Systems Engineering as a Health Care Improvement Strategy

The CMS/CMMI National Demonstration Project – Gathering June 2014

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CMS Innovation Healthcare Systems Engineering Center
NSF Center for Health Organization Transformation
Northeastern University, Boston MA
www.HSyE.org
Disclosure

The speaker has no financial nor other conflicts of interests to disclose. Other than to ask for your help.
1. Systems engineering as an improvement strategy

2. Range of examples
   • Simple to advanced
   • Micro to macro

3. Applications in your processes?

4. Getting involved
Mission: Broad measurable impact on healthcare, nationally, through research, education, and application of industrial and systems engineering.

Partnerships

Project Types

Research

Discover

Applied

Impact

Experiential

Education

Criteria

“Developing what we don’t know” 1 - 2 years

“Doing what we know” 3 - 9 months

“Teaching others by doing” 2 - 6 months

Primary Mechanism

NSF Research Center

CMS Application Center

• Capstone, Co-ops
• Summer Interns
Agricultural extension center model

Center model

HSERC
Healthcare Systems Engineering Regional Center

Bouvé College of Health Sciences
College of Engineering

Healthcare Community

Academic Community

Skilled Nursing Facility Centers
Home Health
Long Term Acute Care
Payers
Hospitals
Integrated Teams

Palliative + Hospice Centers

TESTING, TESTING
by Atul Gawande
THE NEW YORKER DECEMBER 14, 2009
## Participating health systems to-date

### Table of Participating Health Systems

<table>
<thead>
<tr>
<th>Boston/New England</th>
<th>Seattle</th>
<th>Charlotte</th>
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</thead>
<tbody>
<tr>
<td>Massachusetts General Hospital</td>
<td>Cambridge Health Alliance</td>
<td>Virginia Mason Medical Center</td>
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<td>Lahey Health System</td>
<td>Boston Medical Center</td>
<td>Providence Health System</td>
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<tr>
<td>Harvard Vanguard Medical Associates</td>
<td>Tufts Medical Center</td>
<td>Seattle Cancer Care Alliance</td>
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<tr>
<td>Logix Health</td>
<td>Atrius</td>
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<tr>
<td>Hallmark Health System</td>
<td>Dana Farber Cancer Institute</td>
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<tr>
<td>Commonwealth Care Alliance</td>
<td>Brigham &amp; Women’s Hospital</td>
<td>Swedish Health</td>
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<td>Boston Children’s Hospital</td>
<td>Mass General Hospital</td>
<td>San Francisco</td>
</tr>
<tr>
<td>Baystate Medical Center</td>
<td>Maine Medical Center</td>
<td>Sutter</td>
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<tr>
<td>Southcoast (NEQCA)</td>
<td>Lynn Hospital</td>
<td>Kaiser Permanente</td>
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</table>

**Hubs:**
- Boston (primary)
- Seattle, Charlotte (secondary)
- Denver, San Francisco, TX (tertiary)
- ...?
Why? National interest..... but...

Significant interest (IOM, NAE, AHRQ, NSF, NIH, PCAST, etc)

‘Time for science of health care to embrace science of systems engineering... but examples of... impact... are rare’ (JAMA, 2012)

‘Greater use of (IE) principles... widely used in manufacturing and aviation... small number health care organizations... not widespread in U.S. health care’

Institute of Medicine / NAE reports

Advisory report to Obama (5-29-14)
Recent calls for proposals
(2 of $n$ examples)

## Department of Health and Human Services

### Part 1. Overview Information

<table>
<thead>
<tr>
<th>Participating Organization(s)</th>
<th>Participating Organization(s)</th>
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<tbody>
<tr>
<td>NIH</td>
<td>NIH</td>
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#### Components of Participating Organizations

- National Institutes of Health (NIH)
- Office of Behavioral and Social Science
- National Cancer Institute (NCI)
- National Heart, Lung, and Blood Institute
- National Institute on Aging (NIA)
- National Institute on Alcohol Abuse
- National Institute of Biomedical Imaging and Bioengineering
- Eunice Kennedy Shriver National Institute on Child Health and Human Development (NICHD)
- National Institute of Dental and Craniofacial Research
- National Institute of Environmental Health Sciences
- National Institute of General Medical Sciences
- National Institute of Mental Health
- National Institute of Nursing Research

#### Funding Opportunity Title

Patient Safety Learning Laboratories: Innovative Design and Development to Improve Healthcare Delivery Systems (P30)

#### Activity Code

P30 Center Core Grants

Despite the eager endorsement about systems thinking by many health care advocates, there has been a scarcity of effort in actually incorporating systems principles into the design and engineering disciplines in patient safety projects, and partnering with progressive sectors of the economy and other hazardous industries to realize new insights, and robust approaches. In 2005, the National Academy of Engineering and the Institute of Medicine drew from the combined talent in the engineering and health care communities to produce a consensus report and collection of papers entitled [Building a Better Delivery System: A New Engineering/Health Care Partnership](#). Despite the carefully crafted recommendations and thoughtful papers, its impact has been limited.
Healthcare systems engineering evidence base?

Observation ➞ Postulation

- Growing use of basic process improvement methods
  - Lean, PDSA, Six sigma, Safety, etc
  - But what else (other industries)?

- Systems engineering can have significant value
  - Basic methods (for all)
    - ‘Systems engineering for common man’
  - Advanced methods
    - Regional extension center model
  - “By what method?”
What matters

- Safe
- Effective
- Patient centered
- Timely
- Efficient
- Equitable

What IE’s do

- Flow, waits, delays
- Logistics, capacity
- Quality, lean, six sigma
- Safety, reliability
- Treatment, medical decision making
- Policy

INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES

Common Applications of
Systems Engineering

SyE

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What is systems engineering?

- **Industrial and Systems Engineering**
  - **1. Methods-based**
    - PDSA
    - Lean
    - Six Sigma
  - **Model-based**
    - 2. Computer simulation
    - 3. Probability and stochastic models
    - 4. Mathematical optimization

- **Foci**
  - Better systems & processes

- **Methods** (mathematical, computer, graphical)
- **Uses**
  - Improve, optimize, control

**Simple** vs. **Complex**

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## Typical applications

<table>
<thead>
<tr>
<th>Logistics &amp; efficiency</th>
<th>Patient flow &amp; Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Inventory and supply chains</td>
<td>• Access, waits and delays</td>
</tr>
<tr>
<td>• OR scheduling and turn-around</td>
<td>• Patient flow simulation</td>
</tr>
<tr>
<td>• Academic workforce logistics</td>
<td>• Workflow smoothing</td>
</tr>
<tr>
<td>• Regional network design</td>
<td>• Capacity planning, scheduling, and demand management</td>
</tr>
<tr>
<td>• Real time location systems</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Medical decision making</th>
<th>Quality &amp; patient safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Treatment optimization</td>
<td>• Reliable and consistent care</td>
</tr>
<tr>
<td>• Screening and diagnostic tests</td>
<td>• Adverse events reduction</td>
</tr>
<tr>
<td>• Radiation therapy optimization</td>
<td>• Preventable readmissions</td>
</tr>
<tr>
<td>• Patient shared decision support</td>
<td>• Care continuity</td>
</tr>
<tr>
<td>• Palliative and hospice care</td>
<td>• Human factors engineering</td>
</tr>
<tr>
<td>• Medical alternative evaluation</td>
<td>• Quality/improvement science</td>
</tr>
</tbody>
</table>

- Logistics & efficiency
- Patient flow & Access
- Medical decision making
- Quality & patient safety
examples
We do a LOT of this...

6σ, Lean, CQI, PDSA, ...

What are we trying to accomplish?

How will we know that a change is an improvement?

What changes can we make that will result in improvement?
...and we do a lot of this

Max Z= \( \sum_k \sum_t \sum_s w_{kt} \cdot p_{ktrs} \)

\( \sum_t A_{mts} \leq 1 \) \quad \forall i, s and \( \forall m \in G_i \)

\( \sum_s A_{mts} = R_{mt} \) \quad \forall i, t and \( \forall m \in G_i \)

\( A_{mts} = 1 \) \quad \forall (m, t, s) \in O_i

\( \sum_{n \in D_{int}} A_{nts} \geq A_{mts} \) \quad \forall i, t, s and \( \forall m \in G_i, D_{int} \neq \emptyset \)

\( A_{nts} + A_{mts} \leq 1 \) \quad \forall i, t, s and \( \forall m \in G_i \), \( \forall n \in U_{int} \)

\( \sum_m A_{mts} \geq C_{it} \) \quad \forall i, t, s where \( m \in G_i \)

\( \sum_m A_{mts} \geq \sum_k k \cdot p_{ktrs} \) \quad \forall t, r, s where \( m \in Q_r^t \)

\( \sum_r p_{ktrs} \geq Goalt \) \quad \forall t, s

\( A_{mts} \in \{0,1\} \) \quad \forall m, t, s

\( p_{ktrs} \in \{0,1\} \) \quad \forall k, t, r, s
Congestive heart failure readmissions

**Aim:** Reduce CHF readmission costs 25% by increasing post-discharge follow-up appts ≤ 7 days

**Approach:** Basic process flow, data analysis, and CQI
Central line ICU infections

Aim
Reduce ICU CLABSI rate and associated costs by 50% within 9 months through implementation of “bundle”

Approach
- Process flow analysis
- Bundle implementation via reliability science and human factors models

CLABSI Bundle
1. Insertion technique, hand hygiene
2. Low risk site selection
3. Maintenance (sterile)
4. Daily removal assessment

<table>
<thead>
<tr>
<th>Reliability tier</th>
<th>Strategies</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevent</td>
<td></td>
<td>Process</td>
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<tr>
<td>Detect</td>
<td></td>
<td>Outcome</td>
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<tr>
<td>Mitigate</td>
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<tr>
<td>Redesign</td>
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</tbody>
</table>
Peri-operative inventory

Aim
Reduce peri-operative supply costs by 20% via inventory methods, lean concepts, and preference card reduction

Approach
• Establish/revise PAR levels for 80% of “A” items
• Standardize & reduce preference cards
• 5S inventory areas
Room utilization/pooling

Aim
Consolidate low utilized patient rooms to eliminate ~$2m/yr overflow space costs by hybrid room pooling

Approach
• Room sharing simulation
• Open availability real-time RTLS tool
• Pareto/CQI of reasons new process not followed
ED Observation Unit

Standard Process Improvement

- Chest Pain Arrivals
  - ST Elevation?
    - Yes (15%)
    - History and Check-Up
    - NSTEMI
      - Positive Troponin?
        - Yes (16%)
        - Wait Until Ban
        - Resource Available?
          - Yes
          - Stress Test Interpretation
        - No
          - Wait for 2nd Troponin Test Time
    - No (85%)
    - 1st Troponin Test
      - Positive Troponin?
        - Yes (18%)
        - Stress Test
        - Wait Until Ban
        - Resource Available?
          - Yes
          - Stress Test Interpretation
        - No
          - Wait for 2nd Troponin Test Time
      - No (82%)
        - 2nd Troponin Test

- Exit Model (Obs. Complete)

Computer Simulation Analysis

**Computer model** vs **Real system**

<table>
<thead>
<tr>
<th>Test</th>
<th>Average wait time</th>
<th>Process average time</th>
<th>% of all tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTA</td>
<td>0:09</td>
<td>1:35</td>
<td>1%</td>
</tr>
<tr>
<td>ETT Stress</td>
<td>0:48</td>
<td>1:13</td>
<td>51%</td>
</tr>
<tr>
<td>PET/CT</td>
<td>11:21</td>
<td>1:06</td>
<td>22%</td>
</tr>
<tr>
<td>SPECT</td>
<td>0:31</td>
<td>1:31</td>
<td>19%</td>
</tr>
<tr>
<td>SPECT/CT</td>
<td>0:16</td>
<td>2:25</td>
<td>3%</td>
</tr>
<tr>
<td>Stress echo gram</td>
<td>2:42</td>
<td>1:59</td>
<td>3%</td>
</tr>
</tbody>
</table>

**OULOS (hours)**

- Troponin: 3 hrs
- Lab: 4 pm
- Stress test: 10%

**Patient Occupancy**

- Current State
- Trop Delay, ST Fraction
- All 3 Improvements
Predictive models

Logistics applications
- Patient flow (ED admits)
- System-wide flow (bed huddle forecaster)
- ICU or OU bed demand (7 day ahead forecast)

Clinical applications
- Patient decline
- High annual total TCC
- Outlier long LOS
SPC methods

‘Simple’ Methods

Ventilator-Associated Pneumonia (VAP)

Advanced Methods

Complication Rate EWMA

Background Improvement Trend

\[ Y_i = \beta_0 + \beta_1 T_i = 11.15 + .087T \]
Primary care team continuity

### Primary care continuity coverage

<table>
<thead>
<tr>
<th>AM</th>
<th>PM</th>
<th>Total teams</th>
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<tbody>
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</table>

- **Better continuity** → **Better prevention, outcomes, re-visits**
Results

Teamlet Continuity

Access
Third next available appt

Compliance measures

Inpatient Admissions

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Summary

1. Industrial and systems engineering under used in health care

2. National CMS large demonstration project
   • Impact, visibility, workforce development

3. Regional extension center as one model

4. Open to any health system
   • How can we help you?
   • How can you help us?
Thank you

www.hsye.org

Contact information:
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334 Snell Engineering Center
Northeastern University
Boston MA 02215
j.benneyan@neu.edu
Project proposal process

CMS Triple Aim Project Definition [1-pager]

<table>
<thead>
<tr>
<th>Project</th>
<th>Lead Engineer</th>
<th>System</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Status</td>
<td>Approved</td>
<td></td>
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</table>

**Project aim statement** (Accomplish what, by how much, by when, by what method)

<table>
<thead>
<tr>
<th>Aim</th>
<th>Process Measures</th>
<th>Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Care</td>
<td></td>
<td></td>
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<tr>
<td>Health</td>
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</tbody>
</table>

**Approach** (key steps, completion dates)

**Implementation plan**

**Timeline**

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
<td>Scope/define/approve (1-month)</td>
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<td>Conduct (phase1)</td>
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<td>Conduct (phase2)</td>
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<tr>
<td>Implement, refine</td>
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<td>Evaluate, finalize docs</td>
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O: Planned  ✓: Completed  X: Project done

James Benneyan, HSyE Director Date

Supporting Details – Page 2

Causes driver diagrams:

- P1
- P2

Cost

Health

Operational definitions:

<table>
<thead>
<tr>
<th>Name</th>
<th>Calculation</th>
<th>Name</th>
<th>Calculation</th>
</tr>
</thead>
</table>

Baseline run charts: (25% or measures)