Operations Research and Health Care

introductory lecture

Erwin Hans
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www.choir.utwente.nl
Lecturers

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OR/OM in health care research at University of Twente:

**CHOIR**

*Center for Healthcare Operations Improvement & Research*

Our website:
http://www.utwente.nl/choir

Online bibliography:
http://www.utwente.nl/choir/orchestra
Program

http://www.lnmb.nl/courses/ORHC.html

Dates 2012 (10:15-12:00): 20/2, 27/2, 5/3, 12/3, 19/3, 26/3, 2/4, 16/4, 23/4

Lecture overview:

1. Hans: Introductory lecture
2. Hans: Operating room planning
3. Hans: Appointment scheduling, planning
4. Klundert: Human resource planning, crew rostering
5. Klundert: Health Services Research methodology & OR
7. Klundert: Quality, Safety & Risk
8. Hans: Performance measurement and benchmarking (DEA)
9. Hans, Klundert: Reflection, synthesis, feedback on assignments
Assignments are handed out (almost) every lecture
Hand in your work to the lecturer that handed out the assignment
  Preferably PDF
  By email, subject: LNMB Assignment X - name
Contact lecturer if you cannot meet a deadline
There is no exam; the assignments will be graded and averaged
Objective of the course

To teach **advanced operations research techniques** and their **application in a complex environment** of high societal importance
Agenda for Lecture 1

- Introduction:
  - background Operations Research & Health Care

- Introductory case:
  - acute hip fracture

- Hand-out of first assignment:
  - strategic and tactical operating room planning
INTRODUCTION

Operations Research and Health Care
“OR/OM in healthcare is in its infancy”

“<2% from the OR/MS community actually focuses on healthcare”

Michael W. Carter (OR/MS Today, 2002)

This number is rapidly rising in the last few years
Importance of healthcare

- Affects all in society
- Graying population
- More chronically ill, co-morbidity
- Increasingly advanced technology
- Expenditures growing rapidly
- Share of the GDP
  - In Netherlands: ±10% (80 billion €)
  - In the US: 16% (>1300 billion €)
“More $$ doesn’t mean better health”

- ± 40,000 people with age over 100 years in Japan (♀ 87%)
- In US best possible care
  - … if you can afford it
- 4.5 million people without health insurance
- Publicly delivered, HC tends to be cheaper and more effective

Life expectancy

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In Netherlands very little attention for “OR/OM in healthcare” until 2003

Causes (to name a few…):

- Traditionally, “every hospital tries to provide everything”; long patient’s LOS
- Hippocratic Oath
- Financial system did not reward efficiency
- Poor training in OM for healthcare managers
- Poor state of ICT (information systems)
Anno 2003…

You don’t have a waiting list??

... you must be a lousy doctor!!
“It’s not all bad...”

For the second year in a row, the Netherlands has been proclaimed as the country with the most customer-friendly healthcare.

According to the European Health Consumer Index (EHCI), the Netherlands scores well in the areas of medical results, patient rights and medicines.

At the same time... waiting lists amongst the worst in Europe.

Logistical improvements go hand-in-hand with quality improvements: patients that have to visit the hospital less often, have shorter waiting times, and may count on more attention from nurses and physicians.

Logistical quality improvements will yield some 3 to 3.5 billion EUR: almost a quarter of the entire hospital budget…

In other words:

**improved care for less money!**
Cultural change in Dutch healthcare

- Hiring OM experts from industry
- ICT innovation (e.g. EHR systems)
- OM education of healthcare managers
- Safety
- Copying logistical paradigms from industry
- Process reorganization (clinical pathways)
- Introduction of regulated market mechanisms
Example of where market competition can lead to...
Healthcare: a business unlike all others

- Financial model does not reward efficiency
- Patients are *customer* and *product* at the same time
  - Patients cannot be refused
  - Interventions cannot be preempted
- More *variability* than in any other industry
Healthcare: a business unlike all others

- Many different types of care providers
  - Different types of hospitals, different strategies
  - Academic hospitals do almost everything
  - Specialized clinics are often seen as “cream skimmers”
- Multiple decision makers (doctors ↔ managers)
  - Doctors are private entrepreneurs within hospital
    - They cheat the system to advance patients
- Stakeholders often have conflicting goals
The Four Faces of Health Care  
(Glouberman & Mintzberg, 1994)

<table>
<thead>
<tr>
<th>Status Coalition</th>
<th>Trustees / board</th>
<th>Community</th>
<th>Administrators</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Doctors</td>
<td></td>
<td>Nursing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cure</td>
<td></td>
<td>Care</td>
<td></td>
</tr>
</tbody>
</table>

- They (believe they) control the system, but are independent
- They guard the budget
- They want to preserve their jobs and the hospital
- They deliver patient care

Impossibl e to manage!
Healthcare delivery objectives:
The four Es

- The fourth E: Equity!
- Productivity ↔ Quality of care ↔ Quality of labor
Introductory case:
acute hip fracture patient
The acute hip fracture patient
Patient is brought into the hospital’s Emergency Department by ambulance
Ambulances: applications of OR

- Selection of ambulance for (emergency & elective) transports
- Tactical geographic positioning of ambulances
- Assignment of trauma function to hospitals
- Shift planning
- Forming trauma teams for immediate dispatch
- Assignment of trauma helicopter to incidents and to regions & hospitals
Patient arrives at the Emergency Department (ED)
Monthly hip fracture arrivals at the ED

The number of hip fracture patients arrived at surgical or orthopaedics department per month

<table>
<thead>
<tr>
<th>Months</th>
<th>Surgery</th>
<th>Orthopaedic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan '08</td>
<td>10</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Febr</td>
<td>16</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Ma</td>
<td>14</td>
<td>11</td>
<td>25</td>
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<tr>
<td>Apr</td>
<td>19</td>
<td>8</td>
<td>27</td>
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<td>May</td>
<td>27</td>
<td>8</td>
<td>35</td>
</tr>
<tr>
<td>Jun</td>
<td>13</td>
<td>5</td>
<td>18</td>
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<tr>
<td>Jul</td>
<td>15</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Aug</td>
<td>23</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>Sept</td>
<td>16</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>Okt</td>
<td>22</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td>Nov</td>
<td>20</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Dec</td>
<td>35</td>
<td>13</td>
<td>48</td>
</tr>
<tr>
<td>Jan '09</td>
<td>19</td>
<td>10</td>
<td>29</td>
</tr>
<tr>
<td>Febr</td>
<td>22</td>
<td>9</td>
<td>31</td>
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<td>Apr</td>
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<td>May</td>
<td>16</td>
<td>7</td>
<td>24</td>
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<td>Jun</td>
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<td>11</td>
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<td>Jul</td>
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<td>8</td>
<td>30</td>
</tr>
<tr>
<td>Aug</td>
<td>30</td>
<td>7</td>
<td>30</td>
</tr>
</tbody>
</table>
NEWS ITEM: AVERAGE EMERGENCY ROOM WAIT NEARS ONE HOUR, C.D.C SAYS.

YOUR CASE IS QUITE ADVANCED. IT'S BETTER TO CATCH THESE THINGS IN THE EARLY STAGES.

IT WAS ONLY A SMALL PATCH ON MY ARM WHEN I ARRIVED HERE...
(General daily) arrivals at the ED

Average number of patient arrivals

<table>
<thead>
<tr>
<th>Day</th>
<th>Internal M.</th>
<th>G.Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>16,2</td>
<td>52</td>
</tr>
<tr>
<td>Tuesday</td>
<td>16,1</td>
<td>48</td>
</tr>
<tr>
<td>Wednesday</td>
<td>15,5</td>
<td>47</td>
</tr>
<tr>
<td>Thursday</td>
<td>14,1</td>
<td>46</td>
</tr>
<tr>
<td>Friday</td>
<td>18,1</td>
<td>51</td>
</tr>
<tr>
<td>Saturday</td>
<td>11,4</td>
<td>54</td>
</tr>
<tr>
<td>Sunday</td>
<td>11,7</td>
<td>45</td>
</tr>
</tbody>
</table>
(General hourly) arrivals at the ED

Arrivals of G.Surgery every hour

Arrivals of Internal M. patients every hour
ED: applications of OR

- Determination of staffing levels in relation with service level
- 24/7 shift scheduling
  - Various skills
  - Demand prediction (arrivals, LOS)
- Levels of presence during nights:
  - At hospital, awake
  - At hospital, asleep
  - At home, on call

Capacity of nurses vs. total patients in the ED
ED: applications of OR

Capacity of residents vs the number of patients
**ED: applications of OR**

Activity prioritization after triage:

<table>
<thead>
<tr>
<th>Colour</th>
<th>G. Surgery</th>
<th>Internal M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>0,2%</td>
<td>0,1%</td>
</tr>
<tr>
<td>Green</td>
<td>59%</td>
<td>27%</td>
</tr>
<tr>
<td>Yellow</td>
<td>35%</td>
<td>62%</td>
</tr>
<tr>
<td>Orange</td>
<td>4%</td>
<td>9%</td>
</tr>
<tr>
<td>Red</td>
<td>0,5%</td>
<td>0,5%</td>
</tr>
</tbody>
</table>

Typical diagnostic activities:
Patient arrives at the ward

....and waits there for surgery
Wards: applications of OR

- Nurse rostering, staffing
- Determination of required number of staffed beds
- Pool or un-pool wards?
- Bed transportation in hospital
- Planning of bed cleaning
- Positioning of nurses, supplies
Patient arrives at operating room

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Operating rooms: applications of OR

- Pre-operative screening by anesthesiologist
  - Walk-in or appointment based?
- Surgery sequencing, scheduling, planning
  - Elective, add-on, emergency
  - Inpatient, outpatient
  - With movable resources (e.g. X-rays)
  - Integrated with bed planning (ICU, wards)
- Capacity dimensioning of operating rooms
- Staffing, rostering
  - Determination of staffing levels during the night for dealing with emergencies

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Operating rooms: applications of OR

- Instrument tray optimization

Example base instrument tray, which contains 107 instruments
Big Basis Tray

Required instruments for Laparoscopic small surgery

Required instruments for Abdominal surgery
Operating rooms: applications of OR

- Instrument tray optimization
  - Instrument tray composition
    - Tray per surgery type $\leftrightarrow$ 1 tray for all surgery types $\leftrightarrow$ multiple trays per surgery
  - Incrementally, or integrally?
- Inventory levels
Nieuwsbericht - Voorraadbeheer / Forecasting
UMCG-ziekenhuis zet voorraadbeheer op de kaart

Auteur: Harm Beerens
Geplaatst: 9 jun 2009
Een voorraadanalyse bij het Universitair Medisch Centrum Groningen wees uit dat de voorraad 40% omlaag kan. Om dit bereiken moet het voorraadbeheer ingrijpend worden geprofessionaliseerd. Logistek manager Jonnie Mooi legt uit hoe hij dit gaat doen.
Operating rooms: applications of OR

- Optimization of the reverse logistics chain of instrument sterilization (inventory locations)

Source: Health Care Mgmt Science, 11:23-33
Patient returns to the ward for recovery
On average, there are sufficient beds...
After recovery, patient may return home
Or... go to a nursing home
If the nursing homes are full, the patient will stay in the hospital ➔ bed blocking!
Nursing homes: applications of OR

- Transmural care pathways
  - Capacity dimensioning of:
    - Intermediate care wards
    - Nursing homes
- Analysis of care networks
- Contracting between hospitals and nursing homes
  - How many beds?
  - Of which type?
  - When?
- Temporal scheduling of care pathways
- Relation between flexibility in building design and logistical performance
Logistical paradigms

Six Sigma

Total access

LEAN

Benchmarks

BPR

ConWip

Continuous Improvement
What they all have in common

3 basic principles of Operations Management:

- Reduction of waste
  eliminate non-value-adding activities
- Reduction of variability
  eliminate disturbances, errors, fluctuations
- Reduction of complexity
  easiest effective solution is the best
Strengths

- Focus on performance measurement
- Analyzing performance
- Simple principles
- Organization-wide involvement
- Organization-wide improvement
Weaknesses

- Selection of paradigm generally not based on effectiveness, but on enthusiastic consultant
- Paradigm = “Philosophy” / “strive”
  How to attain objective?
- Focus on operational level
  “Low hanging fruit”…

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What is missing?

What performance levels can theoretically be attained?

“10% improvement of a lousy performance is still a lousy performance!”
Research is required

- To develop new concepts
- To test these concepts *prospectively*
  - Using mathematical (simulation) models
  - Under various scenarios, and a long horizon
  - For different types of hospitals
Hierarchical positioning framework for hospital planning & control

<table>
<thead>
<tr>
<th>Strategic</th>
<th>Medical planning</th>
<th>Resource capacity planning</th>
<th>Material planning</th>
<th>Financial planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Society</td>
<td>Research planning, introduction of new treatment methods</td>
<td>Case mix planning, layout planning, capacity dimensioning</td>
<td>Supply chain and warehouse design</td>
<td>Agreements with insurance companies, capital investments</td>
</tr>
<tr>
<td>Tactical</td>
<td>Care pathway planning</td>
<td>Allocation of time and resources to specialties, rostering</td>
<td>Supplier selection, tendering, forming purchasing consortia</td>
<td>Budget and cost allocation</td>
</tr>
<tr>
<td>Operational offline</td>
<td>Diagnosis and planning of an individual treatment</td>
<td>Elective patient scheduling workforce planning</td>
<td>Purchasing, determining order sizes</td>
<td>DRG billing, cash flow analysis</td>
</tr>
<tr>
<td>Operational online</td>
<td>Triage, diagnosing complications</td>
<td>Monitoring, emergency rescheduling</td>
<td>Rush ordering, inventory replenishing</td>
<td>Expenditure monitoring, handling billing complications</td>
</tr>
</tbody>
</table>

← managerial areas →

Hierarchical decomposition
Assignment 1: “OR in the OR”
Introduction operating room planning

- **Strategic level** (year, quarter)
  - Allocation of OR capacity to surgical specialties
- **Tactical level** (month)
  - Weekly allocation of “OR-days” to specialties
- **Operational (offline) level** (weeks)
  - Semi-urgent & elective surgery scheduling
- **Operational (online) level** (days)
  - Emergency surgery scheduling
Assignment 1: strategic and tactical operating room planning

Situation:
- A hospital is going to build a new operating room department

Strategic problem:
- We will investigate how many operating rooms (ORs) to build, and of which type
  - Inpatient ORs (“dedicated” or “generic”)
  - Outpatient ORs
  - Emergency ORs
- Inpatient ORs can be made “dedicated” to one specialty, or can be made “generic” to serve all specialty
Assignment 1:
strategic and tactical operating room planning

- Emergency operating rooms or not?

Concept: “emergency ORs”

Concept: “No emergency ORs”

OR1  OR2  OR3  OR4  OR5  OR6  OR7  OR8  OR9  OR10  OR11  OR12

Reserved OR time for emergency surgery

OR time for elective surgery

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Assignment 1: 
strategic and tactical operating room planning

Tactical problem:

- Annually, the board of the hospital, the operating room management and the surgical services draw a contract regarding the division of the “capacity pie”

We will determine how to divide the dedicated inpatient ORs over the specialties, for every regular working day
Example elective schedule (11 ORs)

Unplanned time

Planned slack: reserved time to deal with variability in surgery durations, to prevent overtime
Assignment 1: strategic and tactical operating room planning

- At the strategic and tactical level, you must account for the planned slack at the operational level.
- This planned slack is dimensioned in such a way, that the probability of overtime is less than 30%.
- We will assume that surgery durations are lognormal distributed.
  - At Erasmus MC, planners assume a normal distribution of the total surgery duration in an operating room.

Total surgery duration:

\[ \mu \quad \mu + \sigma/2 \]

69%
Assignment 1:
strategic and tactical operating room planning

Input for the assignment:
- Given: 10 years of historical process data
  - Surgery durations per surgery type
  - Emergency arrival frequencies per day

ASSIGNMENT: formulate an advice for the hospital’s board, and support this advice with sound, convincing calculations

Download assignment 1 here:

http://www.filedropper.com/inmb1

Good luck!