Health Care Services Research Lab Devoted to Better Health Care in China

Lei Zhao
Tsinghua University, China

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Health Care Services Research Lab

Devoted to Better Health Care in China

Dr. Lei Zhao, Director, Assistant Professor
Health Care Services Research (HCS) Laboratory
Department of Industrial Engineering
Tsinghua University, China

Regenstrief Center for Healthcare Engineering
Purdue University
February 29, 2008
Outline

- About Tsinghua University
- About Industrial Engineering
- Health care services in China
- Health Care Services Research Lab
- Snapshots of ongoing research activities
- Potential collaborations
Tsinghua University

- Established in 1911
- 13 schools, 54 departments
- Over 7,500 faculty and staff members
- Student Enrollment (as of January, 2008)
  - Undergraduate: 13,788
  - Master: 12,842
  - Ph.D: 5,156
  - International: 2,021
- Members of Chinese Academy
  - Science: 36
  - Engineering: 32
- Ranked #1 in China in the past twelve (12) years
Department of Industrial Engineering (IE)

- History
  - 1993, Master program in IE
  - 1997, Bachelor program in IE
  - 2001, Department of IE, Chaired by Prof. Gavriel Salvendy
- Three (3) institutes, one (1) center
  - Institute of Human Factor and Ergonomics
  - Institute of Operations Research and Logistics
  - Institute of Production Engineering
  - Tshinghua-UNC Center for Logistics and Economic Development
- Faculty 27, engineers 2, staff 5, IE education center director 1
- Programs: B.Sc, M.Sc., Ph.D., Int’l Master, MEng
- Students: undergraduate 250, graduate 200, international 50
Department of Industrial Engineering (IE)
IE – A Fast Growing Department

- Ranked #1 in China
- International evaluation (October 2006)
  - Six U.S. NAE members in IE/OR
  - Evaluation result
    - B.Sc. (U.S. Top 20)
    - M.Sc. (U.S. Top 20)
    - Ph.D. (U.S. Top 25)
IE – A Fast Growing Department

- 2007 IIE Innovations in Curriculum Award
  - Logistics System Laboratory (LSL)
  - First place
IE – International Collaborations

- Joint programs
  - Joint Tsinghua-RWTH Aachen Masters Program
    - Global Manufactory
  - ISyE, Georgia Institute of Technology
    - Beijing/Singapore summer program
  - Eindhoven non-degree exchange program
    - Department of Technology Management
Health Care Services in China

- 22% of the world’s population
- 2% of the world’s health care expenditures
- Unsuccessful health care reform
- Imbalanced allocation of (limited) health care resources
- Low government investments
- Largely uncovered in rural population
- Low efficiency/poor quality in health care services
Health Care Services in China

- Focus of public complaints since 2005
- Health care services are
  - Expensive
  - Difficult
Health Care Services in China

- Early 1950s – 1980s
  - Urban: Public funded / labor insurance
    城市单位制医疗保险制度 (公费和劳保医疗)
  - Rural: Cooperative medical system
    农村合作医疗制度
Health Care Services in China

- Health care reform in urban areas
  - Prior to 1985: Demand-side cost control – cost sharing 10~20%
  - Since 1998: Nation-wide reform
Health Care Services in China

- Reform on hospital operations since 1989
  - Non-profit → “profitable” services
  - “Supplier incentive”

- Some facts
  - From 2002 to 2004: hospital total incomes
    - government investment: ~10%
    - medicine sales: ~43%
    - health care services: ~45%
  - From 1990 to 2004: health care cost increases
    - Out-patient visit: 11 times
    - Hospitalization: 9 times
# Health Care Services in China

<table>
<thead>
<tr>
<th></th>
<th>% Giving up doctor visits</th>
<th>% Giving up hospitalization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Urban</td>
</tr>
<tr>
<td>1993</td>
<td>5.2</td>
<td>1.8</td>
</tr>
<tr>
<td>1998</td>
<td>13.8</td>
<td>16.1</td>
</tr>
<tr>
<td>2003</td>
<td>18.7</td>
<td>20.7</td>
</tr>
</tbody>
</table>
# Health Care Services in China

<table>
<thead>
<tr>
<th>Country</th>
<th>Doctors per 1,000 population</th>
<th>Hospital beds per 1,000 population</th>
<th>Health expenditure per capita ($)</th>
<th>% of GDP of health expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1.7</td>
<td>2.4</td>
<td>49</td>
<td>5.2</td>
</tr>
<tr>
<td>Japan</td>
<td>1.9</td>
<td>16.5</td>
<td>2627</td>
<td>8.0</td>
</tr>
<tr>
<td>India</td>
<td>0.4</td>
<td>0.8</td>
<td>24</td>
<td>5.1</td>
</tr>
<tr>
<td>U. K.</td>
<td>2.0</td>
<td>4.1</td>
<td>1835</td>
<td>7.6</td>
</tr>
<tr>
<td>France</td>
<td>3.0</td>
<td>8.2</td>
<td>2109</td>
<td>9.6</td>
</tr>
<tr>
<td>U. S.</td>
<td>2.7</td>
<td>3.6</td>
<td>4887</td>
<td>13.9</td>
</tr>
</tbody>
</table>
Health Care Services in China

- A survey on HIS in China
  - March ~ August, 2006
  - China Hospital Association HIS Committee
  - Hospital types: General, CMT, CMT/WM, Minority, Specialized
  - Survey received: 530
  - Effective sample size: 488
Health Care Services in China
Health Care Services in China

Number of IT FTEs (全职雇员) in Hospitals

- China
- United States

<table>
<thead>
<tr>
<th>Number of IT FTEs</th>
<th>China</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10</td>
<td>18%</td>
<td>18%</td>
</tr>
<tr>
<td>Between 10 and 24</td>
<td>17%</td>
<td>17%</td>
</tr>
<tr>
<td>Between 25 and 50</td>
<td>32%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Between 51 and 100</td>
<td>17%</td>
<td>0.50%</td>
</tr>
<tr>
<td>More than 100</td>
<td>13%</td>
<td>18%</td>
</tr>
</tbody>
</table>

Lei Zhao – IE @ Tsinghua
# Health Care in Beijing vs. in China

<table>
<thead>
<tr>
<th></th>
<th>China</th>
<th>Beijing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million)</td>
<td>1,307</td>
<td>15</td>
</tr>
<tr>
<td>Outpatient visits (million)</td>
<td>138.6</td>
<td>6.2</td>
</tr>
<tr>
<td>daily outpatient visits per doctor</td>
<td>1.06</td>
<td>4.01</td>
</tr>
<tr>
<td>Inpatients (million) per year</td>
<td>51.1</td>
<td>1.1</td>
</tr>
<tr>
<td>daily inpatient visits per Doctor</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>Professionals per 1,000 population</td>
<td>3.49</td>
<td>10.13</td>
</tr>
<tr>
<td>Beds per 1,000 population</td>
<td>2.45</td>
<td>6.39</td>
</tr>
</tbody>
</table>
## Health Care in Beijing vs. in China

### China

<table>
<thead>
<tr>
<th></th>
<th>Turnover of Beds (times)</th>
<th>Average Stay Days</th>
<th>Utilization Rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Hospitals</td>
<td>22</td>
<td>10.9</td>
<td>70.3</td>
</tr>
<tr>
<td>Profit Hospitals</td>
<td>22.3</td>
<td>10.9</td>
<td>71.4</td>
</tr>
<tr>
<td>Non-profit Hospitals</td>
<td>15.7</td>
<td>9.5</td>
<td>48.3</td>
</tr>
</tbody>
</table>

### Beijing

<table>
<thead>
<tr>
<th></th>
<th>Turnover of Beds (times)</th>
<th>Average Stay Days</th>
<th>Utilization Rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Hospitals</td>
<td>15.9</td>
<td>16.6</td>
<td>77.3</td>
</tr>
<tr>
<td>Profit Hospitals</td>
<td>16.2</td>
<td>16.7</td>
<td>79.1</td>
</tr>
<tr>
<td>Non-profit Hospitals</td>
<td>17.2</td>
<td>15.7</td>
<td>40.8</td>
</tr>
</tbody>
</table>
# Hospitals in Beijing

## By specialty type

<table>
<thead>
<tr>
<th></th>
<th>General Hospital</th>
<th>TCM Hospital</th>
<th>TCM-WM Hospital</th>
<th>Minority Hospital</th>
<th>Specialized Hospital</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>351</td>
<td>66</td>
<td>3</td>
<td>3</td>
<td>90</td>
<td>516</td>
</tr>
</tbody>
</table>

## By classification

<table>
<thead>
<tr>
<th>Third Level (TOP)</th>
<th>Second Level</th>
<th>First Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>class</td>
<td>class</td>
<td>class</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>class</td>
<td>class</td>
<td>class</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>8</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>54</td>
<td>18</td>
</tr>
<tr>
<td>class</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>class</td>
<td>130</td>
<td>35</td>
</tr>
</tbody>
</table>
Hospitals in Beijing

- By number of beds

<table>
<thead>
<tr>
<th># Beds</th>
<th>Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50</td>
<td>99</td>
</tr>
<tr>
<td>50-99</td>
<td>7</td>
</tr>
<tr>
<td>100-199</td>
<td>4</td>
</tr>
<tr>
<td>200-299</td>
<td>3</td>
</tr>
<tr>
<td>300-399</td>
<td>2</td>
</tr>
<tr>
<td>400-499</td>
<td>3</td>
</tr>
<tr>
<td>500-799</td>
<td>7</td>
</tr>
<tr>
<td>&gt;800</td>
<td>17</td>
</tr>
<tr>
<td>&gt;800</td>
<td>17</td>
</tr>
</tbody>
</table>
HCS Lab – Missions

- Promote communications and collaborations between IE/OR and health care services communities
- Apply IE/OR methodologies in health care services in China
- Lead health care services research in China and become active in international collaborations
- Contribute to the reform of health care services systems in China
- Strive to provide safe, effective, patient-centered, timely, efficient, and equitable health care services
HCS Lab – Research Areas

- Public policy and economic analysis
  - Estimating risks of public health
  - Allocating resources to control infectious diseases
- Planning and implementation of health programs
  - Community clinics & home nursing
- Health care operations management
  - Capacity planning and management in hospitals
  - Clinical pathway & patient flow
  - Patient access management/appointment scheduling
- Health care information management
- Medical treatment
  - Evidence-based clinical practice
  - Data-driven clinical decision making
HCS Lab – Research Tools

- Systems design tools
  - Human factor tools
  - Management and information system

- Systems analysis tools
  - Modeling and simulation
  - Stochastic analysis
  - Optimization tools for decision making
  - Distributed/agent-based decision making
  - Knowledge discovery and learning
  - Operations research & management

- Systems control tools
  - Statistical process/quality control
Snapshots of Research Activities

- One hospital on-site investigation
- One bachelor and master thesis
  - In vitro fertilization – embryo transfer
  - Optimal control of dosage decisions in controlled ovarian hyperstimulation (COH) cycles
- Three student research training (SRT) projects
  - Pilot study on the improvement of outpatient service efficiency in Beijing
  - Pilot study on the imbalanced patient flows in Beijing
  - Exploratory study on infectious disease monitor and control systems in China
- China CDC

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Snapshots of Research Activities

- Pilot study on the improvement of outpatient service efficiency in Beijing

Peng, Xiaoshan
Shi, Quan
Tang, Dongyi
Zeng, Lishun
Shi, Chunyang
Snapshots of Research Activities

- Pilot study on the **imbalanced patient flows** in Beijing

Peng, Xiaoshan
Shi, Quan

Tang, Dongyi
Zeng, Lishun

Shi, Chunyang
Snapshots of Research Activities

- Exploratory study on infectious disease monitor and control systems in China

Wang, Chenjie

Hou, Xiaolin

Huang, Qiuling

Zhu, Keming
On-Site Hospital Investigations

☐ Difficult access to outpatient services
☐ Long waiting time in a variety of queues
☐ Null movements between services units
☐ Short effective service time

☐ On-site investigations
  ■ Pre-investigation: 6 hospitals
  ■ 2nd level, 1st class hospital (December 28, 2006)
    ☐ ~30 students tracked ~70 patients
  ■ 3rd level, 1st class hospital (later)
Hospital Investigations

**Gender**

- Male: 40.7%
- Female: 52.5%
- N/A: 6.8%

**Residence**

- Beijing: 78.0%
- Other areas: 8.5%
- N/A: 13.6%

**Patients Age**

- Below 20: 1.7%
- 21-30: 28.8%
- Beyond 60: 10.2%

**Number of Visits**

- First visit: 66.1%
- Review: 22.0%
- N/A: 11.9%
Hospital Investigations

Patient Waiting Time Allocation

- Medicine Queue
- Medicine-CMT Queue
- Diagnosis Queue 1
- Diagnosis Queue 2
- Exam Queue 1
- Exam Queue 2
- Consultation Queue

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To increase outpatient service efficiency
- Reduction on unnecessary waiting time
- Improved hospital layout
- Streamlined clinical pathway
Hospital Appointment System in Beijing

- Appointment desk
- By phone
- Online (IC card)

<table>
<thead>
<tr>
<th></th>
<th>General hospital</th>
<th>Specialized hospital</th>
<th>Other hospitals</th>
<th>Total Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitals</td>
<td>351</td>
<td>90</td>
<td>75</td>
<td>516</td>
</tr>
<tr>
<td>Hospitals w/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>appointment system</td>
<td>55</td>
<td>17</td>
<td>0</td>
<td>72</td>
</tr>
</tbody>
</table>

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In Vitro Fertility – Embryo Transfer

- Accounts for more than 99% ART therapies
- 134,260 ART cycles in the US, 2005
  - 38,910 live births
  - 52,041 infants
- 20,000 ART cycles in China, 2004

ART: Assisted Reproductive Technology
In Vitro Fertility – Embryo Transfer

- Controlled Ovarian Hyperstimulation (COH)
- Oocytes Retrieval
- In Vitro Fertilization (IVF)
- Urine Test
  - Failure
  - Positive
  - Negative
- Embryo Transfer (ET)
- Pregnancy
The Natural Menstrual Process

Menstrual Cycle

Day Count

Process

- Single dominant follicle → develop
  - Other follicles → atresia

- Single oocyte
  - Low probability of fertilization
  - Poor quality → unhealthy embryo
Controlled Ovarian Hyperstimulation

- Ovarian Hyperstimulation Syndrome (OHSS)
  - Iatrogenic complication
  - Severe OHSS: 0.7%-1.7%, life-threatening
  - Related to the administration of exogenous gonadotropins

Two follicles reach diameter of 18mm
The COH Cycle

- Age
- BMI
- Starting Dosage
- Daily Dosage
- Mature follicle count
- Ovary Diameter
- E2 Level
- hCG Day
The COH Cycle

- Start
  - Polycystic Ovarian Syndrome (PCOS)
  - Classifications on responsiveness to dosage
  - Patient’s medical characteristics
    - Age, BMI, Antral follicle counts, previous IVF-ET experience

- The COH Cycle
  - Patient’s physiological states
    - E2 level, ovary volume, follicle sizes
  - Dynamic control (dosages)

- hCG day
  - Target range of states
Patient Classification in Practice

Cluster Outcomes

- normally-responsive cluster
- high-responsive cluster

Clinical Decision

- starting dosage 3
- starting dosage 2

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Patient Classifications in Practice

Clustering Outcome

- normally-responsive cluster
- high-responsive cluster

Clinical Decision

- starting dosage 3
- starting dosage 2

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Optimal Dosage Control in COH

- Model: Stochastic dynamic programming model
  - Difficulties
    - Multivariate continuous random evolution of states
    - Uncertain length of COH cycle
    - Nonlinear, non-monotone cost function
  - Markov decision process (MDP)
  - Backward dynamic programming
- Policy evaluation: Simulation
- Impact of Misclassification
HCS Lab – Collaborations

- **Partnerships**
  - Health care professionals
  - International academic institutes/research centers

- **Research activities**
  - Site visits
  - Seminars/Workshops/symposiums
  - Joint research projects/proposals
  - Conferences

- **Education**
  - Study cases in IE/OR curriculum
  - Health care management course
Lei Zhao, Assistant Professor, PhD

- Systems and Industrial Engineering
- Research Interests
  - Stochastic dynamic programming
  - Large-scale optimization
  - Health care services
  - Logistics and supply chain management
- Contact Information
  - Email: lzhao@tsinghua.edu.cn
  - [http://www.ie.tsinghua.edu.cn/~lzhao](http://www.ie.tsinghua.edu.cn/~lzhao)
<table>
<thead>
<tr>
<th>Research Interests &amp; Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Supply risk management (NSFC)</td>
</tr>
<tr>
<td>□ Postal logistics operations and networks design (Sinotrans)</td>
</tr>
<tr>
<td>□ Automatic piping layout (Mitsubishi Heavy Industries)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health Care Related Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Optimal control of dosages in controlled ovarian hyperstimulation</td>
</tr>
<tr>
<td>□ Patient access management/appointment system design</td>
</tr>
<tr>
<td>□ Automated infectious disease information processing (China CDC)</td>
</tr>
</tbody>
</table>
HCS Lab – Faculty Members

Ming Yu, Associate Professor, PhD

- Industrial Engineering
- Research Interests
  - Operations process management
  - Information systems
  - Service engineering

- Contact Information
  - Email: mingyu@tsinghua.edu.cn
  - Tel.: 86-10-62787158
HCS Lab – Faculty Members

Research Interests & Activities

- Social computing technologies
- Design and evaluation of ubiquitous/context-aware computing
- Universal design and assistive technology
- User-centered design
- Cross-cultural differences

Health Care Related Research

- Hospital operations process management
HCS Lab – Faculty Members

Dacheng LIU, Associate Professor, PhD

- Industrial Engineering
- Research Interests
  - Enterprise diagnosis & process reengineering
  - Logistic & supply chain management
  - Internet based remote monitoring
  - Safety capacity simulate and analysis on city

- Contact Information
  - Email: liudac@tsinghua.edu.cn
  - Tel.: 86-10-62773895
HCS Lab – Faculty Members

Research Interests & Activities

- Enterprise diagnosis and efficiency improvement for manufacturing and service industry
- Multi-level inventory management and optimization
- Logistic zone planning and industry aggregation
- Facilities design and material handling

Health Care Related Research

- Chronic rapid diagnosis and process reengineering in hospital
- Study on the multi-level blood inventory for emergency
HCS Lab – Faculty Members

Qin Gao, Assistant Professor, PhD

- Human-Computer Interaction
- Research Interests
  - Human factors in system design
  - Human-computer interaction and user interface design
  - Cognitive science
- Contact Information
  - Email: gaoqin@tsinghua.edu.cn
  - Tel.: 86-10-62788750
HCS Lab – Faculty Members

Research Interests & Activities

- Design and implications of social computing technologies
- Human computer interactions in ubiquitous/context-aware computing
- Universal design and assistive technology
- Cross-cultural differences in HCI

Health Care Related Research

- Ongoing projects:
  - Open architecture for accessible services integration and standardisation (7th Framework Programme)
  - Design information application for older people (jointly with NTT Cyber Lab, Japan)
- Possible future research direction
  - Context-aware computing in hospitals: design, implementation and evaluation
HCS Lab – Faculty Members

Lefei Li, Assistant Professor, PhD

- Systems and Industrial Engineering
- Research Interests
  - Logistics and supply chain management
  - Intelligent transportation systems
  - Operations and service management
- Contact Information
  - Email: lilefei@tsinghua.edu.cn
  - Tel.: 86-10-62796226
HCS Lab – Faculty Members

Research Interests & Activities

- Express delivery service network design
- Gas station maintenance network design
- Transit signal priority for urban transit service

Health Care Related Research

- Medical resource allocation using agent-based social network simulation
- Medical logistics network design
HCS Lab – Faculty Members

Kaibo Wang, Assistant Professor, PhD

- Industrial Engineering and Engineering Management
- Research Interests
  - Healthcare surveillance
  - Statistical process control (SPC), monitoring and diagnosis
  - Quality engineering and management
- Contact Information
  - Email: kbwang@tsinghua.edu.cn
  - http://www.ie.tsinghua.edu.cn/kbwang
HCS Lab – Faculty Members

Research Interests & Activities

- Statistical process adjustment using categorical observations
- High-dimensional process monitoring
- Statistical quality control for nanomanufacturing

Health Care Related Research

- Healthcare surveillance
- Automated information processing (with China CDC)
HCS Lab – Faculty Members

Binfeng LI, Assistant Professor, PhD

- Material Science and Engineering
- Research Interests
  - Statistical process control
  - Simulation modeling and analysis
  - Logistics and supply chain management
- Contact Information
  - Email: libinfeng@tsinghua.edu.cn
  - Tel.: 86-10-62796135
HCS Lab – Faculty Members

Research Interests & Activities

- Community health service network design
- Research on the after sale service system of the manufacturing enterprises

Health Care Related Research

- Research on resource allocation and efficiency
- Optimization of medical service system
Questions?

Discussions?