



**TÉCNICO**  
LISBOA



# Reallocating operating room time: a Portuguese case



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CENTRO HOSPITALAR  
LISBOA NORTE, EPE



HOSPITAL DE  
SANTAMARIA



- 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

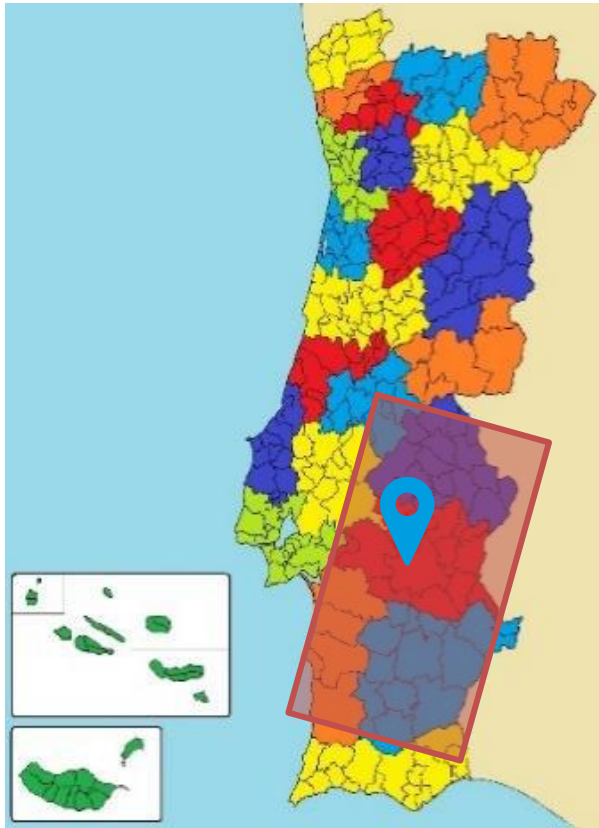


Operating rooms are the main center of costs and revenues at an hospital

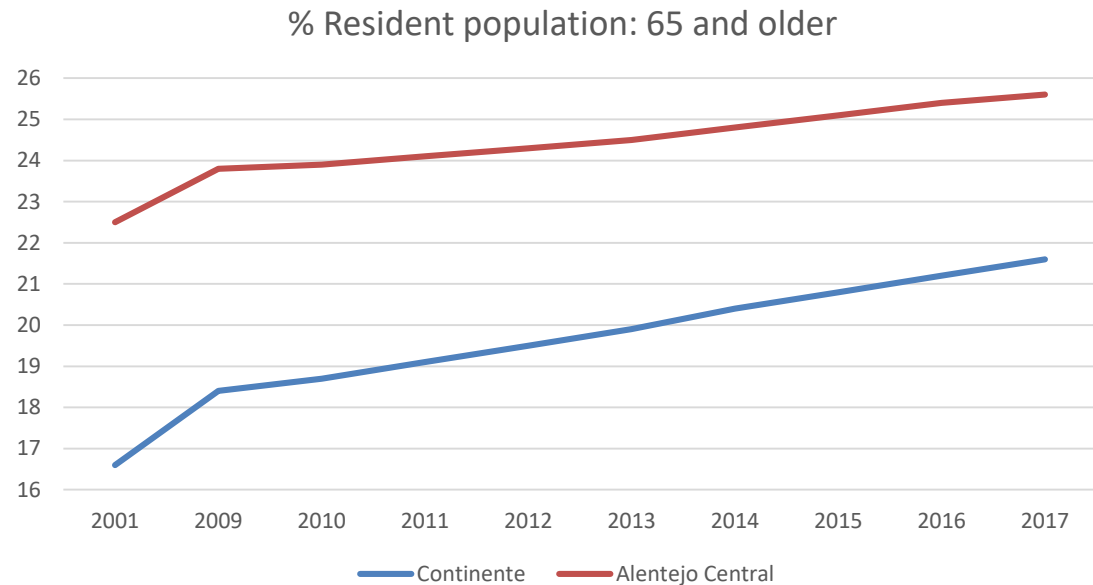


Coordination of scarce resources

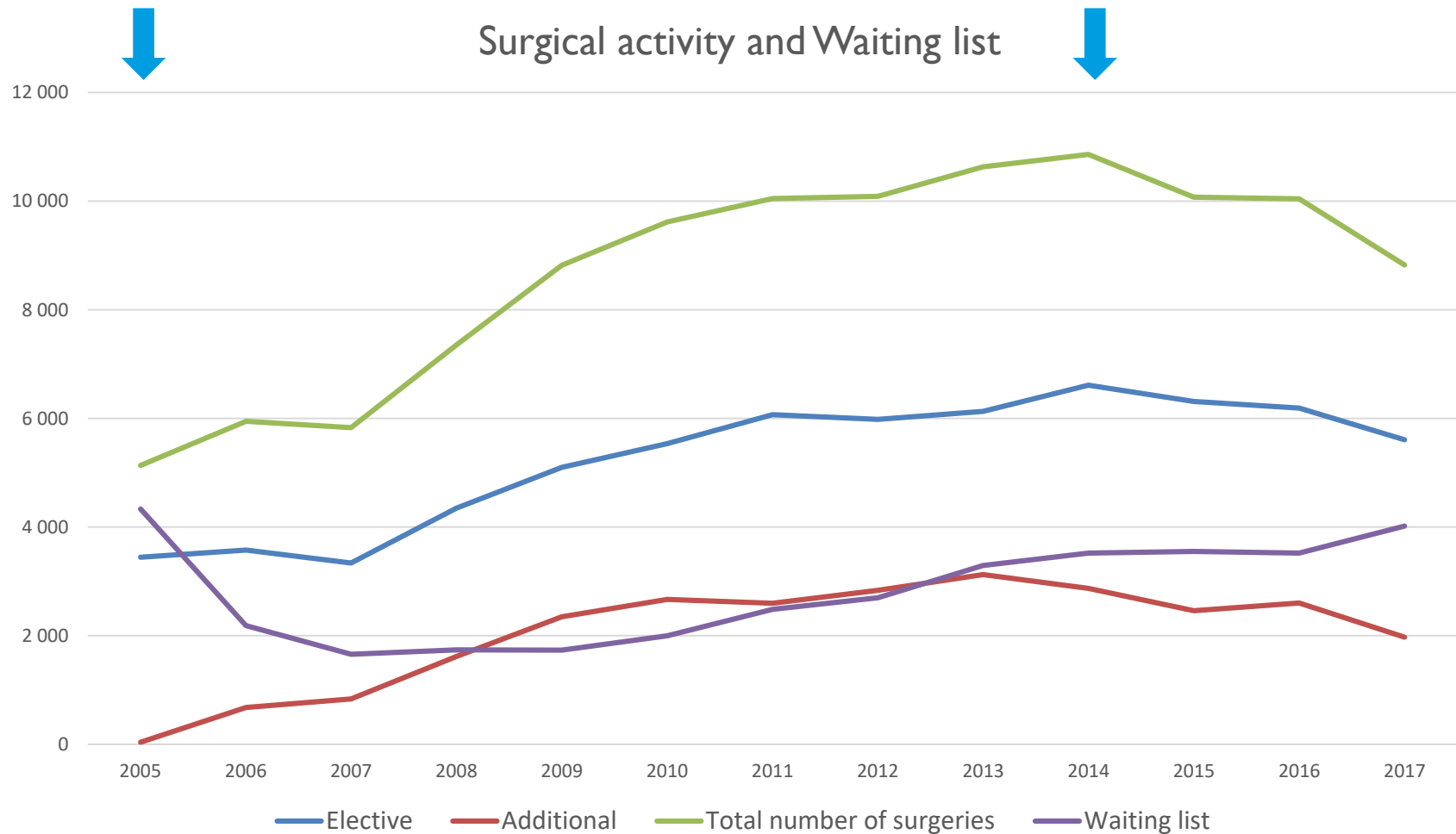
Lack of surgeons  
Lack of anesthesiologists  
Lack of beds



Influence area of  
the hospital  
(325.237 people)



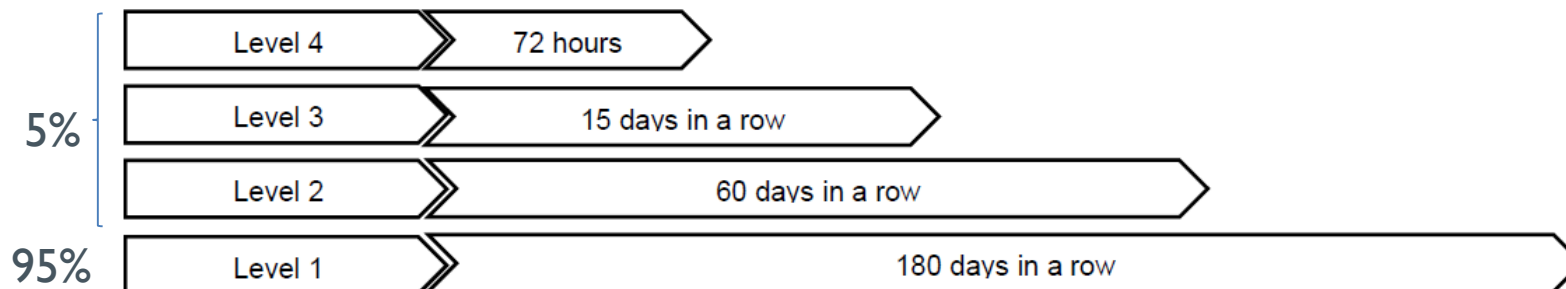
- Évora: 27.22% of population are 65 years old and over (2011)
- For each 100 young people, there are 206.1 elderly people in Central Alentejo (2017)



# 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
<b>Total</b>	<b>2856</b>	<b>100</b>	<b>2165</b>	<b>75.8</b>	<b>691</b>	<b>24.2</b>	<b>195</b>	<b>6.8</b>	<b>105</b>	<b>3.7</b>	<b>383</b>	<b>13.4</b>	<b>43</b>

## Elective surgery:




Indicators	OR 1	OR 2	OR 3	OR 4	OR 5	Total
Number of weekly allocated hours	48	48	12	30	36	198
Average weekly number of used hours	31.9	33.6	10	21	2.4	102
Occupancy rate	66.5%	70.0%	83.3%	70.0%	6.7%	51.5%

Bed pool	Specialties	Number of beds
Surgery 1	General, plastic, estomatology	47
Surgery 2	General, estomatology, urology	28
Surgery 3	Orthopedic, ophthalmology, ORL	47
Pediatric surgery	Pediatrics	18
Total		140

# 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



Hospital do  
Évora **Espírito Santo** E.P.E.

Oncologia	↑
Liga Portuguesa Contra o Cancro	↑
Cargas e Descargas	→
Consultas Externas Gerais	←
Consultas Externas de Pediatria	←
Visitas	←
Informações	←
Internamentos	←
Laboratório de Saúde Pública	←
Imunohemoterapia	←
Dadores de Sangue	←
Entrada Principal (Outros Serviços)	←
Unidade de Radioterapia	←
Unidades de Saúde Familiar	←



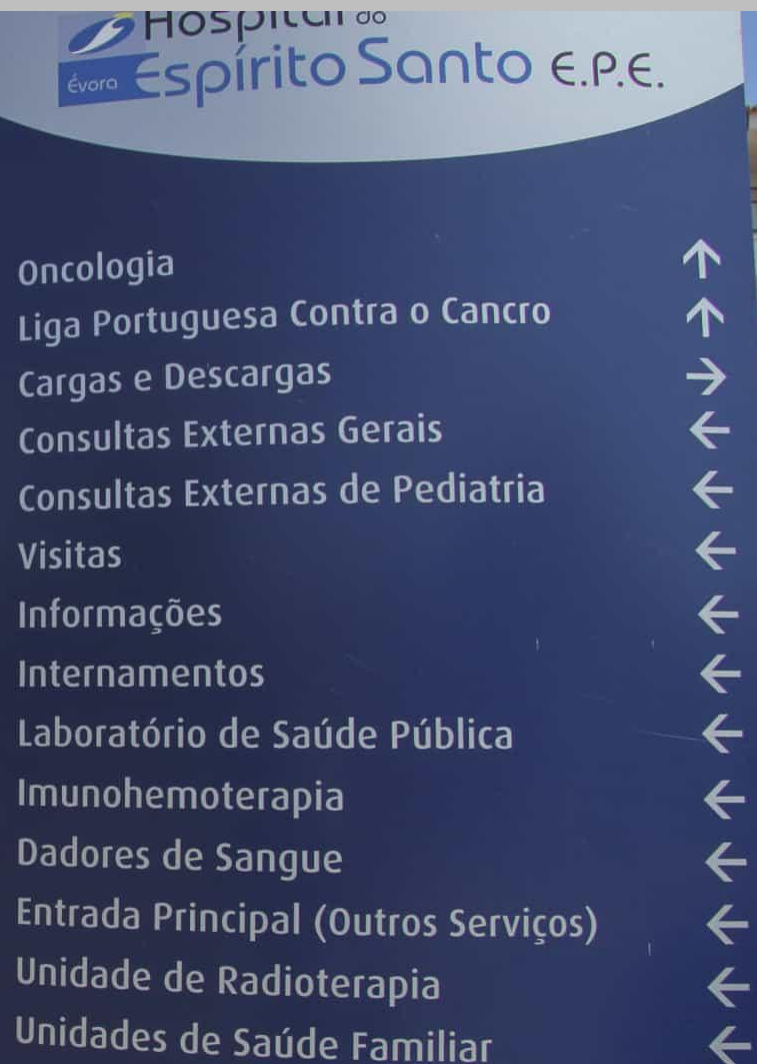
# CASE STUDY

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



# CASE STUDY

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Unidades de Saúde Familiar	←

- 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





SURGICAL TEAM  
PREFERENCES



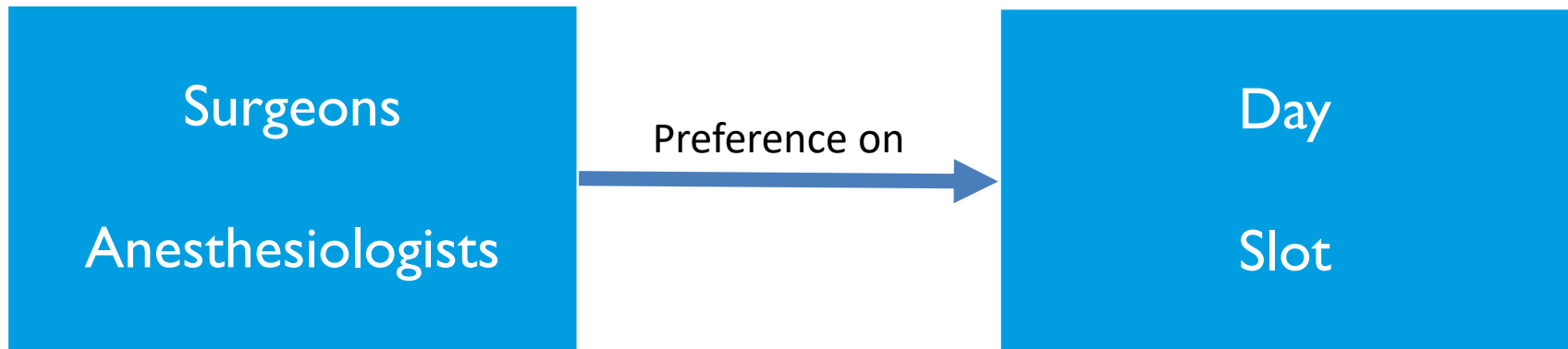
BALANCE SUPPLY AND  
DEMAND



UP- AND DOWNSTREAM  
UNITS WORKLOAD



## SURGICAL TEAM PREFERENCES





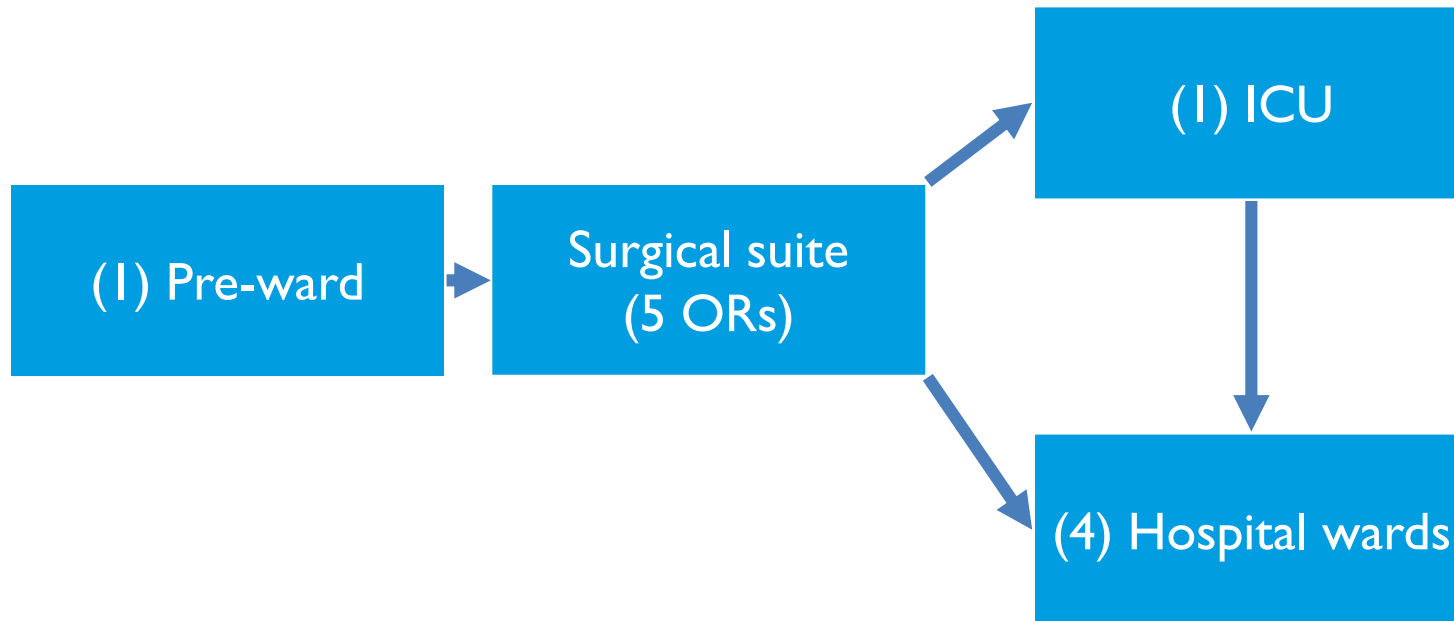
## BALANCE SUPPLY AND DEMAND

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 %
Ophtalmology	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 %

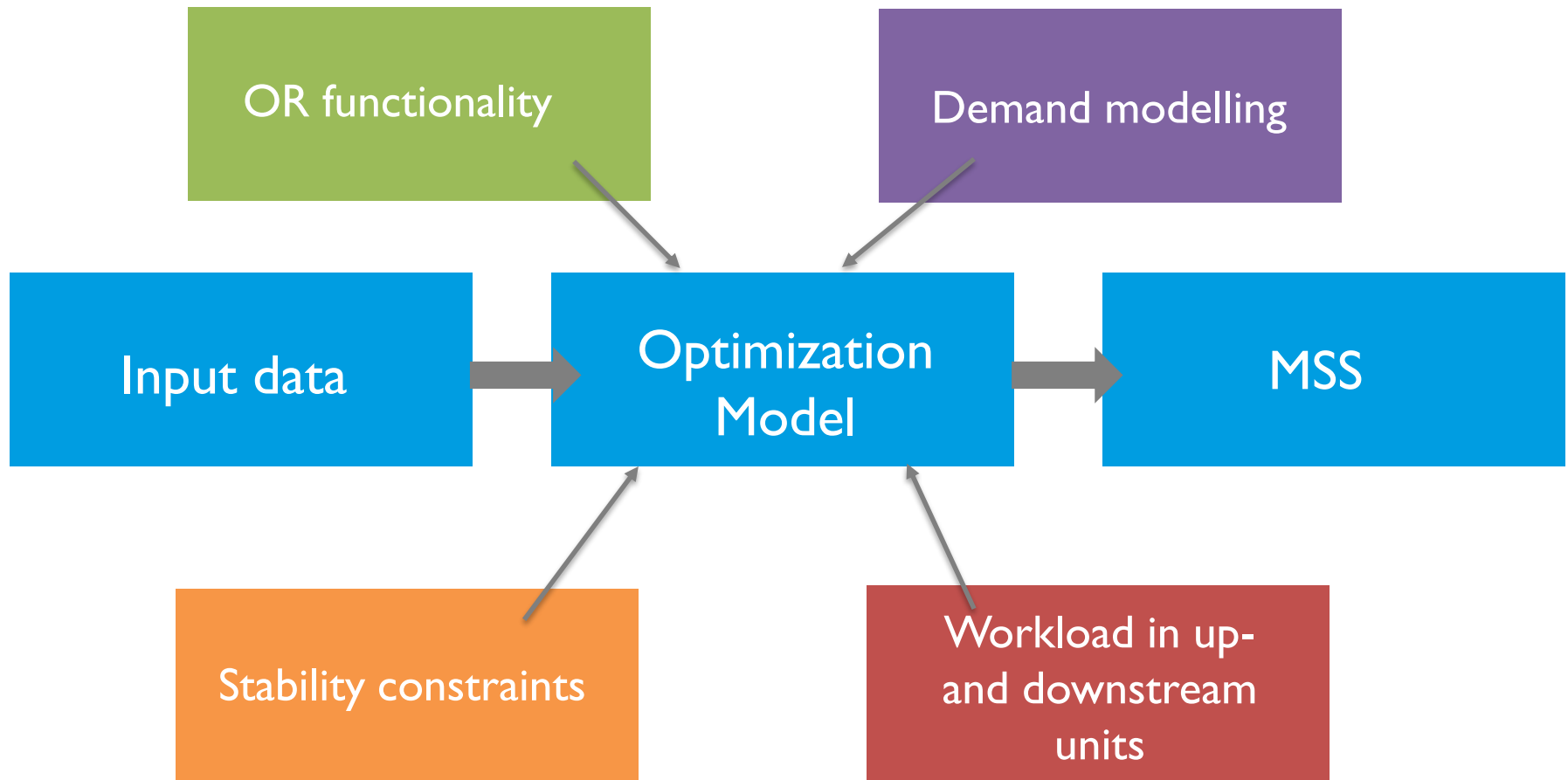


## UP- AND DOWNSTREAM UNITS WORKLOAD



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 PEF			
Marques et al. (2019)			MIN VARIABILITY	MAX STAB
<b>OUR PROPOSAL</b>	<b>SURG + ANEST PEF</b>	<b>OR TIME</b>	<b>TARGET WORK + CAP</b>	<b>STAB CONSTRAINT</b>





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

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

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

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

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

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

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

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

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

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

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

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

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

Input  
data

$$\max \sum_{s \in S} \sum_{w \in W} \sum_{d \in D} \sum_{b \in B} \sum_{r \in R} \left( \frac{\sum_{i \in I_s} \kappa_{idb}^{surg}}{|I|} + \frac{\sum_{a \in A} \kappa_{adb}^{anest}}{|A|} \right) x_{swdbr}$$

$$- \frac{1}{|W|} \sum_{s \in S} \sum_{w \in W} (t_{sw}^- + t_{sw}^+) - \sum_{z \in Z} w_z \sum_{k \in K} \frac{u_{zk}^- + u_{zk}^+}{u_{zk}}$$

	OR1	OR2	OR3	OR4	OR5
MON	C. Geral	Urologia		Ortopedia	Oftalmologia
	C. Geral	C. Geral Tira I ou Tira II a)	Urgência		
TUE	C. Geral	C. Geral	Urgência	Ortopedia	Oftalmologia
	C. Mama	C. Plástica			Oftalmologia
WED	C. Plástica	C. Pediátrica	Urgência	Ortopedia	Oftalmologia
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THU	C. Geral	C. Geral	Urgência	Ortopedia	Oftalmologia
	Urgência	Urologia	O.R.L.		
FRI	C. Geral	Estomat. <sup>5)</sup> Implantofix <sup>6)</sup>	Urgência	Ortopedia	Oftalmologia c/ locais

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

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

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

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

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

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

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

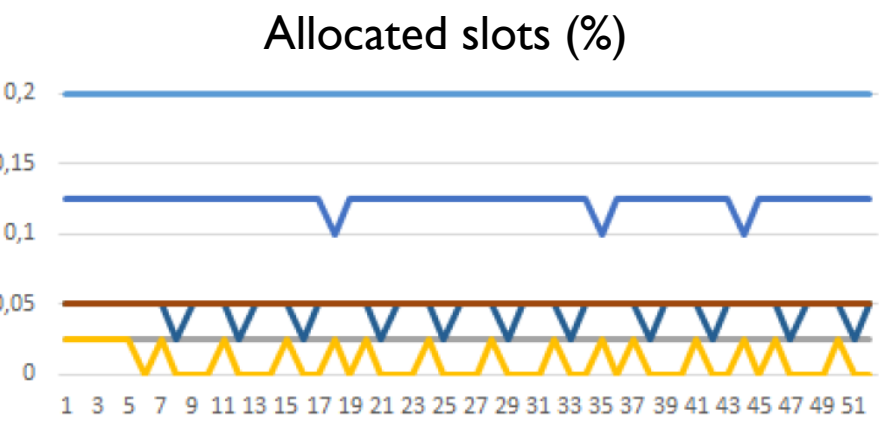
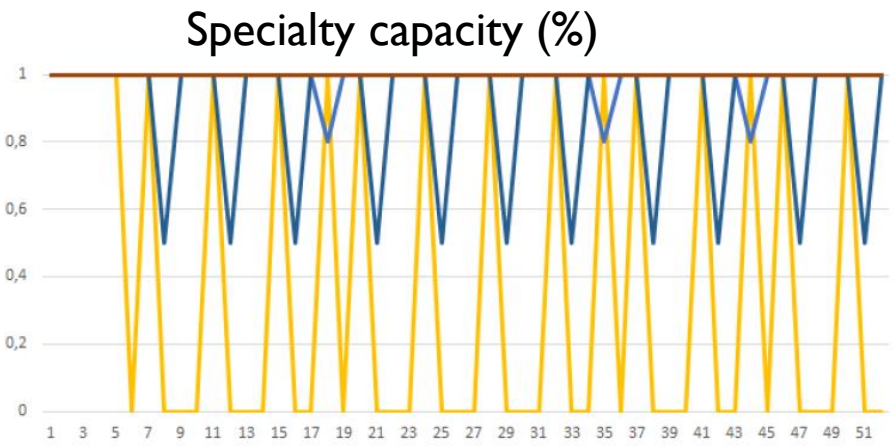
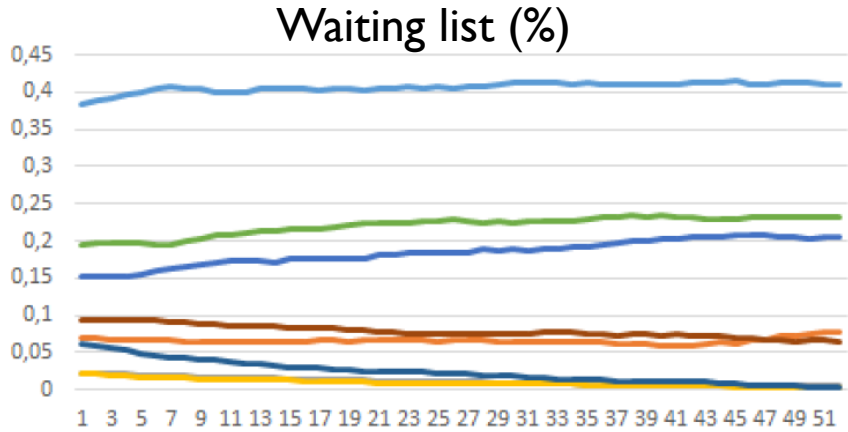
$$u_{zk}^- \leq G(1 - v_{zk}^u) \quad \forall z \in Z, k \in K$$

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

## Real Capacity

Low demand

High demand, short surgeries, high resources consumption



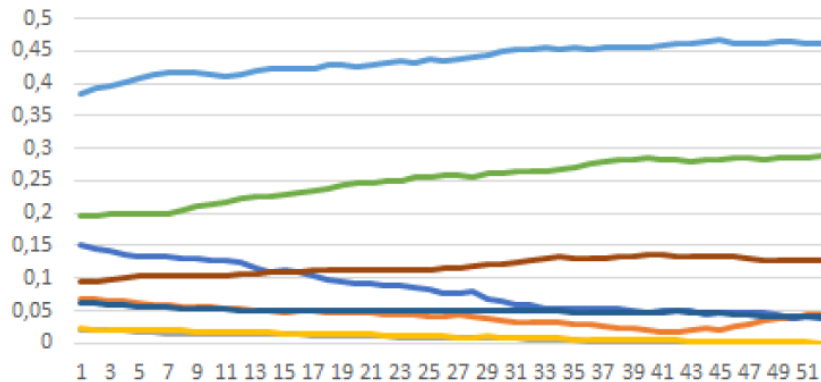
- Specialties at max capacity
- Low compliance supply vs demand
- Only 55% slots assigned

— General surgery    — Plastic surgery    — Pediatric  
— Stomatology    — Ophthalmology    — Orthopedics  
— ORL    — Urology

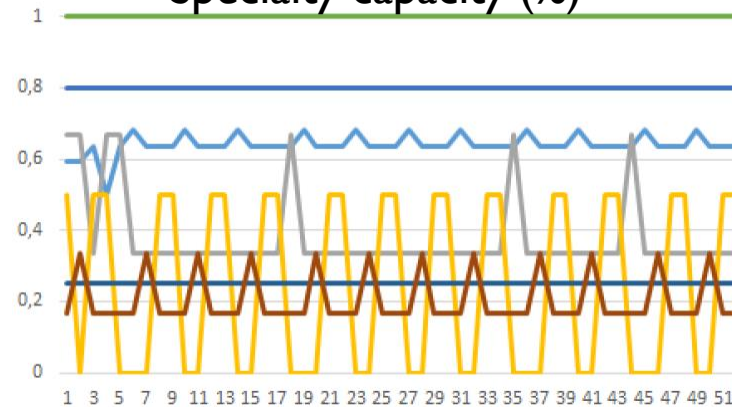
High demand, long surgeries, 5 surgeons – difficult to match demand

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

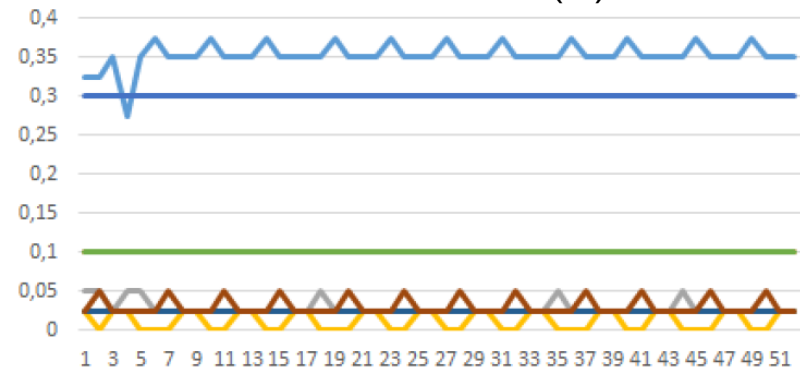
### Waiting list (%)



### Specialty capacity (%)



### Allocated slots (%)



— General surgery    — Plastic surgery    — Pediatric  
— Stomatology    — Ophthalmology    — Orthopedics  
— ORL    — Urology



More flexibility regarding capacity



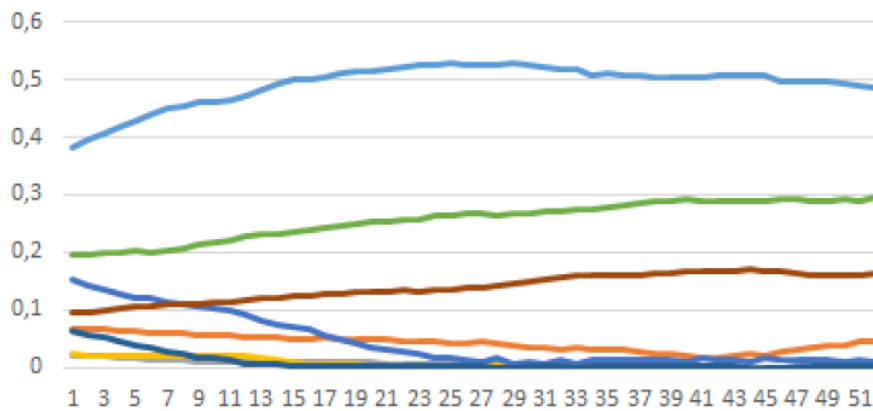
Better compliance supply vs demand



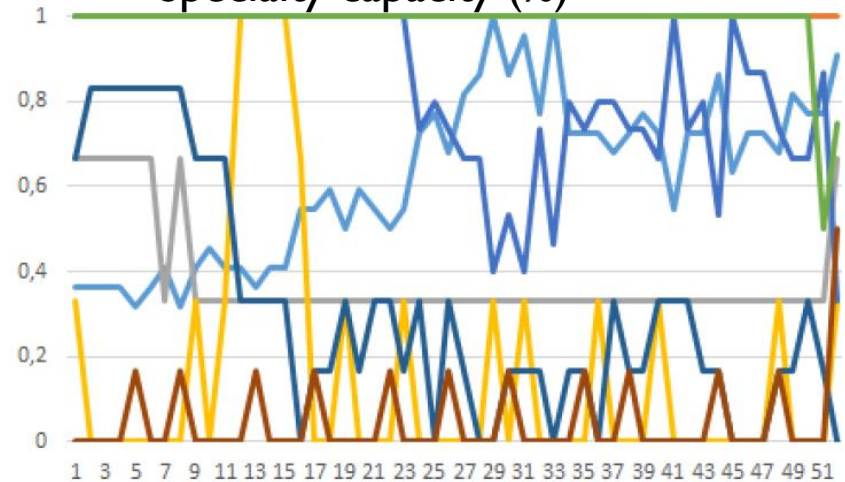
About 95% slots assigned

## ■ Increased Capacity + No Stability Constraints

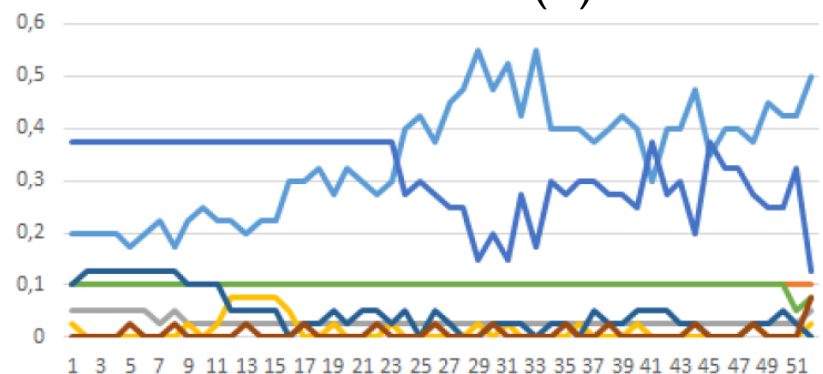
Waiting list (%)



Specialty capacity (%)



Allocated slots (%)



More flexibility to chase demand



Potential to schedule more patients



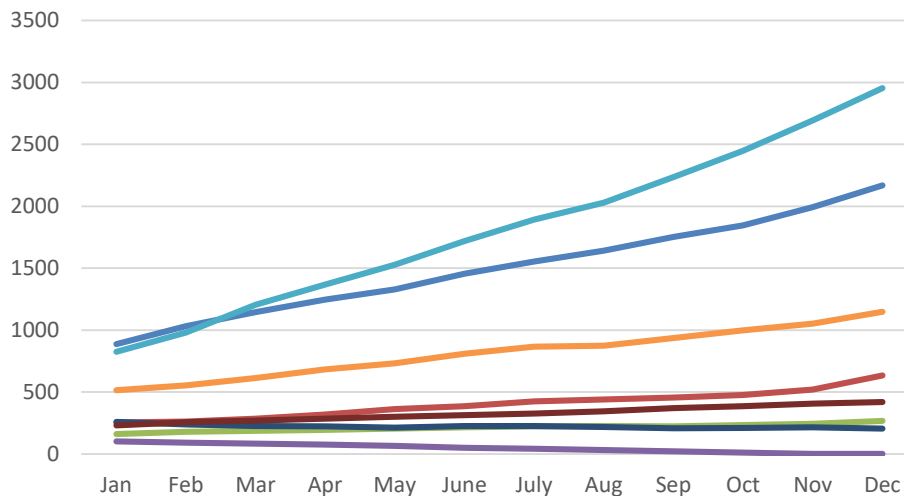
About 95% slots assigned



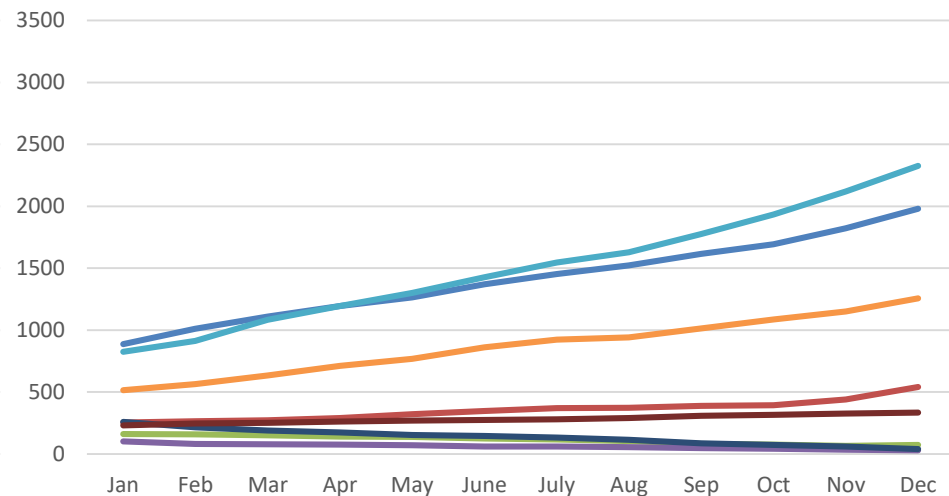
Doctors not satisfied

## ■ Real Capacity: Evolution of the waiting list

WL Evolution - Hospital



WL Evolution - Real Instance

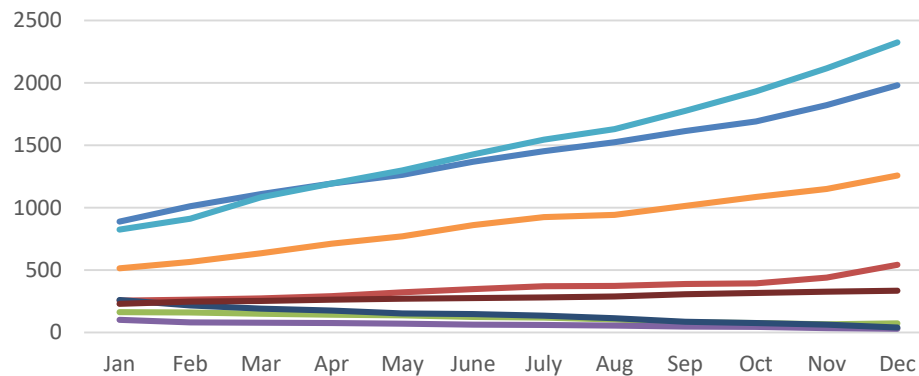


- ✓ Results are about the same – no decrease in the overall WL
- ✓ Slight increase in specialties with more patients in the WL

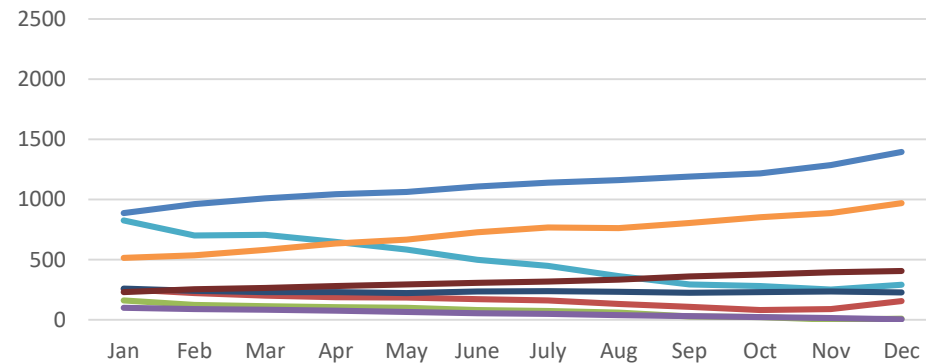


## ■ Increased Capacity: Evolution of the waiting list

WL Evolution - Real Instance\*



WL Evolution - Increased Capacity



\* Assuming 100% utilization

✓ WL reduces for large demand specialties

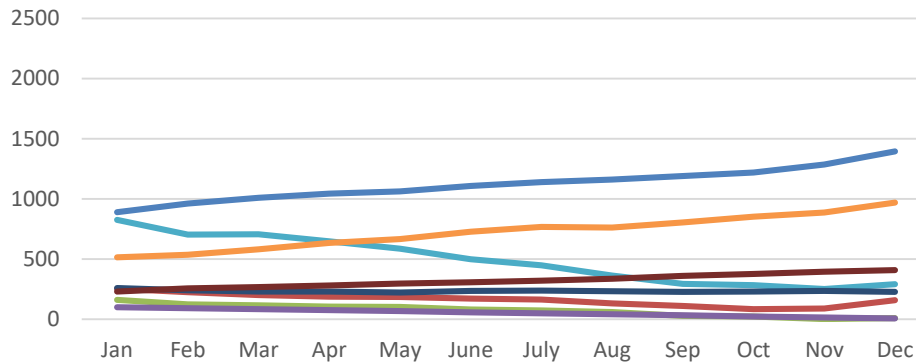
✓ Ophthalmology, General surgery, Orthopedics

Specialty	General	Plastic	Pediatric	Stomatology	Ophtalmology	Orthopedics	ORL	Urology
#Doctors	14	2	2	2	10	5	4	4

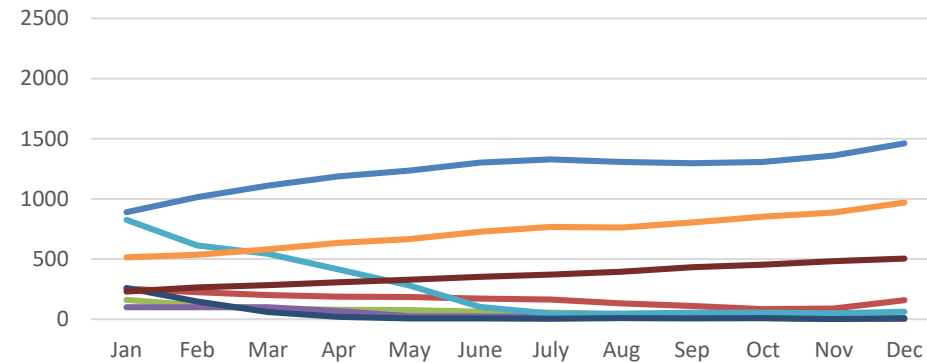
— General     — Plastic     — Pediatric     — Stomatology  
— Ophthalmology     — Orthopedics     — ORL     — Urology

## ■ No Stability Constraints: Evolution of the waiting list

WL Evolution - Increased Capacity (IC)



WL Evolution – IC without Stability



- ✓ WL reduces for most specialties
- ✓ Except **General surgery** and **Orthopedics** (already reduced in IC) and **Urology** (4 surgeons)





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

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

## Thank you!

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PORTUGAL  
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