and reallocate resources
  – Examine ‘what if’ scenarios about potential changes in care processes that can be implemented as ‘what if’ scenarios in the model to explore intended and unintended consequences
Data Overview Diagram

Model Resource Inputs
Sample average Cost/Case Calculation Summary

Avg. physician cost/case + Avg. allied health cost/case
Average cost/case
Costs/case = # of visits * cost per visit

D. In Primary Care prior to referral to specialist (rheum or MSK MD)
Duration: 5.4 years
Sample Patient Pathway - Referred Directly from PC to OS

### Average Duration of Sample Patient Pathway

<table>
<thead>
<tr>
<th>Grouped Stages</th>
<th>Stages</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
<th>Delta</th>
<th>Epsilon</th>
<th>Alberta</th>
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<tr>
<td>In Primary Care (Years)</td>
<td>D</td>
<td>5.1</td>
<td>5.3</td>
<td>5.3</td>
<td>5.6</td>
<td>6.1</td>
<td>5.4</td>
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<td>In Specialist Care (Days)</td>
<td>L, M, Q</td>
<td>500.4</td>
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<td>462.2</td>
<td>564.4</td>
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<td>In Acute Care (Days)</td>
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<td>4.5</td>
<td>3.8</td>
<td>3.9</td>
<td>3.8</td>
<td>4.2</td>
<td>4.1</td>
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<tr>
<td>Post Surgery (Years)</td>
<td>X, Z</td>
<td>7.3</td>
<td>6.8</td>
<td>7.3</td>
<td>63</td>
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### OA Related Cost for Sample Patient Pathway

<table>
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<td>$529</td>
<td>$808</td>
<td>$455</td>
<td>$435</td>
<td>$597</td>
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<td>In Acute Care</td>
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<td>$12,463</td>
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<td>Post Surgery</td>
<td>X, Z</td>
<td>$970</td>
<td>$735</td>
<td>$1,047</td>
<td>$686</td>
<td>$895</td>
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<tr>
<td>Total</td>
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<td>$15,814</td>
<td>$14,887</td>
<td>$15,495</td>
<td>$14,838</td>
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### Sample ‘What if’ Scenarios

- **Base case**
  - All data based on analysis of data from sources

- **Orthopaedic surgeon and Surgery wait**
  - Surgeon wait = 6 months
  - Surgery wait = 14 weeks

- **Primary Care referrals ↓ 10%**
  - Proportion of PC patients referred to specialists (Rheum, MSK MD, ortho surgeon) * 0.9
  - Remaining 10% remain in Primary care until departure

- **Rheumatology wait = 3 months**
# of patients in years 2012 & 2035

Select Stages

# of patients by zone

Stage K & L: awaiting Ortho Surg. consult
Costs of care by stage, year 2012

Provider Costs by referral source, Base Case
Conclusions

• SD modeling can help evaluate care quality and system performance, balancing the tradeoffs between access, effectiveness and efficiency

• Inform choices about planning health system interventions considering intended and unintended consequences

• Next step is optimization...

Thank you!

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