Modeling Complex Healthcare Interventions: Dynamic Systems and Feedback Loops

Peter S. Hovmand, PhD, MSW
Founding Director & Associate Professor of Practice
Brown School Social System Design Lab
Washington University in St. Louis
phovmand@wustl.edu

Innovations for Research on Improving Safety, Quality and Value in Health Care
Academy Health Annual Research Meeting, San Diego | June 10, 2014

Peter S. Hovmand, PhD | ARM San Diego, 2014
Quality improvement feedback loop

Real system
Quality improvement feedback loop

Quality indicator

Real system
Quality improvement feedback loop

- Standard
- Gap
- Quality indicator
- Real system
Quality improvement feedback loop
Improving cue selection and interpretation (e.g., dashboards and balanced scorecards)
Improving selection of goals (e.g., shifting from quantity of services to outcomes)
Improving “operator logic” (e.g., evidence based medicine)
Improving “design logic” (e.g., improving cognitive models)
Example: misperceptions of accumulations
Example: misperceptions of accumulations
Example: misperceptions of accumulations
Different types of system insights

Surface system insights
- There is a system
- The components of a system
- How the components are related through feedback
- How people might think about a system
- Where one could intervene

Deep system insights
- What is transformation
- What is the generic structure
- What are the implications of accumulations and nonlinear relationships
- What systems can generate the dynamic behavior
- Where are the leverage points
- When do boundary conditions determine behavior
- Why do things happen
Different types of system insights

There is a system
The components of a system
How the components are related through feedback
How people might think about a system
Where one could intervene
What is transformation
What is the generic structure
What are the implications of accumulations and nonlinear relationships
What systems can generate the dynamic behavior
Where are the leverage points
When do boundary conditions determine behavior
Why do things happen
Different types of models for different types of system insights

- There is a system
- The components of a system
- How the components are related through feedback
- How people might think about a system
- Where one could intervene
- What is transformation
- What is the generic structure
- What are the implications of accumulations and nonlinear relationships
- What systems can generate the dynamic behavior
- Where are the leverage points
- When do boundary conditions determine behavior
- Why do things happen

Deep system insights

Surface system insights

Informal to Formal

- System pictures or diagrams
- Graphical models or causal maps
- Mathematical simulation models

Peter S. Hovmand, PhD | ARM San Diego, 2014
System Dynamics

- System dynamics is the use of informal maps and formal models with computer simulation to uncover and understand endogenous sources of system behavior (Richardson, 2011, p. 241)

System Dynamics

• System dynamics is the use of informal maps and formal models with computer simulation to uncover and understand **endogenous sources** of system behavior (Richardson, 2011, p. 241)

• Foundations of system dynamics:
  
  – **Endogenous perspective**
    
    • Stock or level (state) variables representing accumulations
      
      – Flow or rate variables representing activity
        
        » Using computers to simulate more realistic mathematical models

Potential leverage points

- **Wellness**
  - Increasing resiliency
  - Increase in risk
  - Universal primary prevention

- **At risk**
  - Onset of condition
  - Recovery
  - Treatment

- **Needing services**
  - Referral
  - Average time to referral
  - Access

- **Receiving appropriate care and support**
  - Losing appropriate care or support
  - Fraction losing appropriate care or support
  - Quality of care
  - Average time to recovery
  - Recovery and resiliency

- **Receiving inappropriate care or support**

---

Peter S. Hovmand, PhD | ARM San Diego, 2014
### Percent change from baseline at 25 years

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Not needing care</th>
<th>People needing care</th>
<th>People in care</th>
<th>Quality of care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Universal primary prevention</td>
<td>14%</td>
<td>-47%</td>
<td>-29%</td>
<td>10%</td>
</tr>
<tr>
<td>Selective primary prevention</td>
<td>6%</td>
<td>-19%</td>
<td>-10%</td>
<td>3%</td>
</tr>
<tr>
<td>Secondary prevention</td>
<td>11%</td>
<td>-36%</td>
<td>-21%</td>
<td>8%</td>
</tr>
<tr>
<td><strong>Access</strong></td>
<td><strong>7%</strong></td>
<td><strong>-32%</strong></td>
<td><strong>19%</strong></td>
<td><strong>-6%</strong></td>
</tr>
<tr>
<td><strong>Quality of care</strong></td>
<td><strong>5%</strong></td>
<td><strong>-15%</strong></td>
<td><strong>-12%</strong></td>
<td><strong>23%</strong></td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td><strong>3%</strong></td>
<td><strong>-6%</strong></td>
<td><strong>-27%</strong></td>
<td><strong>10%</strong></td>
</tr>
<tr>
<td><strong>Treatment and tertiary prevention</strong></td>
<td><strong>16%</strong></td>
<td><strong>-50%</strong></td>
<td><strong>-37%</strong></td>
<td><strong>13%</strong></td>
</tr>
</tbody>
</table>
Group Model Building (GMB)

• Method of involving participants and other stakeholders in the modeling process:
  - Problem conceptualization
  - Formulation
  - Policy analysis
  - Implementation

• Reasons for using GMB
  - Sharing of insights
  - Developing consensus
  - Design for implementation
  - “Dignity of risk”
Overview of maternal health system

Community

Women of childbearing age → Pregnant women → Receiving antenatal care at health center

Near Hospital

Hospital

Peter S. Hovmand, PhD | ARM San Diego, 2014
Overview of maternal health system

Community

Women of childbearing age

Women with complication delivering in community

Pregnant women seeking Help

Receiving antenatal care at health center

Near Hospital

Hospital

Overview of maternal health system

Peter S. Hovmand, PhD | ARM San Diego, 2014
Overview of maternal health system

Women of childbearing age

- Women with complication delivering in community
- Pregnant women seeking Help

Community

- Maternal deaths at 1st delay
- Maternal deaths at 2nd delay

Pregnant women seeking Help

- Receiving antenatal care at health center

Near Hospital

Maternal deaths at 3rd delay

Hospital

Peter S. Hovmand, PhD | ARM San Diego, 2014
Overview of maternal health system

- Women of childbearing age
- Pregnant women
- Women with complication delivering in community
- Pregnant women seeking Help
- Receiving antenatal care at health center
- Hospital
- Clinic for mothers and infants

Community

Near Hospital
Overview of maternal health system

Community

Women of childbearing age

Women with complication delivering in community

Pregnant women

Pregnant women seeking Help

Receiving antenatal care at health center

Near Hospital

Hospital

Clinic for mothers and infants

Overview of maternal health system

Peter S. Hovmand, PhD | WUDIR May 22, 2014
Overview of maternal health system

Community

Women of childbearing age

Pregnant women

Women with complication delivering in community

Pregnant women seeking Help

Receiving antenatal care at health center

Near Hospital

Hospital

Clinic for mothers and infants

L1

L2

L3

L4

L5

L6

L7

L8

L9

L10

L11
Overview of maternal health system

Women of childbearing age

Pregnant women

Women with complication delivering in community

Pregnant women seeking Help

Receiving antenatal care at health center

Hospital

Clinic for mothers and infants

Community

Near Hospital

Peter S. Hovmand, PhD | WUDIR May 22, 2014
Overview of maternal health system

- Women of childbearing age
- Pregnant women
- Women with complication delivering in community
- Pregnant women seeking Help
- Receiving antenatal care at health center
- Hospital
- Clinic for mothers and infants

Community

Near Hospital

L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11

Peter S. Hovmand, PhD | WUDIR May 22, 2014
Quality improvement feedback loop

- Standard
- Gap
- Planned action
- Quality indicator
- Real system
Quality improvement feedback loop

- **Agreeing on standards**
- **System dynamics modeling**
- **Using evidence based practices**
- **Establishing and tracking indicators**

**Real system**

**Gap**

**Planned action**

**Quality indicator**

**Standard**
Capability traps in process improvement

Closing points

• Human tendency to misperceive complex systems
• Need for causal maps and formal models with computer simulation for:
  – Seeing system
  – How components are related through feedback
  – Identifying potential leverage points
  – Assessing implications of accumulations and delays
  – Assessing leverage points
• Results are most sensitive to structure of system
• Find/improve reinforcing reinvestment loops
Five critical questions to consider before starting a system dynamics project

Peter S. Hovmand, PhD | ARM San Diego, 2014

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the problem? Is the problem dynamic?</td>
<td>Drawing a reference mode with the desired and feared behavior over time over a defined period of time.</td>
</tr>
<tr>
<td>What kind of problem is it?</td>
<td>Primary diagnosis as a learning, coordination, analysis, or restructuring problem.</td>
</tr>
<tr>
<td>Does the system involve feedback mechanisms?</td>
<td>Drawing a diagram of the system that involves one or more feedback loops.</td>
</tr>
<tr>
<td>What kinds of insights would help solve the problem?</td>
<td>Identifying the types of model based insights such as visualizing the system or identifying leverage points that will help solve the problem.</td>
</tr>
<tr>
<td>What is the purpose of the model?</td>
<td>Write a model project description that defines the problem, explains why it is dynamic and involves feedback, and clearly states the purpose in terms of the type of insights that will help solve the problem.</td>
</tr>
</tbody>
</table>

Questions?