IE/OR in Health Care
(what’s so ‘non-traditional’?)

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President, Society for Health Systems
Institute for Healthcare Improvement, Senior Fellow
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1. Rich history of IE in health care
2. What do IE’s do in health care?
3. Examples
4. How to get into field
5. Questions
Mission & Methods

The leading professional organization for analysis and improvement of healthcare processes.

- Education
- Resources
- National initiatives
- Partnerships with other organizations
- Job bank, coop jobs, and student mentoring

- Part of the Institute of Industrial Engineers (IIE)
- Industrial engineers and process improvement professionals
- Excellent annual conference
- Largest and most active society within IIE
- www.shsweb.org
Healthcare systems engineering

IE/OR in Healthcare

• Rich and diverse history
• As old as the field of industrial engineering itself
• Gilbreth’s 1911 surgical studies

Application Areas

• Hospital operations
  – Patient and information flow
  – Appointment access
  – Scheduling
  – Facility layout and location

• Public health
  – Vaccination optimization
  – Outbreak surveillance
  – Emergency response

• Public policy
  – Disease screening
  – Regional planning
  – Organ sharing
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1911-18</td>
<td>Time studies of surgery and delays (F. Gilbreth)</td>
<td></td>
</tr>
<tr>
<td>1920-40</td>
<td>Basic process and capacity analysis</td>
<td></td>
</tr>
<tr>
<td>1945</td>
<td>‘Management engineering’ invented and applied to nursing (L. Gilbreth)</td>
<td></td>
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<tr>
<td>1957</td>
<td>Deming advocates use of SPC in healthcare</td>
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<tr>
<td>1959</td>
<td>First queueing and scheduling studies (Smalley, others)</td>
<td></td>
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<tr>
<td>1965</td>
<td>Clinical information systems (Kennedy et al)</td>
<td></td>
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<tr>
<td>1965</td>
<td>Hospital inventory optimization (Reed, Stanley)</td>
<td></td>
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<tr>
<td>1965-66</td>
<td>First simulation queueing studies of patient waits (Nuffield Report, Fetter, Thompson)</td>
<td></td>
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<tr>
<td>1970-72</td>
<td>Nurse scheduling (branch and bound) algorithms (Warner, Wolfe)</td>
<td></td>
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<tr>
<td>1970-72</td>
<td>Perishable inventory theory applied to blood banks (Pierskalla)</td>
<td></td>
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<tr>
<td>1972-73</td>
<td>Simulation planning models (Rising)</td>
<td></td>
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<tr>
<td>1974</td>
<td>Regional planning OR models (Wolfe)</td>
<td></td>
</tr>
<tr>
<td>1967-82</td>
<td>Diagnostic-related groups (DRG’s)</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>Forecasting bed needs (Griffith)</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Cancer screening optimization (Eddy)</td>
<td></td>
</tr>
<tr>
<td>1980’s</td>
<td>MDM utility theory (Weinstein)</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>Total quality management (Berwick)</td>
<td></td>
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<tr>
<td>1990’s</td>
<td>Patient safety movement (Leape)</td>
<td></td>
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</table>
Healthcare system today

Descriptive Statistics

- Largest single industry in the world
- $1.04 trillion/yr on US healthcare (1996), 14-17% of GDP
- Expenses increasing at 4 - 10% annually
- Major pressure to become more efficient and provide higher quality care

Costs of poor quality

- Estimated 35% of all healthcare costs = waste
- Duplication, non-value add, redundancies
- Medical errors, adverse events, preventable deaths, process defects

Sound familiar?

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Report card: How are we doing?

Reliability Estimates (IOM)

Endemic AE's

Medical errors and iatrogenic injury:
• 98,000 deaths/year
• 770,000 - 2 million patient injuries

$17 - $29 billion

6 - 10% of hospital patients suffer 1 or more serious adverse events

• Adverse drug events (ADE)
• Surgical site infections (SSI)
• Needle sticks
• Wrong side/site surgery
• Device-associated infections

770,000 to 2 million per year

$4.2 billion annually

Hospital-acquired infections:

25 illness per $3,000
• Ventilator-associated pneumonia
• Catheter & central line infections

Per episode average costs:
• ADE: $4,000 - $5,000
• NSI: $2,000 - $3,000
• VAP: 13 additional days & 30 -

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More US deaths than for traffic accidents, breast cancer, & AIDS.

50% attributable mortality

• SSI: Can exceed $14,000
**We’re *not* the best: IE needed!**

(1 = best, 5 = worst)

<table>
<thead>
<tr>
<th></th>
<th>Australia</th>
<th>Canada</th>
<th>New Zealand</th>
<th>UK</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Safety</td>
<td>2.5</td>
<td>4</td>
<td>2.5</td>
<td>1</td>
<td>5</td>
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<tr>
<td>Patient-Centeredness</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Timeliness</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>3</td>
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<tr>
<td>Efficiency</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
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<tr>
<td>Effectiveness</td>
<td>4.5</td>
<td>2.5</td>
<td>2.5</td>
<td>1</td>
<td>4.5</td>
</tr>
<tr>
<td>Equity</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>5</td>
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</tbody>
</table>

Source: Davis, *et al.*, The Commonwealth Fund, 2004
## Where do IE’s work in healthcare?

<table>
<thead>
<tr>
<th>Organizations</th>
<th>Departments</th>
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</thead>
<tbody>
<tr>
<td>• Hospitals</td>
<td>• System engineering</td>
</tr>
<tr>
<td>• HMO’s</td>
<td>• Management engineering</td>
</tr>
<tr>
<td>• Physician offices</td>
<td>• Quality management</td>
</tr>
<tr>
<td>• Long-term care facilities</td>
<td>• Process improvement</td>
</tr>
<tr>
<td>• Outpatient clinics</td>
<td>• Clinical safety</td>
</tr>
<tr>
<td>• Public health (CDC, etc)</td>
<td>• Information systems</td>
</tr>
<tr>
<td>• Insurance organizations</td>
<td>• Facilities management</td>
</tr>
<tr>
<td>• Government agencies</td>
<td>• others</td>
</tr>
</tbody>
</table>

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## What do IE’s do in healthcare?

<table>
<thead>
<tr>
<th>Practitioners</th>
<th>Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data analysis</td>
<td>Statistical quality control</td>
</tr>
<tr>
<td>Benchmarking</td>
<td>Disease screening optimization</td>
</tr>
<tr>
<td>Cost analysis and reduction</td>
<td>Scheduling algorithms</td>
</tr>
<tr>
<td>Economic analysis</td>
<td>Regional capacity planning</td>
</tr>
<tr>
<td>Feasibility studies</td>
<td>Organ transplant optimization</td>
</tr>
<tr>
<td>Process/quality improvement</td>
<td>Statistical surveillance</td>
</tr>
<tr>
<td>Simulation flow analysis</td>
<td>Cognitive and human factors research</td>
</tr>
<tr>
<td>Space planning and layout</td>
<td>Public policy</td>
</tr>
<tr>
<td>Appointment scheduling</td>
<td></td>
</tr>
</tbody>
</table>
aka... “Hospital Management Engineers”

✓ Project Management/Facilitation
✓ Productivity
✓ Simulation
✓ Labor Management
✓ Time Studies
✓ Process Improvement
✓ Action Plan Development

Hey, That’s Just IE!
Examples
Billing Error Process

- New Member Application, Termination, or Re-Enrollment
- Data Entry Process
- Print Out New Entries at End of Each Day
- 100% Inspection of Previous Day’s Input
- Highlight Error for Correction
- Data Entry Error Found?
  - Yes
    - Process Remaining p/w, Activate Member’s Record
  - No

Basic Data Analysis

Correlation to Paperwork Volume?

Error Reduction Over Time

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Quality control examples

**Falls and Slips**

![Falls and Slips Chart]

**Surgical Site Infections**

![Surgical Site Infections Chart]

**Ventilator-Associated Pneumonia (VAP)**

![Ventilator-Associated Pneumonia (VAP) Chart]

**Perioperative Antibiotic Timing X-bar Chart**

![Perioperative Antibiotic Timing X-bar Chart]

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Simulation example

Current Chemotherapy Process

- Arrive
  - Vitals Signs
    - 13/30
    - Depart
  - Blood Drawn: Phlebotomy
    - 1/6
    - 2/5
    - Depart
  - Blood Drawn: Central Line
    - 1/6
    - 11/15
    - Depart
  - Medical Examination
    - 1/10
    - Depart
  - Extended Chemotherapy Infusion
    - Depart
  - Standard Chemotherapy Infusion
    - Depart

Resources and Process Durations

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrivals</td>
<td>60/day (8 hr)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>= 1 arrival</td>
<td>8 min</td>
</tr>
<tr>
<td></td>
<td>every 8 min</td>
<td></td>
</tr>
<tr>
<td>Vitals Signs</td>
<td>Mean = 10 Mins</td>
<td>5 Mins</td>
</tr>
<tr>
<td></td>
<td>Ph: 15 (5) mins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CL: 10 (5) mins</td>
<td></td>
</tr>
<tr>
<td>Blood Drawn: Phlebotomy</td>
<td>Mean = 30 mins</td>
<td>15 Mins</td>
</tr>
<tr>
<td>Medical Examination</td>
<td>Mean = 90 mins</td>
<td>12 Mins</td>
</tr>
<tr>
<td>Extended Chemotherapy Infusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Chemotherapy Infusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depart</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depart</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depart</td>
<td></td>
<td></td>
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<tr>
<td>Depart</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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“What If?”

Blood before vitals

- Arrive
- Draw Blood
- Vital Signs
- Exam
- Infusion
- Depart

Shortest line

- Arrive
- Join Short Line
- Blood
- Vitals
- CL Blood
- Exam
- Infusion
- Extended Infusion
- Standard Infusion

1 line for 1st available resource

- Arrive
- Wait for 1st avail
- Blood
- CL
- Vitals
- Exam
- Infusion
- Extended Infusion
- Std. Infusion

One shared room

- Arrive
- Multi-Purpose Room
  - Draw blood
  - Vitals
  - Exam
- Infusion
- Multi Purpose
- Standard
- Extended Infusion
- Depart
- www.shsweb.org
### Results

<table>
<thead>
<tr>
<th>Performance measure averages</th>
<th>Current process</th>
<th>Blood before</th>
<th>Shortest line</th>
<th>Shared room</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTIS (all pts)</td>
<td>96 min</td>
<td>67 min</td>
<td>56 min</td>
<td>42 min</td>
</tr>
<tr>
<td>TTIS (vitals only)</td>
<td>65 min</td>
<td>44 min</td>
<td>24 min</td>
<td>11 min</td>
</tr>
<tr>
<td>TTIS (no chemo)</td>
<td>107 min</td>
<td>69 min</td>
<td>66 min</td>
<td>54 min</td>
</tr>
<tr>
<td>TTIS (chemo)</td>
<td>176 min</td>
<td>146 min</td>
<td>144 min</td>
<td>122 min</td>
</tr>
<tr>
<td>NVAT (all pts)</td>
<td>53%</td>
<td>38%</td>
<td>23%</td>
<td>6%</td>
</tr>
<tr>
<td>NVAT (vitals only)</td>
<td>73%</td>
<td>61%</td>
<td>40%</td>
<td>8%</td>
</tr>
<tr>
<td>NVAT (no chemo)</td>
<td>41%</td>
<td>22%</td>
<td>9%</td>
<td>5%</td>
</tr>
<tr>
<td>NVAT (chemo)</td>
<td>21%</td>
<td>11%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Total time in Q</td>
<td>56 min</td>
<td>36 min</td>
<td>17 min</td>
<td>4 min</td>
</tr>
<tr>
<td>Time in Q (vitals)</td>
<td>56 min</td>
<td>35 min</td>
<td>14 min</td>
<td>1.3 min</td>
</tr>
<tr>
<td>Time in Q (blood)</td>
<td>.03 min</td>
<td>.4 min</td>
<td>1.2 min</td>
<td>.9 min</td>
</tr>
<tr>
<td>Time in Q (exam)</td>
<td>.18 min</td>
<td>.6 min</td>
<td>1.4 min</td>
<td>1.4 min</td>
</tr>
<tr>
<td>Percent travel time</td>
<td>10%</td>
<td>4%</td>
<td>7%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

TTIS: Total time in system, NVAT: Non value add time
IE beyond hospitals

- Simulation of smallpox or bird flu spread (CDC)
- Emergency services planning
- Medical decision making
- Risk-benefit analysis of alternate treatments
- Statistical surveillance of infectious diseases
- Regional capacity planning models
- Organ donation logic optimization
- Drug labeling (human factors)
Public health example

Response Planning for Avian Flu

No intervention

Interventions

Link to simulation video – no intervention

Link to simulation video – with intervention

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Optimal Number Reviews of Pap Smear or Mammogram

- 55-60 million Pap smears per year
- $275 million spent on Pap smears for early detection
- Billions spent on cervical cancer treatment / year
- 1.5% pathologists in false-negative lawsuits
- Average settlement: $3.5M - $6.3M
- Expected cost inspection error models...

$$EC_{j,r} = k_1 n \left\{ p \left[ \frac{1 - \alpha_c}{1 - \alpha_c} \right] + (1 - p) \left[ \frac{1 - (1 - \beta_c)^j}{\beta_c} \right] \right\} + k_2 n \left[ 1 - (1 - r) p' \right] + k_3 n (1 - p) \beta_c \left[ 1 - (1 - \beta_c)^j (1 - r) \right] + k_4 n p \left[ 1 - (1 - \alpha_c) \left[ 1 - \alpha_c (1 - r) \right] \right],$$

where $$p' = p \alpha_c^j + (1 - p) (1 - \beta_c)^j.$$
Institute for Healthcare Improvement (IHI)

Focus Areas

- Medical errors
- Patient & staff safety
- Waits, delays, flow, access
- Improved outcomes
- Efficiencies, cost reduction

National Demonstration Project (‘If Toyota can, why can’t we?’)

- Improved outcomes
- Efficiencies, cost reduction

Methods

- Quality management
- Data-driven improvement
- Lean, Toyota production system, Six Sigma

RWJ: “Pursing Perfection: Creating Hospital Toyotas”

- “Efficiently provide the right care, at the right time, with patient’s desired provider, on-time, error-free.”

- Sounds a lot like IE!
“100,000 Lives Campaign”

• Campaign sense of urgency

• Save 100,000 lives by 6/14/06 (9 am EST)

• Focus on six defects:
  • Adverse drug events (2k)
  • Surgical site infection (8k)
  • Myocardial infarction (10k)
  • Ventilator pneumonia (10k)
  • Central line infection (10k)
  • Rapid response teams (60k)

• Over 3,200 U.S. hospitals participating

• 90% of acute care beds

• Accomplish via process standardization & defect elimination

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Possible career paths

• **Hospitals**
  – Management engineering (IE) department
  – Quality, process improvement

• **Non-hospitals**
  – HMO’s, medical practices, senior care, others
  – Government, regulatory agencies, other

• **Industry**
  – Biomedical
  – Pharmaceutical

• **Graduate school**
  – IE/OR with healthcare emphasis (see me!)
  – Healthcare degrees (MPH, MHA, etc)
Further information / Next steps

- benneyan@coe.neu.edu
- www.shsweb.org
  - Coop jobs, Internships, Job bank
  - Student webpage, Mentoring
  - Annual conference
  - Paper competitions, Senior projects
- Local hospitals
- Other organizations
  - HIMSS (www.himss.org)
  - ASQC HCD (www.healthcare.org)
  - INFORMS (www.trinity.edu/aholder/HealthApp)
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Professor Benneyan is the director of the Quality and Productivity Lab at Northeastern University, president of the IIE Society for Health Systems, a senior fellow at the Institute for Healthcare Improvement, and former senior systems engineer for Harvard Community Health Plan. His primary research interests are in quality engineering, patient and drug safety models, simulation, and all aspects of healthcare systems engineering. Jim is the editor of a forthcoming healthcare issue of *IIE Transactions*, an editor of *Health Care Management Science*, and a Fellow of the Healthcare Information and Management Systems Society.
Some references


Gilbreth references
Data & graphical analysis examples

Root Cause Analysis: Patient Restraints

Methods
- Policy requires restraint
- Policy requires restraint to be restrained

Materials
- Alternatives to restraints not available

People
- Nurses have outdated attitudes
- Fear of legal action
- Bed alarm faulty
- News media hype falls injuries
- Closed circuit system down falls film showing prevented

Machines
- Increased Restraint Use
- Increased Restraint Use

Admission to Angio Delay

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<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Primary Service</td>
<td>7</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Angio Delay</td>
<td>4</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Non-Invasive Test</td>
<td>2</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Comorbidities</td>
<td>5</td>
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<tr>
<td>Test Delay</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>PAME Delay</td>
<td>4</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Reverse Al</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Orange/Bib</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
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</table>

Average Length of Stay

- AMCC
- Mayo

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