Operating room time allocation to surgical services: the case of a public hospital in Portugal

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Portugal
INTRODUCTION

ImproveOR project

MOTIVATION

Case Study

PROBLEM DESCRIPTION

Objectives, Literature Review, Methodology, Model

PRELIMINARY RESULTS

Conclusions

FUTURE WORK
Propose changes to resource planning and scheduling on the operating rooms

Improve operating rooms efficiency
- Increase surgeries production (to increase hospital financing from the state)
- Health improvements to the patient
- Maximize surgeons satisfaction
- Comply with the goals established by Sistema Integrado de Gestão de Inscritos para Cirurgia (SIGIC)
**MOTIVATION**

**Continuously increasing complexity of health care organizations**

- Aging population
- Increasing demand
- New and expensive technologies

**Operating rooms are the main center of costs and revenues at an hospital**

**Coordination of scarce resources**

- Lack of surgeons
- Lack of anesthesiologists
- Lack of beds
Influence area of the hospital (325,237 people)
CASE STUDY

Surgical activity and Waiting list

- Elective
- Additional
- Total number of surgeries
- Waiting list


0 2000 4000 6000 8000 10000 12000
# CASE STUDY (WL 2018 Dec 28)

**Specialty Patients**

<table>
<thead>
<tr>
<th>Specialty</th>
<th>WT ≤180 days</th>
<th>WT &gt; 180 days</th>
<th>WT 181-270 days</th>
<th>WT 271-260 days</th>
<th>WT &gt; 360 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#</td>
<td>%</td>
<td>#</td>
<td>%</td>
<td>#</td>
</tr>
<tr>
<td>General</td>
<td>1043</td>
<td>36.5</td>
<td>745</td>
<td>71.4</td>
<td>298</td>
</tr>
<tr>
<td>Plastic</td>
<td>295</td>
<td>10.3</td>
<td>292</td>
<td>99.0</td>
<td>3</td>
</tr>
<tr>
<td>Stomatolology</td>
<td>14</td>
<td>0.5</td>
<td>9</td>
<td>64.3</td>
<td>5</td>
</tr>
<tr>
<td>Ophthalmology</td>
<td>684</td>
<td>24.0</td>
<td>606</td>
<td>88.6</td>
<td>78</td>
</tr>
<tr>
<td>Orthopedics</td>
<td>240</td>
<td>8.4</td>
<td>204</td>
<td>85.0</td>
<td>36</td>
</tr>
<tr>
<td>ORL</td>
<td>226</td>
<td>7.9</td>
<td>104</td>
<td>46.0</td>
<td>122</td>
</tr>
<tr>
<td>Pediatric</td>
<td>89</td>
<td>3.1</td>
<td>88</td>
<td>98.9</td>
<td>1</td>
</tr>
<tr>
<td>Urology</td>
<td>265</td>
<td>9.3</td>
<td>117</td>
<td>44.2</td>
<td>148</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2856</strong></td>
<td><strong>100</strong></td>
<td><strong>2165</strong></td>
<td><strong>75.8</strong></td>
<td><strong>691</strong></td>
</tr>
</tbody>
</table>

**Surgeons**

- General: 14
- Plastic: 2
- Stomatolology: 2
- Ophthalmology: 10
- Orthopedics: 5
- ORL: 4
- Pediatric: 2
- Urology: 4

**Elective surgery:**

- Level 4: 72 hours
- Level 3: 15 days in a row
- Level 2: 60 days in a row
- Level 1: 180 days in a row

5% of patients will have surgery within 15 days in a row.

95% of patients will have surgery within 180 days in a row.
## CASE STUDY

<table>
<thead>
<tr>
<th>Indicators</th>
<th>OR 1</th>
<th>OR 2</th>
<th>OR 3</th>
<th>OR 4</th>
<th>OR 5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of weekly allocated hours</td>
<td>48</td>
<td>48</td>
<td>12</td>
<td>30</td>
<td>36</td>
<td>198</td>
</tr>
<tr>
<td>Average weekly number of used hours</td>
<td>31.9</td>
<td>33.6</td>
<td>10</td>
<td>21</td>
<td>2.4</td>
<td>102</td>
</tr>
<tr>
<td>Occupancy rate</td>
<td>66.5%</td>
<td>70.0%</td>
<td>83.3%</td>
<td>70.0%</td>
<td>6.7%</td>
<td>51.5%</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Bed pool</th>
<th>Specialties</th>
<th>Number of beds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-ward</td>
<td>All specialties</td>
<td>32</td>
</tr>
<tr>
<td>Surgery 1</td>
<td>General, plastic, estomatology</td>
<td>47</td>
</tr>
<tr>
<td>Surgery 2</td>
<td>General, estomatology, urology</td>
<td>28</td>
</tr>
<tr>
<td>Surgery 3</td>
<td>Orthopedic, ophthalmology, ORL</td>
<td>47</td>
</tr>
<tr>
<td>Pediatric surgery</td>
<td>Pediatrics</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>172</td>
</tr>
</tbody>
</table>
CASE STUDY

- Portuguese public hospital
  - Serves 325,237 people
  - 5 operating rooms
  - 8 surgical specialties
- Changes in surgical demand and staff pattern
- Almost unchanged MSS for more than 30 years
- High rates of idle OR time
- High waiting times for elective patients
## CASE STUDY

- **Portuguese public hospital**
- Serves 325,237 people
- 5 operating rooms
- 8 surgical specialties

### Changes in surgical demand and staff pattern
- Almost unchanged MSS for more than 30 years
- High rates of idle OR time
- High waiting times for elective patients

<table>
<thead>
<tr>
<th>Day</th>
<th>OR1</th>
<th>OR2</th>
<th>OR3</th>
<th>OR4</th>
<th>OR5</th>
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<tbody>
<tr>
<td>Mon</td>
<td>C. Geral</td>
<td>Urologia</td>
<td>Orthopedia</td>
<td>Oftalmologia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C. Geral</td>
<td>C. Geral Tira I ou Tira II a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tue</td>
<td>C. Geral</td>
<td>C. Geral</td>
<td>Orthopedia</td>
<td>Oftalmologia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C. Mama</td>
<td>C. Plástica</td>
<td></td>
<td></td>
<td>Oftalmologia</td>
</tr>
<tr>
<td>Wed</td>
<td>C. Plástica</td>
<td>C. Pediátrica</td>
<td>Orthopedia</td>
<td>Oftalmologia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C. Ger. Varizes</td>
<td></td>
<td></td>
<td>O.R.L.</td>
<td></td>
</tr>
<tr>
<td>Thu</td>
<td>C. Geral</td>
<td>C. Geral</td>
<td>Orthopedia</td>
<td>Oftalmologia</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urologia</td>
<td>O.R.L.</td>
<td></td>
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<tr>
<td>Fri</td>
<td>C. Geral</td>
<td>Estomat. b)</td>
<td>Orthopedia</td>
<td>Oftalmologia c/ locais</td>
<td></td>
</tr>
</tbody>
</table>
CASE STUDY

- Portuguese public hospital
  - Serves 325,237 people
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PROBLEM DESCRIPTION

- Capacity planning - MSS
  - Tactical (aggregate) level
- Long planning horizon
- MSS stability
- Max number of slots assigned to each specialty
  - specialty capacity
  - defined by the # doctors and the max workload of each surgeon
  - surgeon workload measured in number of slots
- Up- and downstream capacity
OBJECTIVES

SURGICAL TEAM PREFERENCES

BALANCE SUPPLY AND DEMAND

UP- AND DOWNSTREAM UNITS WORKLOAD
OBJECTIVES

SURGICAL TEAM PREFERENCES

Surgeons
Anesthesiologists

Preference on

Day
Slot
## OBJECTIVES

### BALANCE SUPPLY AND DEMAND

WL in 28-12-2018

<table>
<thead>
<tr>
<th>Specialties</th>
<th>% Overall WL length (WL)</th>
<th>% Overall WL duration (WD)</th>
<th>% Allocated blocks (AB)</th>
<th>Difference (WL-AB)</th>
<th>Difference (WD-AB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>36.5 %</td>
<td>48.6 %</td>
<td>37.2 %</td>
<td>-0.7 %</td>
<td>11.4 %</td>
</tr>
<tr>
<td>Plastic</td>
<td>10.3 %</td>
<td>8.6 %</td>
<td>6.6 %</td>
<td>3.7 %</td>
<td>2.0 %</td>
</tr>
<tr>
<td>Stomatology</td>
<td>0.5 %</td>
<td>0.3 %</td>
<td>0.3 %</td>
<td>0.2 %</td>
<td>0.0 %</td>
</tr>
<tr>
<td>Ophtalmology</td>
<td>24.0 %</td>
<td>13.6 %</td>
<td>18.6 %</td>
<td>5.4 %</td>
<td>-5.0 %</td>
</tr>
<tr>
<td>Orthopedics</td>
<td>8.4 %</td>
<td>10.0 %</td>
<td>16.3 %</td>
<td>-7.9 %</td>
<td>-6.3 %</td>
</tr>
<tr>
<td>ORL</td>
<td>7.9 %</td>
<td>5.8 %</td>
<td>9.2 %</td>
<td>-1.3 %</td>
<td>-3.4 %</td>
</tr>
<tr>
<td>Pediatric</td>
<td>3.1 %</td>
<td>1.3 %</td>
<td>2.4 %</td>
<td>0.7 %</td>
<td>-1.1 %</td>
</tr>
<tr>
<td>Urology</td>
<td>9.3 %</td>
<td>11.8 %</td>
<td>9.3 %</td>
<td>0.0 %</td>
<td>2.5 %</td>
</tr>
</tbody>
</table>
OBJECTIVES

UP- AND DOWNSTREAM UNITS WORKLOAD

(1) Pre-ward → Surgical suite (5 ORs) → (1) ICU → (4) Hospital wards
# Literature Review

## Objectives

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Surgical team preferences</th>
<th>Balance supply and demand</th>
<th>Up and downstream units workload</th>
<th>Stability/Flexibility of MSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banditori et al. (2013)</td>
<td># PAT WL + DUEDATE</td>
<td></td>
<td></td>
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<tr>
<td>Abdelrasol et al. (2014)</td>
<td></td>
<td></td>
<td></td>
<td>MOD BLOCK SCHED</td>
</tr>
<tr>
<td>Malik et al. (2015)</td>
<td></td>
<td>MIN # PAT WL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visintin et al. (2016)</td>
<td></td>
<td></td>
<td></td>
<td>FLEX_ALLOW VAR</td>
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<td>Abedini et al. (2017)</td>
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<td></td>
<td></td>
<td>PAT FLOW</td>
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<tr>
<td>Dellaert et al. (2017)</td>
<td></td>
<td></td>
<td></td>
<td>TARGET WORKLOAD</td>
</tr>
<tr>
<td>Penn et al. (2017)</td>
<td>MAX SURG PREF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marques et al. (2019)</td>
<td></td>
<td></td>
<td>MIN VARIABILITY</td>
<td>MAX STAB</td>
</tr>
<tr>
<td><strong>OUR PROPOSAL</strong></td>
<td>SURG + ANEST PREF</td>
<td>OR TIME</td>
<td>TARGET WORK + CAP</td>
<td>STAB CONSTRAINT</td>
</tr>
</tbody>
</table>
METHODOLOGY

**Input data**
- OR functionality
- Demand modelling

**Optimization Model**
- Stability constraints
- Workload in up- and downstream units

**MSS**
MODEL

Demand modelling

\[
p_{sw} = p_{s,w-1} + \text{ent}_{s,w-1} - \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} \lambda_{s,w,d,b,r} x_{s,w,d,b,r} \quad \forall s \in S, w \in W \setminus \{1\}
\]

\[
p_{s1} = \text{inis}_{s} \quad \forall s \in S
\]

\[
t_{sw} = p_{sw} t_{sw} \quad \forall s \in S, w \in W
\]

\[
\theta \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} x_{swdbr} + t_{sw} = t_{sw} + t_{sw}^{+} \quad \forall s \in S, w \in W
\]

OR Functionality

Input data

Stability

Up and downstream units

\[
\sum_{s \in S} \sum_{w \in W} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} \left( \frac{\sum_{i \in I_{b}}^{s} \lambda_{s,w,d,b,r}}{1} + \sum_{a \in A} \lambda_{s,w,d,b,r} \right) x_{swdbr}
\]

\[
- \frac{1}{W} \sum_{s \in S} \sum_{w \in W} \left( t_{sw} + t_{sw}^{+} \right) - \sum_{w \in W} \sum_{m \in M} \sum_{l=0}^{n_{w}-1} \frac{u_{z,k}^{+} + u_{z,k}^{-}}{u_{z,k}^{+}}
\]

\[
| x_{swdbr} - x_{sw_{s,w_{d,b,r}}} | = y_{swdbr} \quad \forall s \in S, w \in W \setminus \{w_{m}\}, m \in M, d \in D, b \in B, r \in R
\]

\[
\sum_{s \in S} \sum_{w \in W} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} y_{swdbr} \leq \Delta_{w} \quad \forall w \in W
\]

\[
| x_{swdbr} - x_{sw_{s,w_{d,b,r}}} | = y_{swdbr} \quad \forall s \in S, w \in W_{m}, m \in M, d \in D, b \in B, r \in R
\]

\[
0 \leq f_{z,k} - \sum_{s \in S} \sum_{b \in B} \sum_{r \in R} \sum_{l=0}^{n_{w}-1} \lambda_{s,w,d,b,r} x_{s,w,d,b,r} \leq 1 \quad \forall z \in Z, k \in K: k \rightarrow (w,d), w \in W, d \in D
\]

\[
f_{z,k} + u_{z,k}^{+} - u_{z,k}^{-} = u_{z,k} \quad \forall z \in Z, k \in K
\]

\[
u_{z,k}^{+} \leq c_{z,k} - u_{z,k} \quad \forall z \in Z, k \in K
\]

\[
u_{z,k}^{+} \leq G (1 - v_{z,k}^{+}) \quad \forall z \in Z, k \in K
\]

\[
u_{z,k}^{-} \leq G v_{z,k}^{+} \quad \forall z \in Z, k \in K
\]
RESULTS

- Real Capacity

  Waiting list (%)

  Specialty capacity (%), compared to the max capacity of the specialty

Specialties at max capacity

Low compliance supply vs demand

Only 55% slots assigned

Allocated slots (%): percentage of total available slots
RESULTS

Real Capacity: Evolution of the waiting list

WL Evolution - Hospital

WL Evolution - Real Instance

✓ Capacity constraints
✓ Better management of low resources
RESULTS

- **Increased Capacity** (Real Capacity + 2 slots per doctor)

  - Waiting list (%)
  - Specialty capacity (%)
  - Allocated slots (%)

- More flexibility regarding capacity
- Better compliance supply vs demand
- About 95% slots assigned

High demand, long surgeries, 5 surgeons – difficult to match demand
### RESULTS

**Increased Capacity: Evolution of the waiting list**

- **WL Evolution - Real Instance**
- **WL Evolution - Increased Capacity**

* Assuming 100% utilization

- WL reduces for large demand specialties
- **Ophthalmology**, **General surgery**, **Orthopedics** (lower decrease)

<table>
<thead>
<tr>
<th>Specialty</th>
<th>General</th>
<th>Plastic</th>
<th>Pediatric</th>
<th>Stomathology</th>
<th>Ophtalmology</th>
<th>Orthopedics</th>
<th>ORL</th>
<th>Urology</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Doctors</td>
<td>14</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

**Diagrams**

- General
- Plastic
- Pediatric
- Stomathology
- Ophtalmology
- Orthopedics
- ORL
- Urology
RESULTS

- Increased Capacity + No Stability Constraints

Waiting list (%)

More flexibility to chase demand
Potential to schedule more patients
About 95% slots assigned
Doctors not satisfied

Specialty capacity (%)

Allocated slots (%)

No Stability Constraints: Evolution of the waiting list

- WL reduces for most specialties
- Except General surgery and Orthopedics (already reduced in IC) and Urology (4 surgeons)
- Schedules more patients
- Tradeoff nb of surgeries vs surgeons satisfaction
CONCLUSIONS

Static & old MSS
Inefficient use of OR
Long WT

Major bottleneck: workforce (mainly surgeons)
Stability constraints and workload capacity influence the compliance with the dynamic demand
FUTURE WORK

- Sensitivity analysis on stability parameters
- Predictive model for demand forecast
- Consistent models for stakeholders’ preferences
- Simulation model for an evaluation of the model at disaggregated level
- Impact of preferences in OR utilization
Reallocating operating room time: a Portuguese case

Thank you!

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