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Reallocating operating room capacity: a Portuguese case study



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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)*

THIS TALK: year 0





Continuously increasing complexity of health care organizations

Aging population
Increasing demand
New and expensive technologies



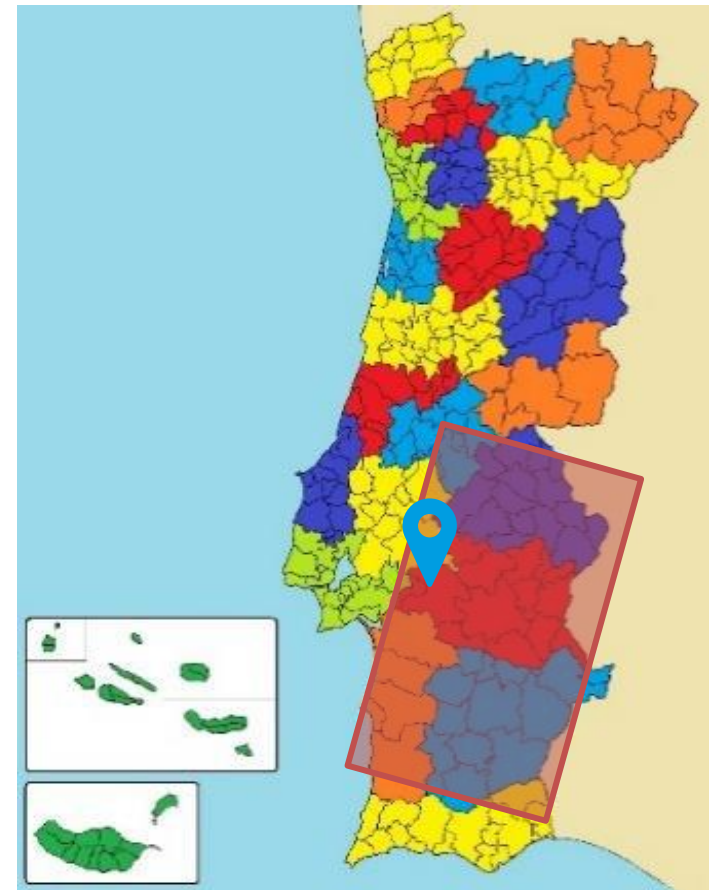
Operating rooms are the main center of costs and revenues at an hospital



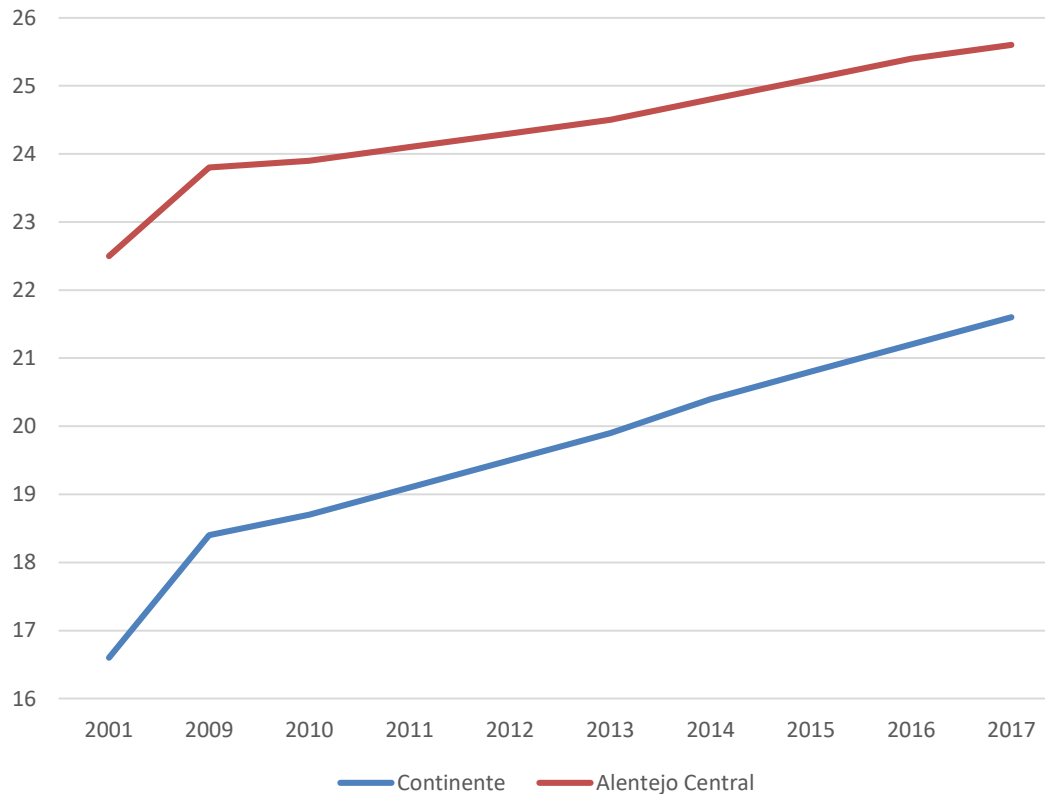
Coordination of scarce resources

Lack of surgeons
Lack of anesthesiologists
Lack of beds

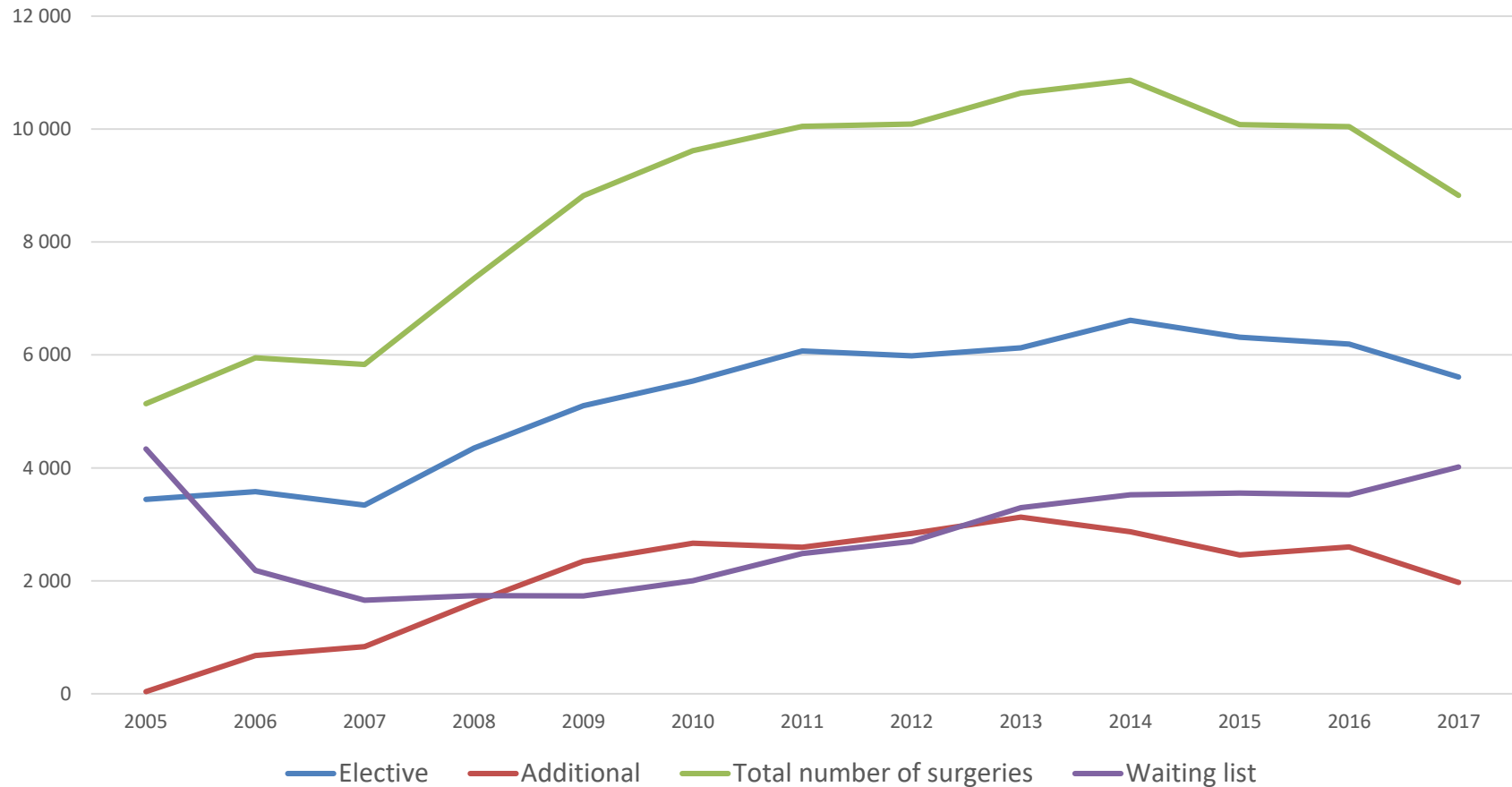
- Portuguese public hospital
 - Serves 325.237 people
 - 5 operating rooms
 - Occupancy rate 51.5%
 - 8 surgical specialties



% Resident population: 65 and older



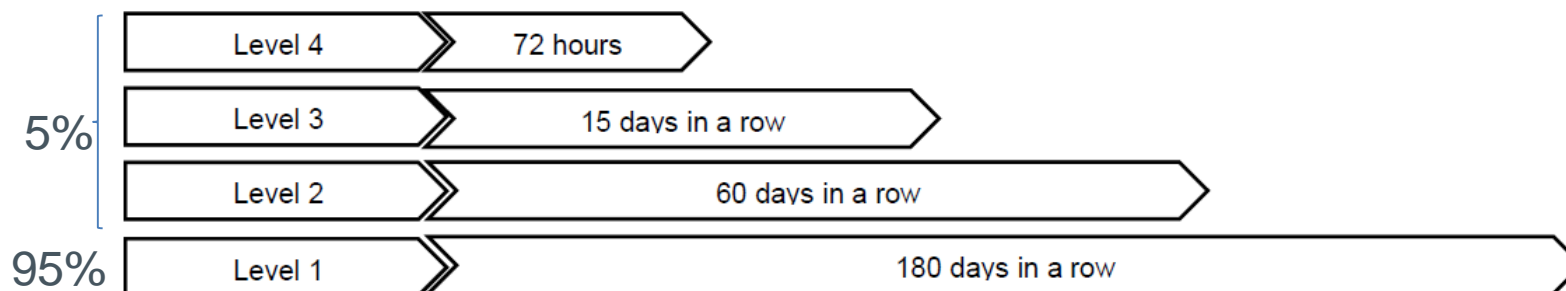
Surgical activity and Waiting list



CASE STUDY (WL 2018 Dec 28)

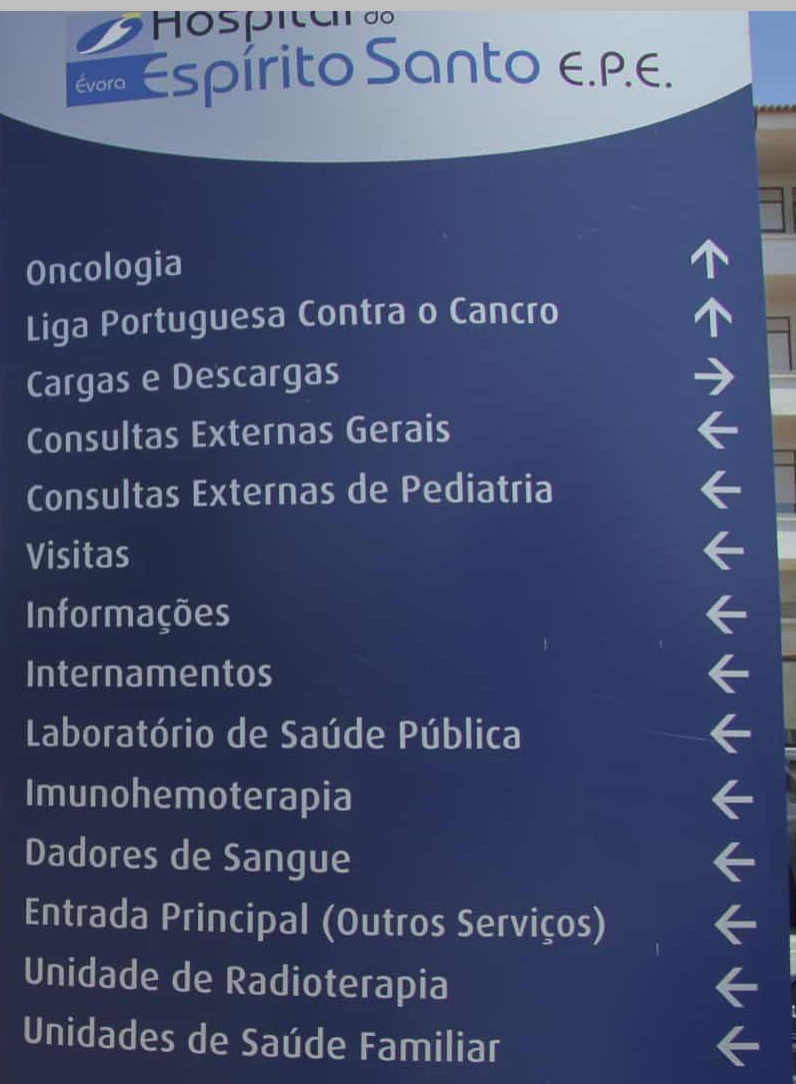
Specialty	Patients		WT ≤180 days		WT > 180		WT 181-270 days		WT 271-260 days		WT > 360 days		Surgeons
	#	%	#	%	#	%	#	%	#	%	#	%	
General	1043	36.5	745	71.4	298	28.6	91	8.7	55	5.3	151	14.5	14
Plastic	295	10.3	292	99.0	3	1.0	3	1.0	0	0	0	0	2
Stomatology	14	0.5	9	64.3	5	35.7	2	14.3	1	7.1	2	14.3	2
Ophthalmology	684	24.0	606	88.6	78	11.4	39	5.7	12	1.8	19	2.8	10
Orthopedics	240	8.4	204	85.0	36	15.0	18	7.5	7	2.9	11	4.6	5
ORL	226	7.9	104	46.0	122	54.0	21	9.3	7	3.1	94	41.6	4
Pediatric	89	3.1	88	98.9	1	1.1	1	1.1	1	1.1	0	0	2
Urology	265	9.3	117	44.2	148	55.8	20	7.5	22	8.3	106	40.0	4
Total	2856	100	2165	75.8	691	24.2	195	6.8	105	3.7	383	13.4	43

Elective surgery:



CASE STUDY

- Portuguese public hospital
 - High levels of demand
 - Low resources
- Changes in surgical demand and staff pattern
- High rates of idle OR time
- High waiting times for elective patients
- **Almost unchanged MSS for more than 30 years**



CASE STUDY

	OR1	OR2	OR3	OR4	OR5
MON	C. Geral	Urologia		Ortopedia	Oftalmologia
	C. Geral	C.Geral Tira I ou Tira II a)			
TUE	C. Geral	C. Geral		Ortopedia	Oftalmologia
	C. Mama	C. Plástica			Oftalmologia
WED	C. Plástica	C. Pediátrica		Ortopedia	Oftalmologia
	C. Ger. Varizes		O.R.L.		
THU	C. Geral	C. Geral		Ortopedia	Oftalmologia
		Urologia	O.R.L.		
FRI	C. Geral	Estomat. ^{b)}		Ortopedia	Oftalmologia
		Implantofix ^{c)}			c/ locais



- Capacity planning - MSS
 - Tactical (aggregate) level
- Long planning horizon
- MSS stability
- 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





SURGICAL TEAM
PREFERENCES



BALANCE SUPPLY AND
DEMAND



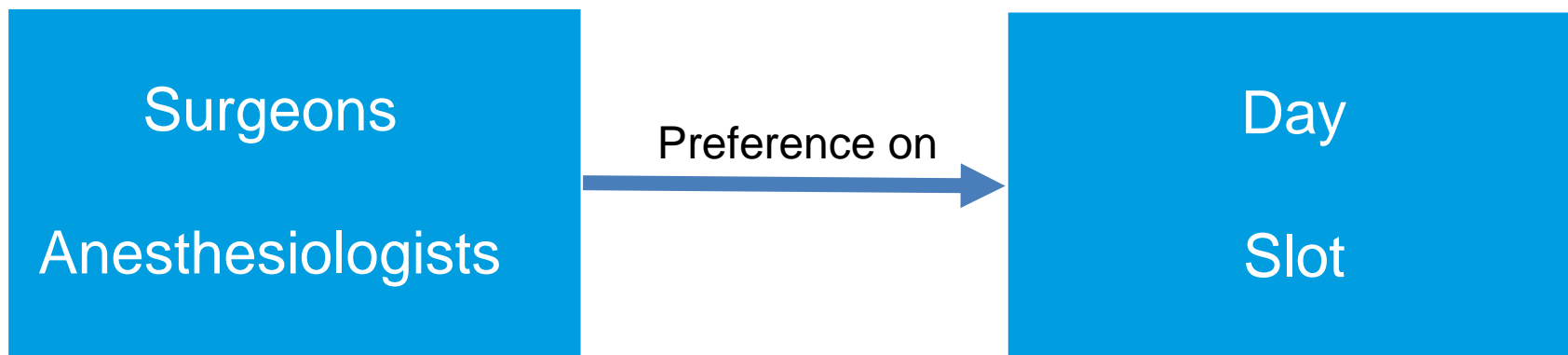
UP- AND DOWNSTREAM
UNITS WORKLOAD

LITERATURE REVIEW

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



SURGICAL TEAM PREFERENCES





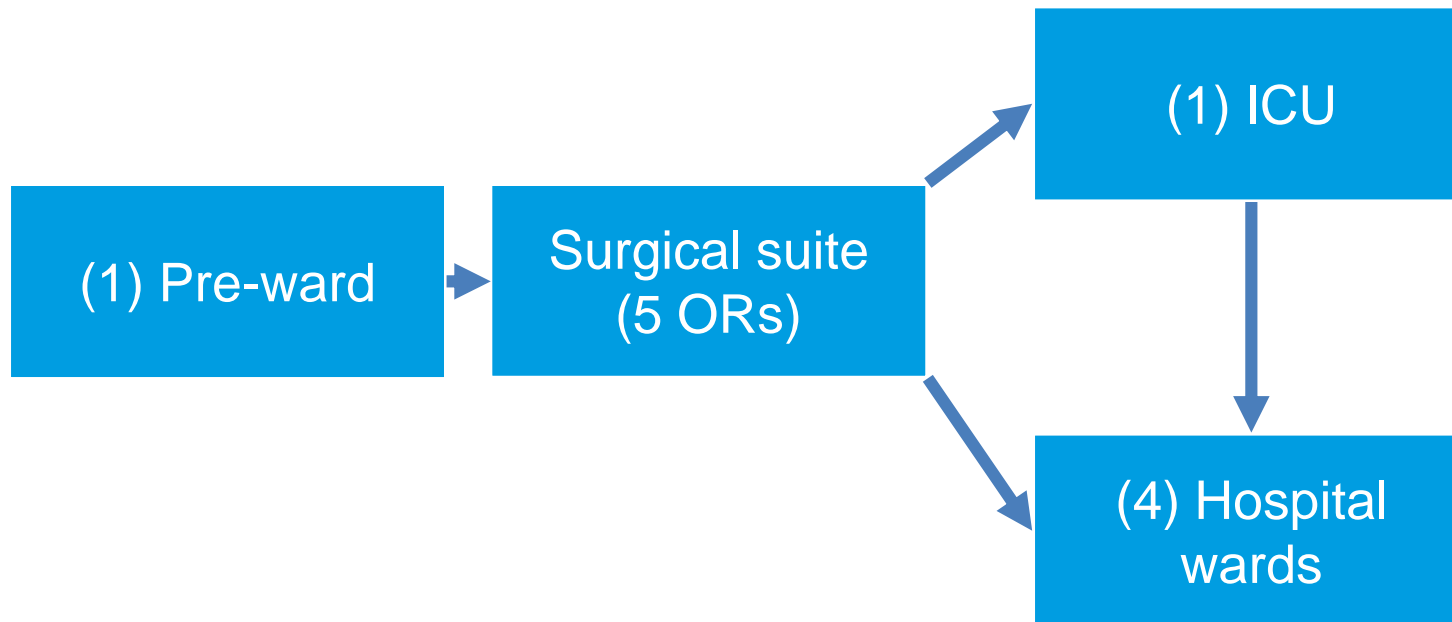
BALANCE SUPPLY AND DEMAND

WL in 28-12-2018

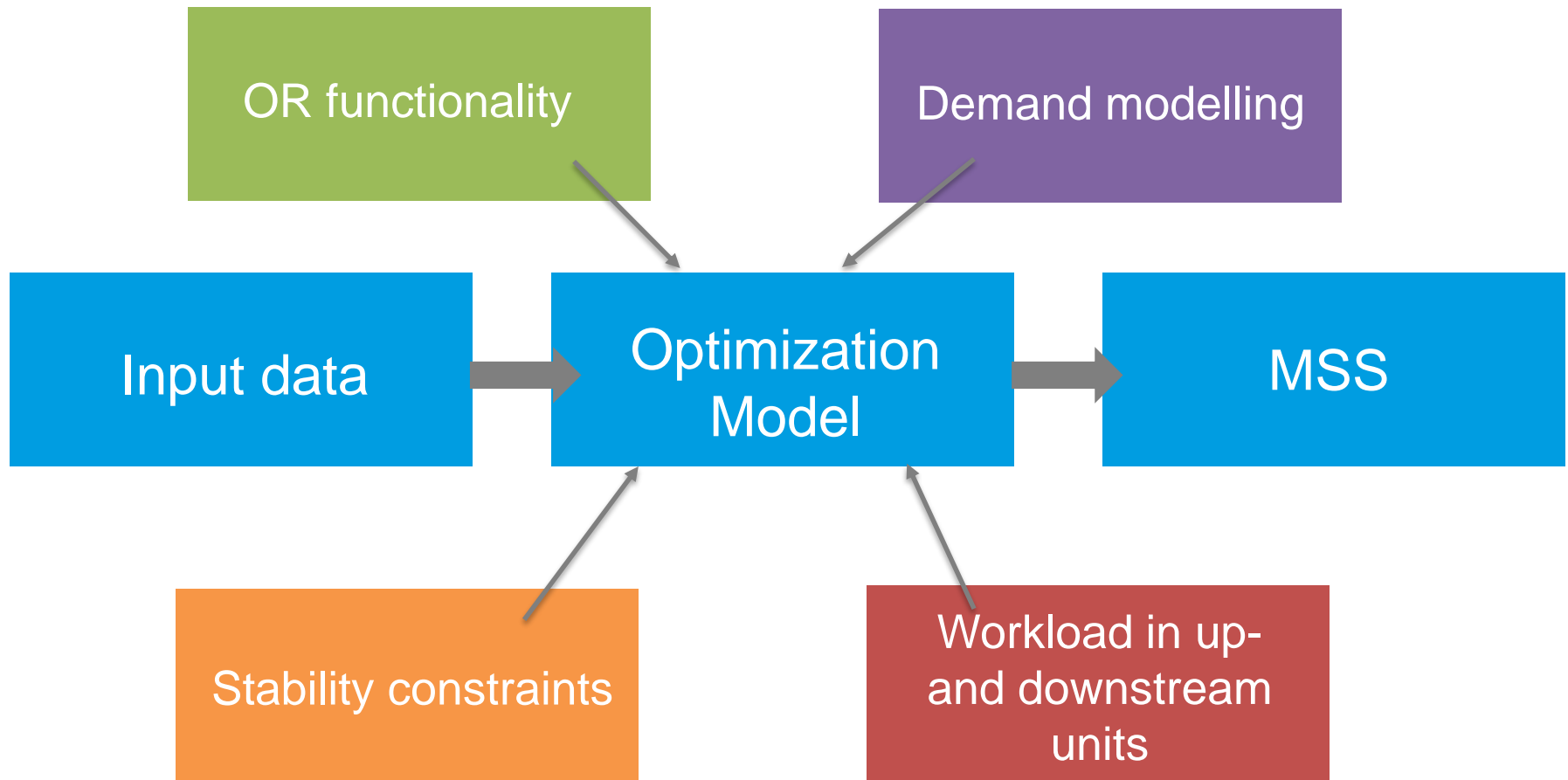
Specialties	% Overall WL length (WL)	% Overall WL duration (WD)	% Allocated blocks (AB)	Difference (WL-AB)	Difference (WD-AB)
General	36.5 %	48.6 %	37.2 %	- 0.7 %	11.4 %
Plastic	10.3 %	8.6 %	6.6 %	3.7 %	2.0 %
Stomatology	0.5 %	0.3 %	0.3 %	0.2 %	0.0 %
Ophthalmology	24.0 %	13.6 %	18.6 %	5.4 %	-5.0 %
Orthopedics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



UP- AND DOWNSTREAM UNITS WORKLOAD



Gaps: 0.21-2.34 30min CPU



OR Functionality

$$\sum_{s \in S} x_{swdbr} \leq 1 \quad \forall w \in W, d \in D, b \in B, r \in R$$

$$\sum_{s \in S} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} x_{swdbr} \leq slot_{sw} \quad \forall w \in W$$

$$\delta^{surg} \sum_{r \in R} x_{swdbr} \leq a_{swdb}^{surg} \quad \forall s \in S, w \in W, d \in D, b \in B$$

$$\delta^{surg} \sum_{b \in B} \sum_{r \in R} x_{swdbr} \leq \sum_{i \in I_s} a_{iwd}^{surgD} \quad \forall s \in S, w \in W, d \in D$$

$$\delta^{surg} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} x_{swdbr} \leq \sum_{i \in I_s} ww_i^{surg} \quad \forall s \in S, w \in W$$

$$\delta^{anest} \sum_{s \in S} \sum_{r \in R} x_{swdbr} \leq a_{wdb}^{anest} \quad \forall w \in W, d \in D, b \in B$$

$$\delta^{anest} \sum_{s \in S} \sum_{b \in B} \sum_{r \in R} x_{swdbr} \leq \sum_{a \in A} a_{awd}^{anestD} \quad \forall w \in W, d \in D$$

$$\delta^{anest} \sum_{s \in S} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} x_{swdbr} \leq \sum_{a \in A} ww_a^{anest} \quad \forall w \in W$$

$$\sum_{w \in W_m} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} x_{swdbr} \geq mw_{sm} \quad \forall s \in S, m \in M$$

- One specialty in each slot
- Total OR capacity/constraints
- Portuguese legislation
- Staff availability
- Maximum number of slots for staff
- Minimum number of slots for specialty

Demand modelling

$$p_{sw} = p_{s,w-1} + ent_{s,w-1} - \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} \lambda_s x_{s,w-1,d,b,r} \quad \forall s \in S, w \in W \setminus \{1\}$$

$$p_{s1} = inic_s \quad \forall s \in S$$

$$t_{sw} = p_{sw} dur_s \quad \forall s \in S, w \in W$$

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

- Demand definition
 - Number of patients in the waiting list
 - Expected duration of surgeries
- Waiting list evolution
 - Weekly
 - Past results
 - New entries forecast

Stability

$$|x_{swdbr} - x_{sw_{1m}dbr}| = y_{swdbr} \quad \forall s \in S, w \in W_m \setminus \{w_{1m}\}, m \in M, d \in D, \\ b \in B, r \in R$$

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

$$|x_{swdbr} - x_{sl dbr}| = j_{swdbr} \quad \forall s \in S, w \in W_m, m \in M \setminus \{1\}, \\ l = w - \sum_{g < m} |W_g|, d \in D, b \in B, r \in R$$

$$\sum_{s \in S} \sum_{w \in W_m} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} j_{swdbr} \leq \Delta_m \quad \forall m \in M$$

- Monthly differences number in MSS
- Weekly differences number in MSS
- Maximum number of monthly differences
- Maximum number of weekly differences

Up and downstream units

$$0 \leq f_{zk} - \sum_{s \in S_z} \sum_{b \in B} \sum_{r \in R} \sum_{l=0}^{n_{zs}-1} \lambda_s e_{zsk} x_{s,w,d \pm l,b,r} \leq 1 \quad \forall z \in Z, k \in K : k \rightarrow (w,d),$$

$$w \in W, d \in D$$

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

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

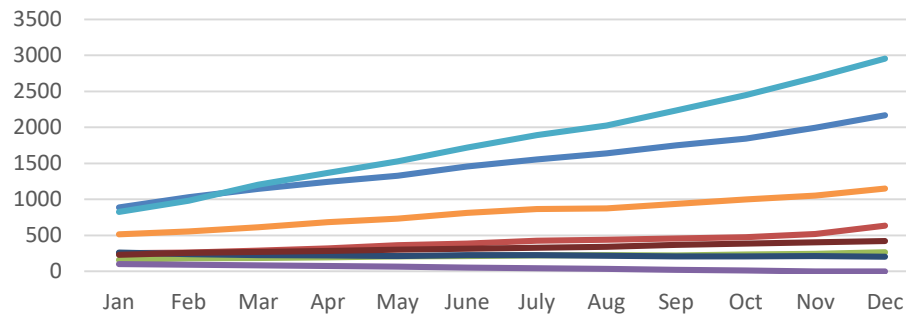
$$u_{zk}^- \leq G(1 - v_{zk}^u) \quad \forall z \in Z, k \in K$$

$$u_{zk}^+ \leq G v_{zk}^u \quad \forall z \in Z, k \in K$$

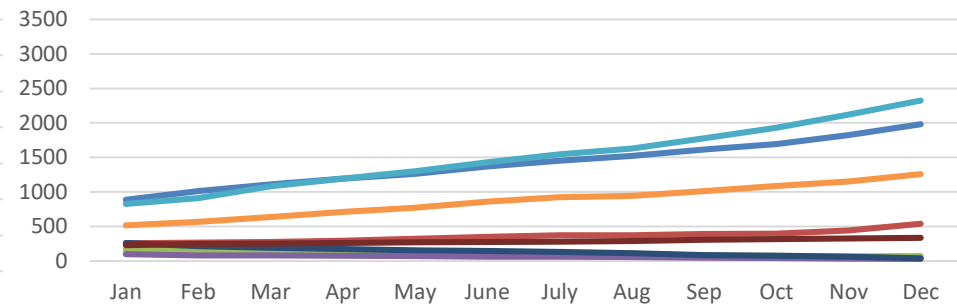
- Expected number of patients in pre-ward
- Expected number of patients in each ward
 - Specialty wards
- Overutilization definition
- Underutilization definition

■ Real Capacity

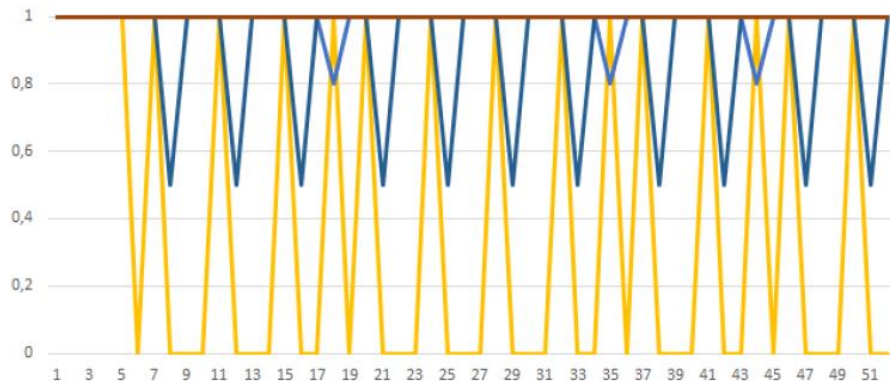
WL Evolution - Hospital



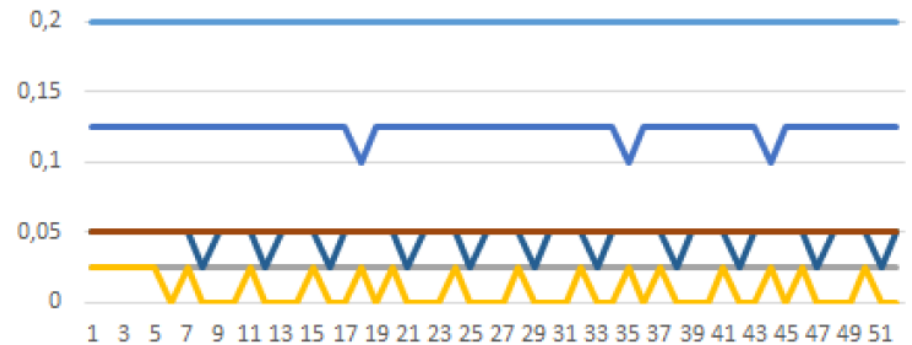
WL Evolution - Real Instance



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

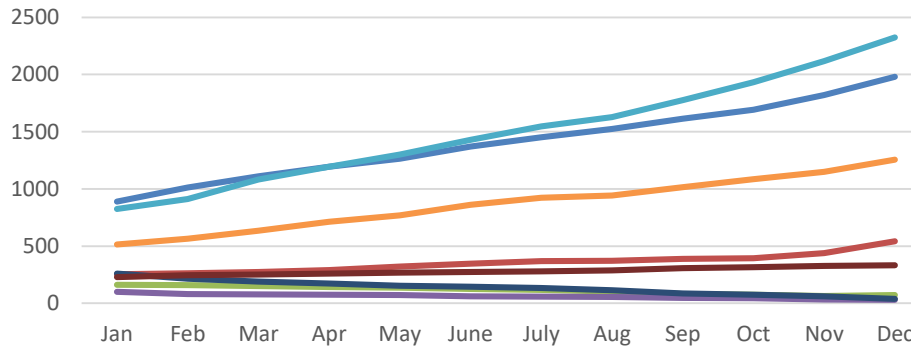


Allocated slots (%): percentage of total available slots

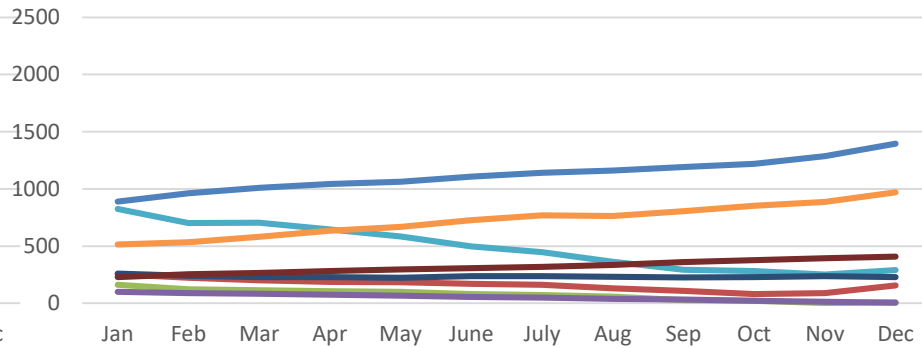


■ Increased Capacity (Real Capacity + 2 slots per doctor)

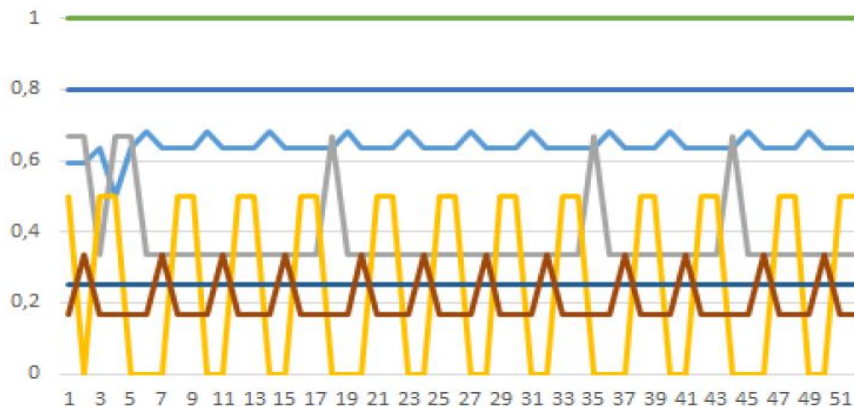
WL Evolution - Real Instance



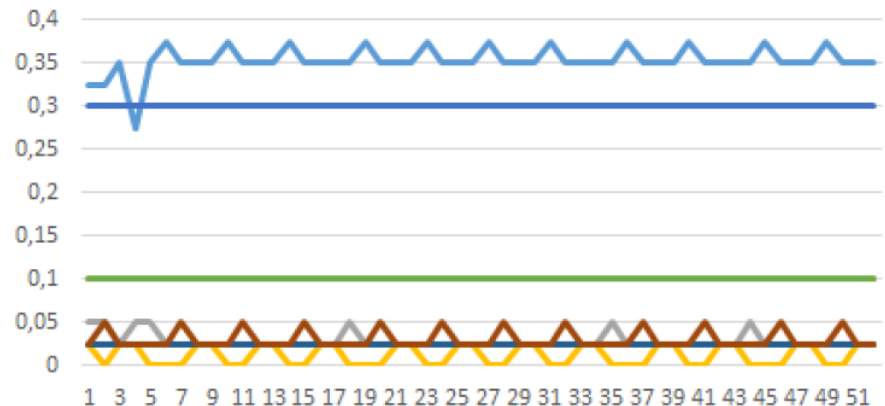
WL Evolution - Increased Capacity



Specialty capacity (%)

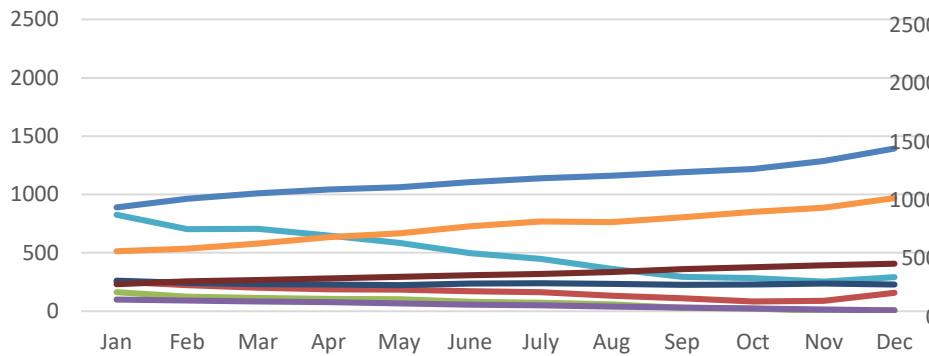


Allocated slots (%)

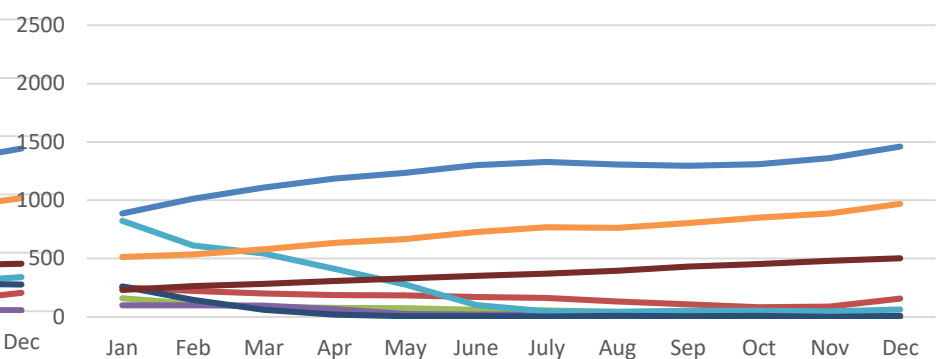


■ Increased Capacity + No Stability Constraints

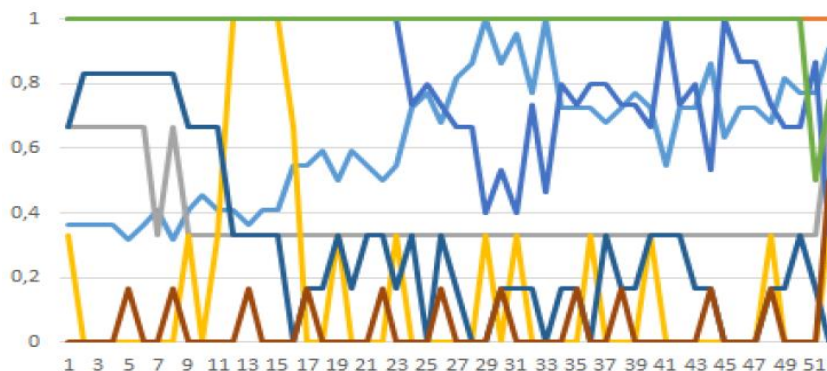
WL Evolution - Increased Capacity (IC)



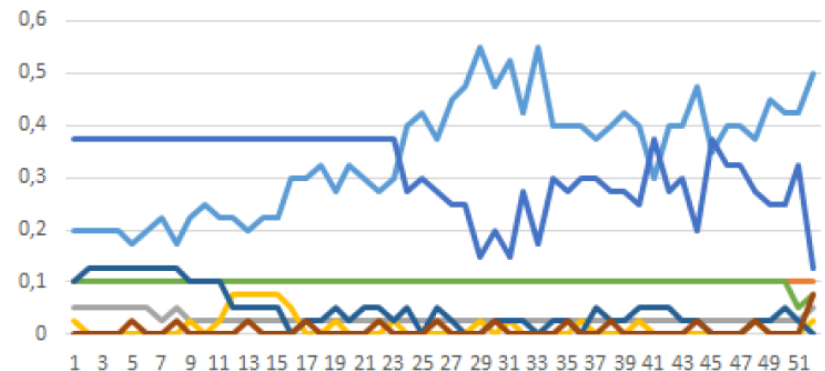
WL Evolution – IC without Stability



Specialty capacity (%)



Allocated slots (%)



Static old MSS
Inefficient use of OR
Long WT



Major bottleneck: workforce (mainly surgeons)

- Real Instance

- Increased Instance

- Increased Instance without Stability



Specialties at max capacity



Low compliance supply vs demand



Only 55% slots assigned



More flexibility regarding capacity



Better compliance supply vs demand



About 95% slots assigned



More flexibility to chase demand



Potential to schedule more patients



About 95% slots assigned



Doctors not satisfied

Predictive model
for demand
forecast

Consistent
models for
stakeholders'
preferences

Sensitivity
analysis on
stability
parameters

Simulation model
for an evaluation
of the model at
disaggregated
level

Impact of
preferences in OR
utilization

Reallocating operating room time: a Portuguese case

Obrigada!

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