Séminaire des doctorants de l’équipe Aide à la décision

OPTIMISATION DES SERVICES D’URGENCES

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Outline

➢ Research context

➢ Simulation-based optimization of an emergency department staffing levels
  o Building a realistic ED model
  o Model application

➢ Other contributions
  o Shift definition
  o A comprehensive literature review on KPIs in EDs

➢ Future works
Research context

- **Emergency Departments in Hospitals**
  - The problem of **Overcrowding**

- **Research perimeter**
  - Collaboration with ED of Saint-Camille hospital
  - **Objective**: to improve the average LOS by increasing resources staffing levels.

  **By how much should the current staffing budget be increased and how should this additional budget be used in the allocation of human resources?**

  A **need** for: A realistic DES model for EDs
Building a realistic ED model

1. Formulation of the problem
2. Data collection and model design
3. Conceptual model verification
4. The computerized model
5. Validation of the computerized model
6. Experimentation and analysis of results
Building a realistic ED model

3 different data types and 4 sources for data collection

Fitting distributions for processing times (26 in total) using Arena software’s Input Analyzer.
Building a realistic ED model

1. Formulation of the problem
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Building a realistic ED model

1. Formulation of the problem
2. Data collection and model design
3. Conceptual model verification
4. The computerized model
5. Validation of the computerized model
6. Experimentation and analysis of results

- From arrival to triage
- Initial consultation
- Diagnostic tests
- Interpretation and decision
- Process outcome
Tool used: ARENA

Formulation of the problem
Data collection and model design
Conceptual model verification
The computerized model
Validation of the computerized model
Experimentation and analysis of results
Building a realistic ED model

3 indicators
- LOS per patient type
- Resources workload
- The durations of the five stages of the process
# Building a realistic ED model

## The model’s granularity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival Process</td>
<td>Depends on periods of the day</td>
<td>Depends on week days</td>
<td>Depends on week days</td>
<td>Depends on day hours</td>
<td>Depends on the period of the day</td>
<td>Depends on week days and day hours</td>
</tr>
<tr>
<td>Patients’ categories</td>
<td>Yes (4)</td>
<td>Yes (2)</td>
<td>Yes (5)</td>
<td>Yes (3)</td>
<td>Yes (4)</td>
<td>Yes (5)</td>
</tr>
<tr>
<td>Included resources</td>
<td>Doctors, Nurses, boxes (called beds)</td>
<td>Doctors, Nurses, Boxes (rubicles)</td>
<td>Doctors, Nurses, Boxes</td>
<td>Reoptionists, Doctors, Nurses, Lab technicians, Boxes (ER), Beds</td>
<td>Doctors, Nurses, SickBeds (SR)</td>
<td>Doctors, Nurses, Stretcher bearer, SR, Boxes, beds</td>
</tr>
<tr>
<td>Resources subdivisions</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Severity and/or expertise based processing times</td>
<td>Yes, based on severity</td>
<td>Yes, based on severity</td>
<td>Yes, based on severity</td>
<td>No</td>
<td>No</td>
<td>Yes, based on both</td>
</tr>
<tr>
<td>Lab tests/Radiology</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Transportation times</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Staff Shifts</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Teaching aspects</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Specialist</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Abandonment</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Observation Unit</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Experiments</td>
<td>Simulation combined with Integer Linear Programming</td>
<td>Intuitive What-if scenarios</td>
<td>Intuitive What-if scenarios</td>
<td>Simulation Optimization</td>
<td>Simulation Optimization</td>
<td>Simulation Optimization</td>
</tr>
<tr>
<td>Control variables in the experiments</td>
<td>Nurses</td>
<td>All included resources</td>
<td>All included resources</td>
<td>Doctors, Nurses, Lab technicians</td>
<td>Doctors and Nurses</td>
<td>All included Human</td>
</tr>
</tbody>
</table>
Experiments

- **Simulation Optimization** (Optquest for ARENA)

- We formulate an optimization problem that
  - seeks to minimize the LOS
  - under a budgetary constraint, and a constraint on TTFT
  - for urgent patients
Mathematical model:

\[
\begin{align*}
\text{min } & \overline{LOS} \\
\text{subject to } & \sum_{i=1}^{n} \sum_{j=1}^{m} C_{i,j} X_{i,j} \leq C(1 + \alpha) \quad \forall i \in I, j \in J \\
& TTFT \leq L,
\end{align*}
\]

where

- $\overline{LOS}$ = Average length of stay in the system,
- $X_{i,j}$ = Amount of resource $i$ during shift $j$,
- $C_{i,j}$ = Salary for resource $i$ during shift $j$,
- $C$ = Current staffing budget,
- $\alpha$ = Percentage of additional staffing budget,
- $TTFT$ = Average time to first treatment for LC patients (ESIs 1, 2 and 3),
- $L$ = $TTFT$ limit.

Performing sensitivity analysis
### Results of sensitivity analysis

<table>
<thead>
<tr>
<th>Additional Staffing Budget (a)</th>
<th>57</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>367</td>
<td>485</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>5%</td>
<td>323</td>
<td>389</td>
<td>397</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>10%</td>
<td>246</td>
<td>277</td>
<td>277</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>20%</td>
<td>205</td>
<td>205</td>
<td>205</td>
<td>229</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>30%</td>
<td>182</td>
<td>182</td>
<td>182</td>
<td>182</td>
<td>221</td>
<td>INF</td>
</tr>
<tr>
<td>40%</td>
<td>171</td>
<td>171</td>
<td>171</td>
<td>171</td>
<td>192</td>
<td>INF</td>
</tr>
<tr>
<td>50%</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>INF</td>
</tr>
</tbody>
</table>
Experiments

Result n°1:
### Result n°1:

<table>
<thead>
<tr>
<th>Staffing budget (α)</th>
<th>Optimal LOS (minutes)</th>
<th>Improvement of LOS</th>
<th>Optimal solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>323</td>
<td>12%</td>
<td>One additional Senior SC during Day shift</td>
</tr>
<tr>
<td>10%</td>
<td>246</td>
<td>33%</td>
<td>One additional Senior LC during Night shift</td>
</tr>
</tbody>
</table>
| 20%                 | 205                   | 44%               | One additional Senior LC during Night shift  
Two additional nurses LC during Night shift |
| 30%                 | 182                   | 50%               | Two additional Seniors LC during Night shift  
One additional Senior SC during Day shift  
One additional Nurse LC during Night shift  
One additional Triage Nurse during Day shift  
One additional Junior ESI$_{45}$ during Day shift |
**Result n°2:**

Analyse of resource staffings:
- Under TTFT constraint, the budget is devoted to urgent patients
- The resource ‘doctor’ is always a priority
- For high budgets, additional nurses are staffed

<table>
<thead>
<tr>
<th>Additional Staffing Budget (a)</th>
<th>TTFT limit (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>57</td>
</tr>
<tr>
<td>0%</td>
<td>367</td>
</tr>
<tr>
<td>5%</td>
<td>323</td>
</tr>
<tr>
<td>10%</td>
<td>246</td>
</tr>
<tr>
<td>20%</td>
<td>205</td>
</tr>
<tr>
<td>30%</td>
<td>182</td>
</tr>
<tr>
<td>40%</td>
<td>171</td>
</tr>
<tr>
<td>50%</td>
<td>165</td>
</tr>
</tbody>
</table>
Other contributions: **Shift definition**

**Method**

**Simulation Optimization**
- Staffing Levels for each hour of the day

**Mathematical Programming**
- Grouping of staffing levels that leads to coherent shifts

**Heuristic**
- Reducing staffing hours by affecting performance as less as possible
Other contributions: **Shift definition**

**Simulation Optimization**
- Min LOS
- s.t. BUDGET

**Linear Programming**
- Min BUDGET
- s.t. Performance Standards

**Staffing Levels**

**Shift Scheduling**
Other contributions: Shift definition

Results

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>Real (2 shifts)</th>
<th>Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>269</td>
<td>245</td>
<td></td>
</tr>
</tbody>
</table>

With the use of the same budget!

Conclusions

Novel heuristic that leads to improved performance while obeying to the most important constraints encountered in EDs
ED studies can be classified according to:

- **OR tool**
  - Simulation models
  - Analytical methods

- **Source of improvement**
  - Resource-related
  - Process-related
  - Environment-related

... and according to the metric used to measure the ED performance: **KPI**
Other contributions: KPIs in EDs

- Time To First Treatment
- Length of stay
- Left Without Being Seen
- Ambulance Diversion
Future works

- Same patient same physician
- Anticipation methods
- Point-of-care testing
Merci de votre attention