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Facing dynamic demand for surgeries in a Portuguese case study



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Portugal



Introduction

ImproveOR project



Motivation

Case Study



Problem Description

Objectives, Literature Review,
Methodology, Model



Preliminary results



Conclusions



Future work

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

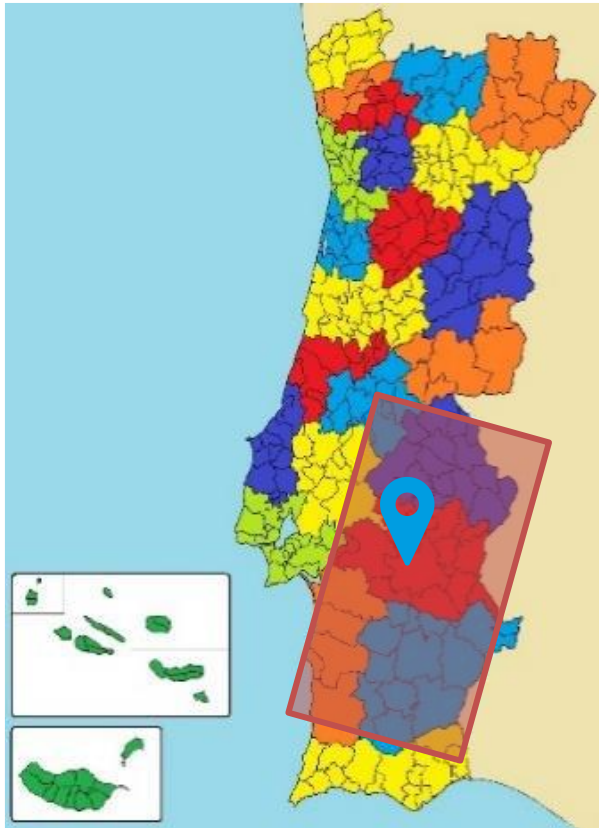


Operating rooms are the main center of costs and revenues at an hospital

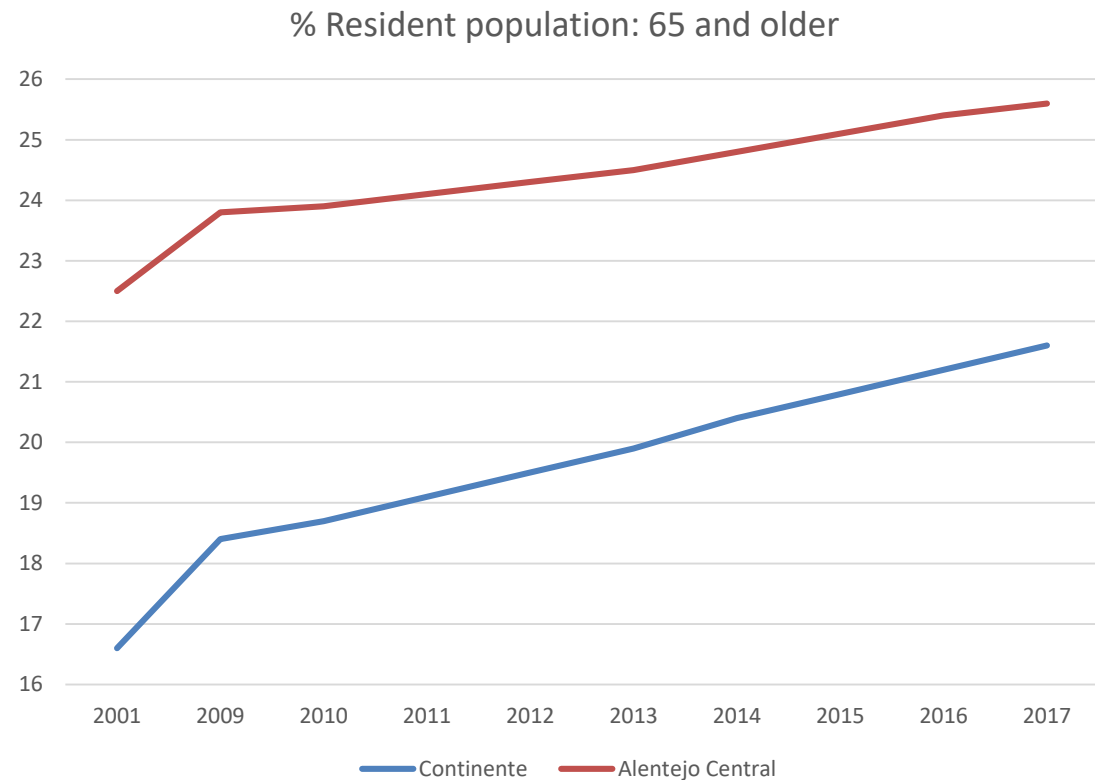


Coordination of scarce resources

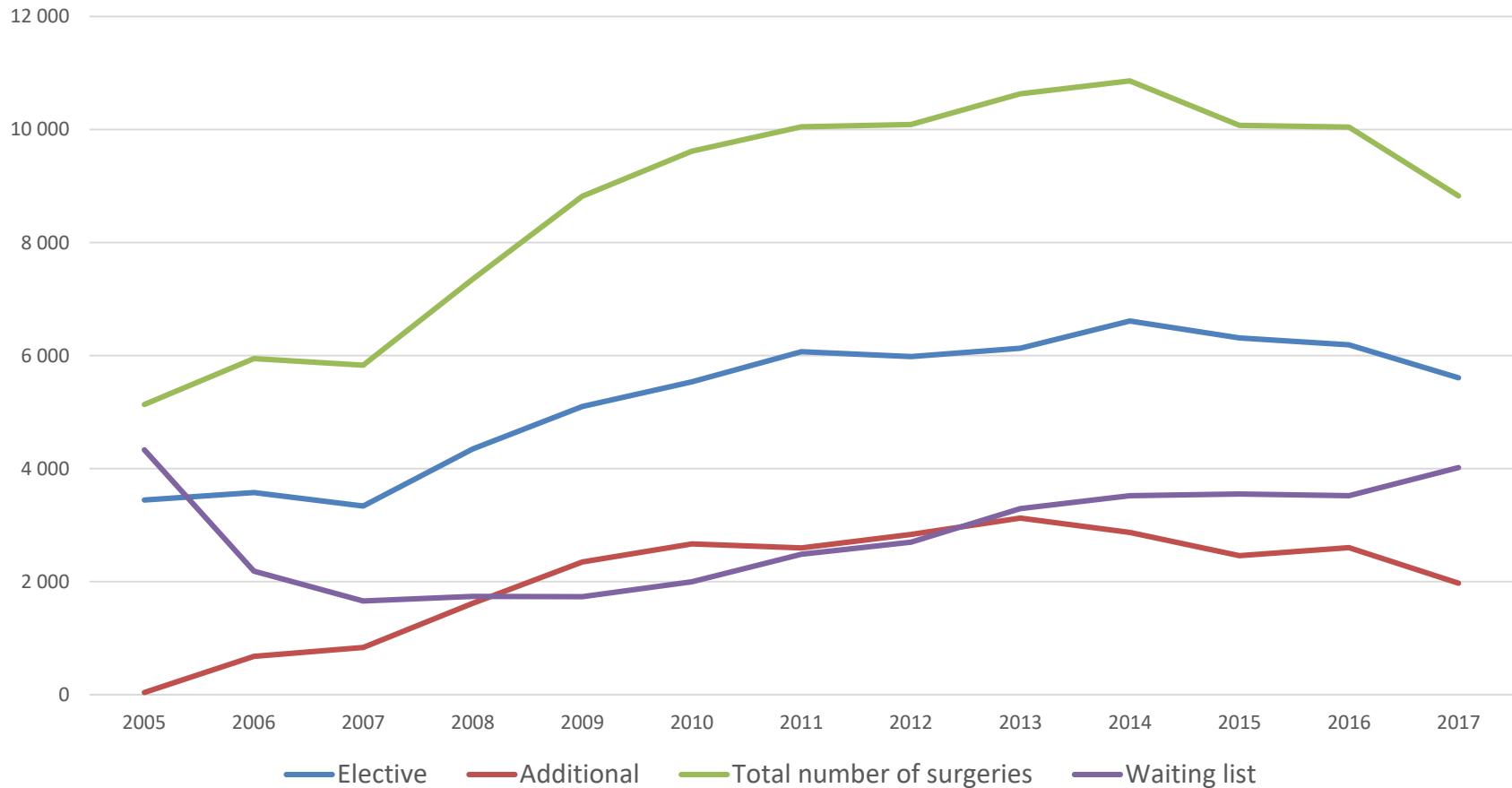
Lack of surgeons
Lack of anesthesiologists
Lack of beds



Influence area of
the hospital
(325.237 people)

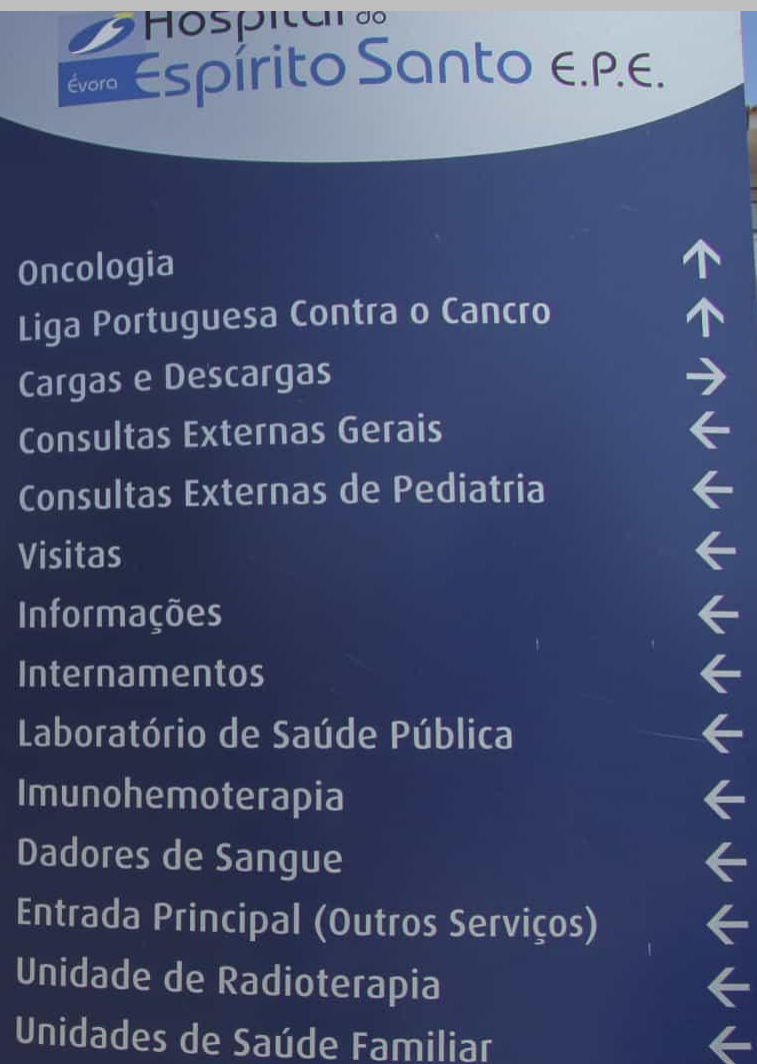


Surgical activity and Waiting list



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



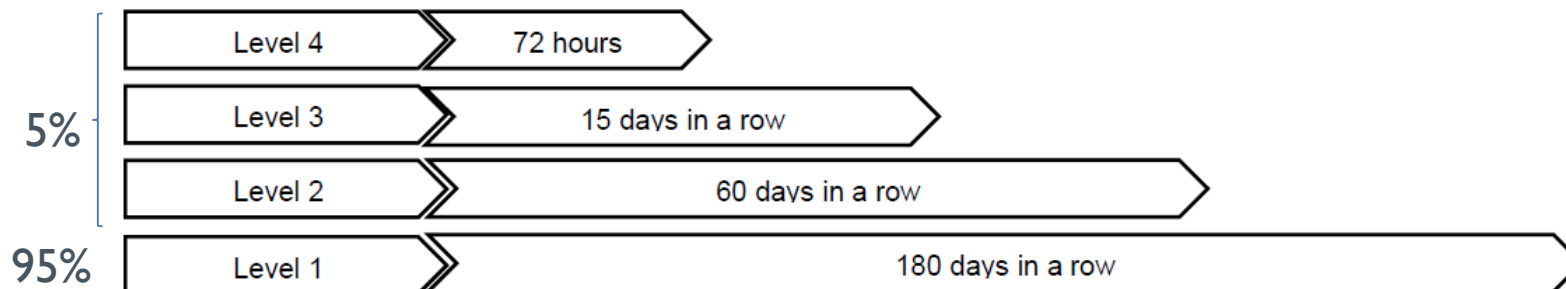
Hospital do
Évora **Espírito Santo** E.P.E.

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 (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:



- 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



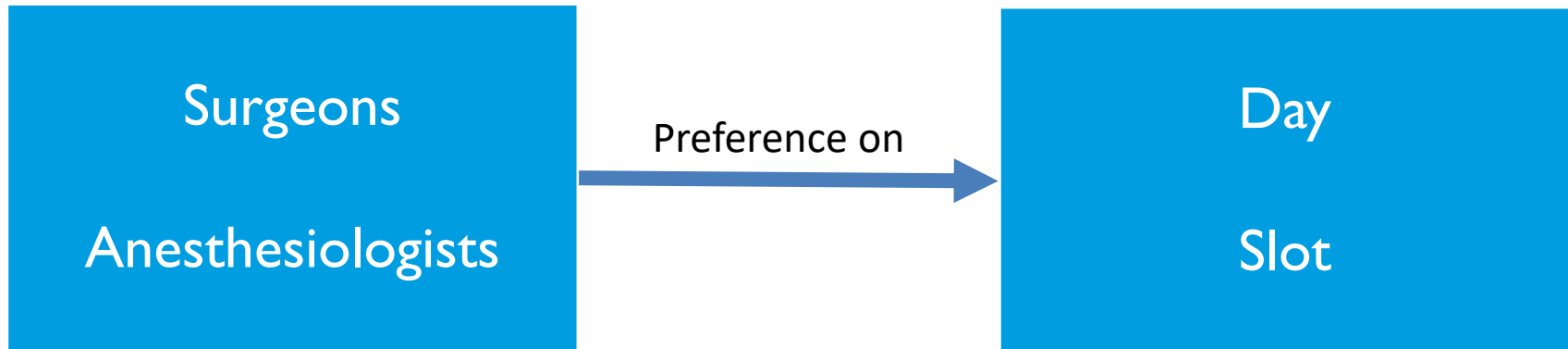
BALANCE SUPPLY AND
DEMAND



UP- AND DOWNSTREAM
UNITS WORKLOAD



SURGICAL TEAM PREFERENCES





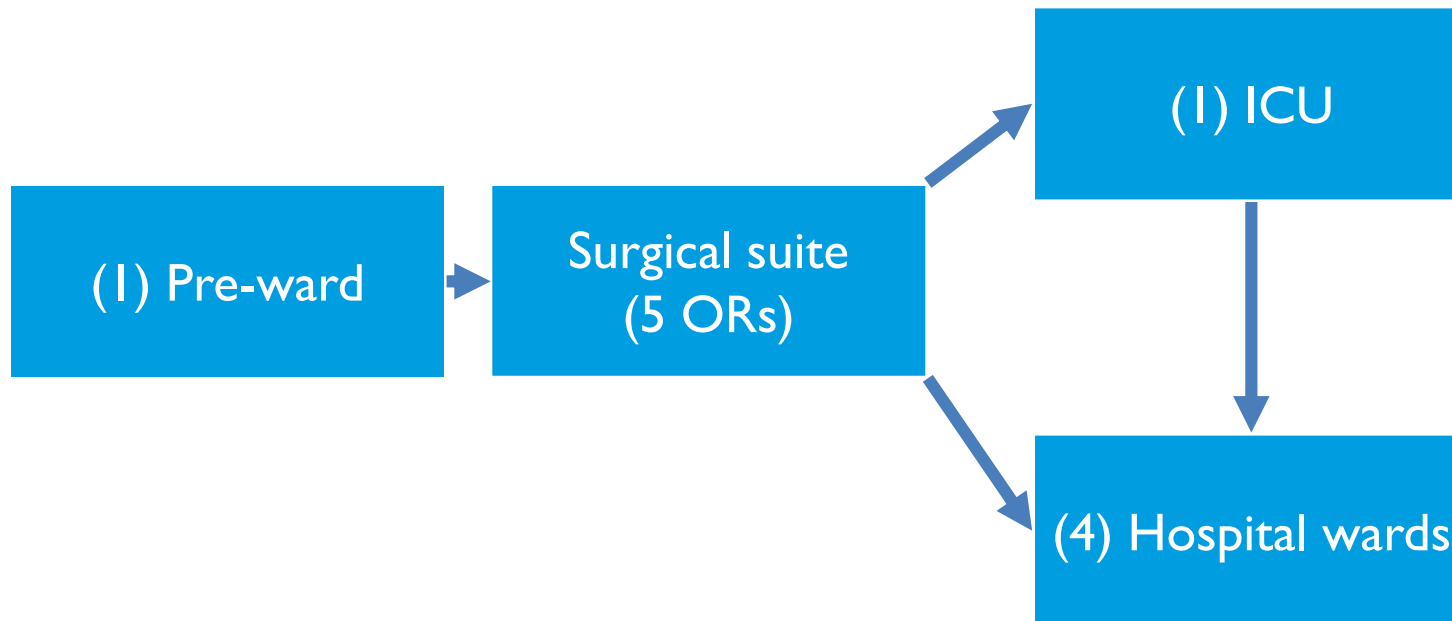
BALANCE SUPPLY AND DEMAND

WL in 28-12-2018

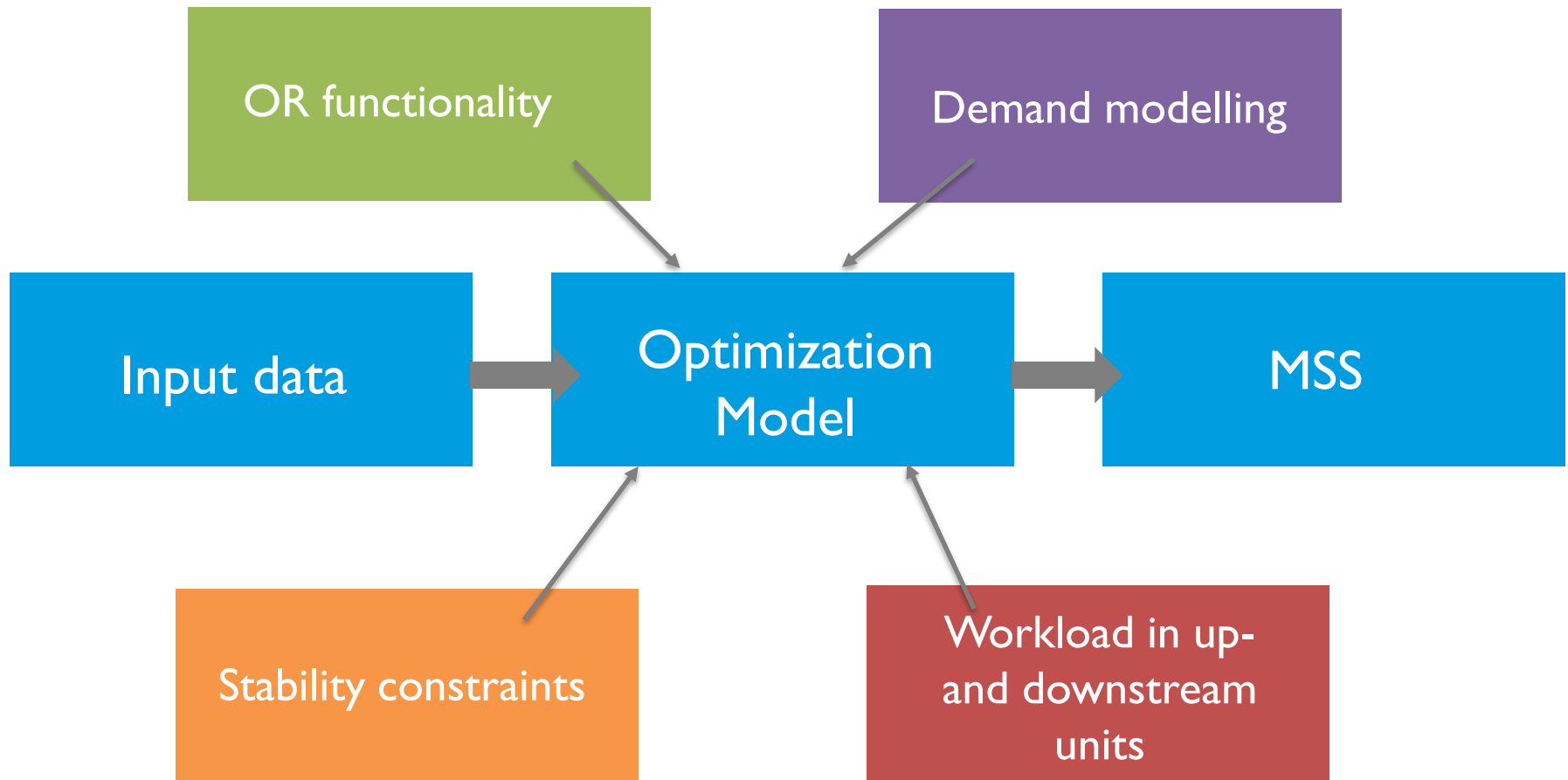
Specialties	% Overall WL length (WL)	% Overall WL duration (WD)	% Allocated blocks (AB)	Difference (WL-AB)	Difference (WD-AB)
General	36.5 %	48.6 %	37.2 %	- 0.7 %	11.4 %
Plastic	10.3 %	8.6 %	6.6 %	3.7 %	2.0 %
Stomatology	0.5 %	0.3 %	0.3 %	0.2 %	0.0 %
Ophtalmology	24.0 %	13.6 %	18.6 %	5.4 %	-5.0 %
Orthopedics	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 PREF			
Marques et al. (2019)			MIN VARIABILITY	MAX STAB
OUR PROPOSAL	SURG + ANEST PREF	OR TIME	TARGET WORK + CAP	STAB CONSTRAINT



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

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

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

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

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

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

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

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

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

OR Functionality

Demand modelling

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

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

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

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

Input
data



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

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

Stability

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

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

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

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

Up and downstream units

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

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

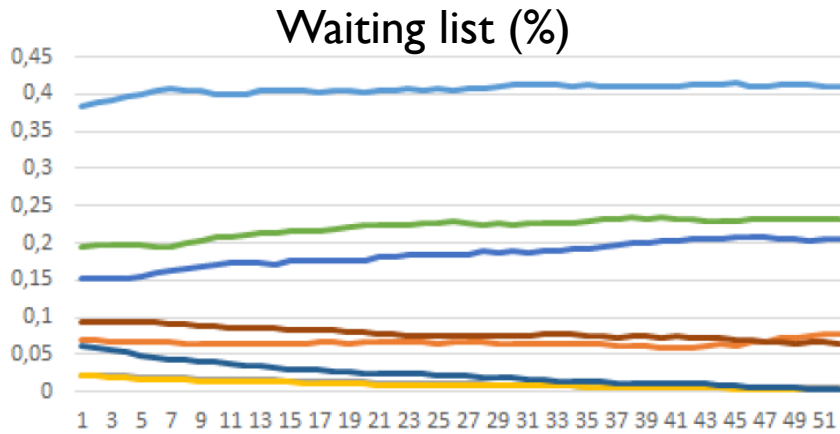
$$u_{zk}^+ \leq c_{zk} - u_{zk} \quad \forall z \in Z, k \in K$$

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

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

	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
	C. Ger. Varizes	Urgência	O.R.L.		
THU	C. Geral	C. Geral	Urgência	Ortopedia	Oftalmologia
	Urgência	Urologia	O.R.L.		
FRI	C. Geral	Estomat. ^{b)} Implantofix ^{c)}	Urgência	Ortopedia	Oftalmologia c/ locais

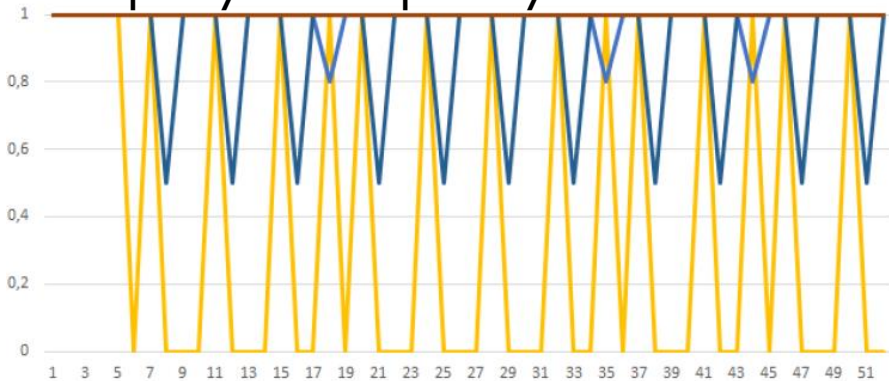
Real Capacity



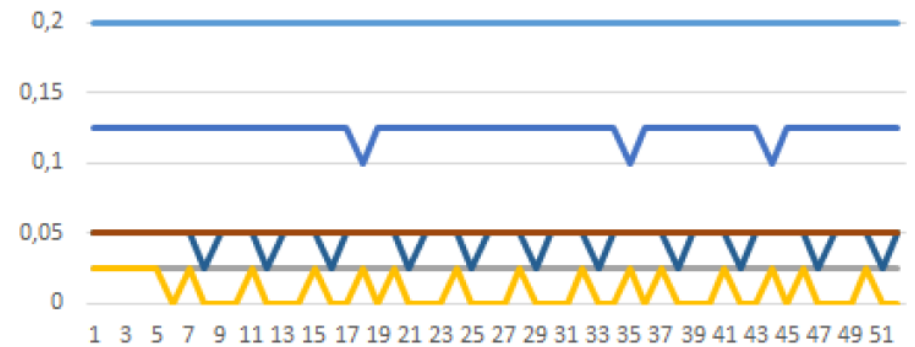
Low demand

High demand, short surgeries, high resources consumption

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



Allocated slots (%): percentage of total available slots



Specialties at max capacity

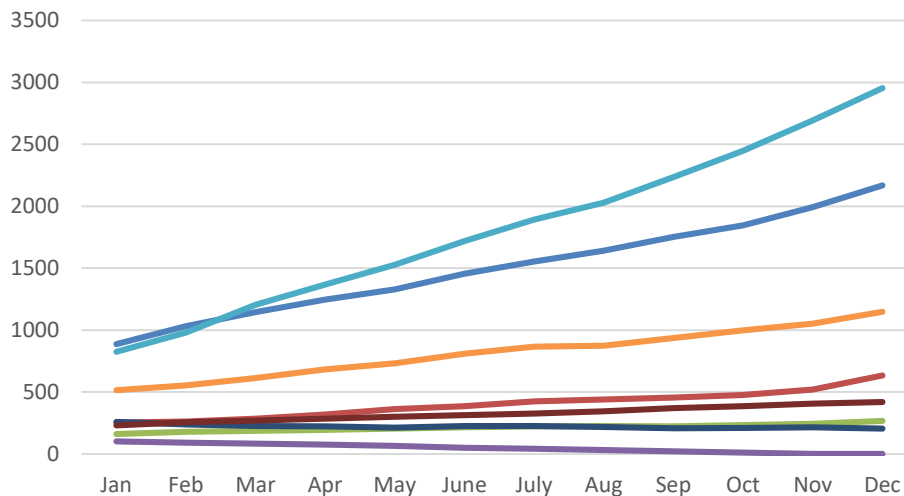
Low compliance supply vs demand

Only 55% slots assigned

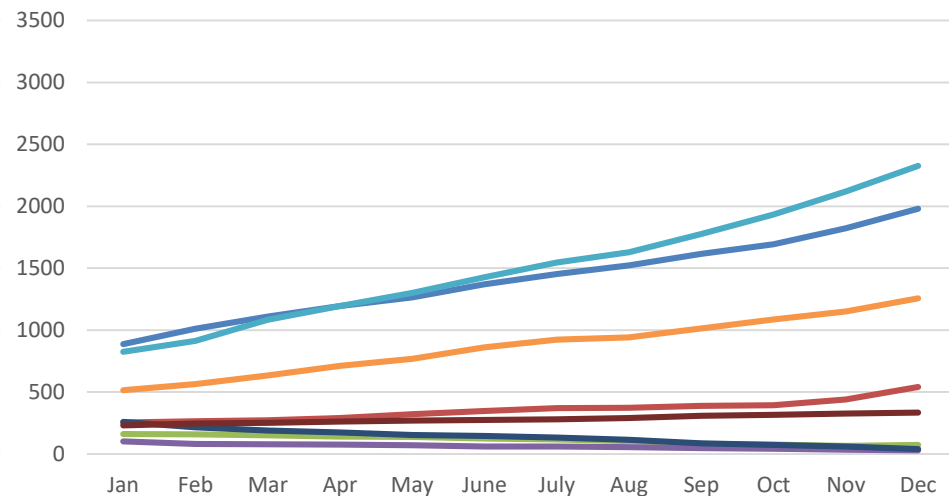


Real Capacity: Evolution of the waiting list

WL Evolution - Hospital



WL Evolution - Real Instance



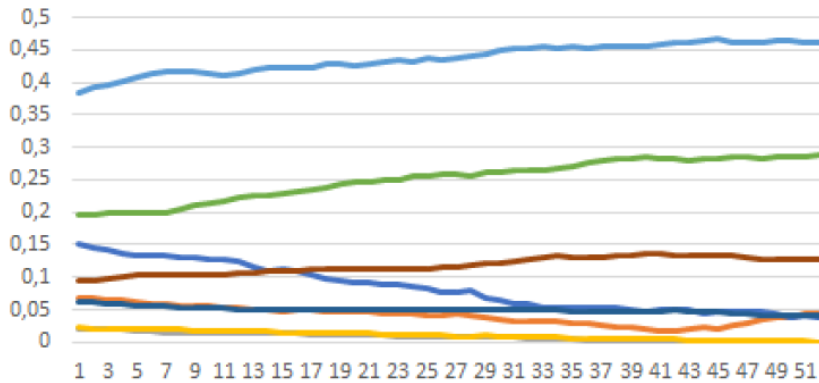
- ✓ Capacity constraints
- ✓ Better management of low resources



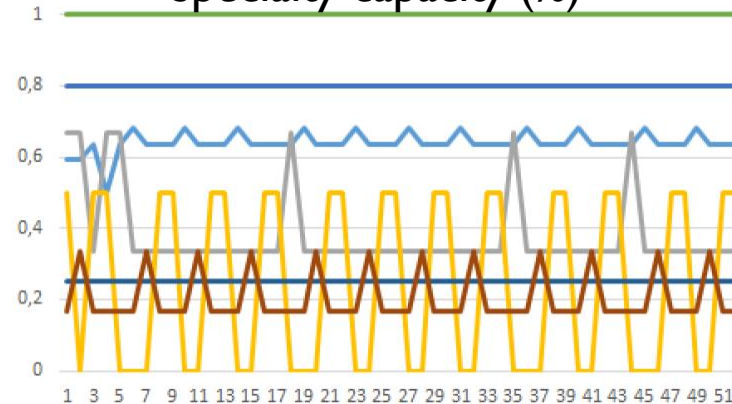
High demand, long surgeries, 5 surgeons – difficult to match demand

Increased Capacity (Real Capacity + 2 slots per doctor)

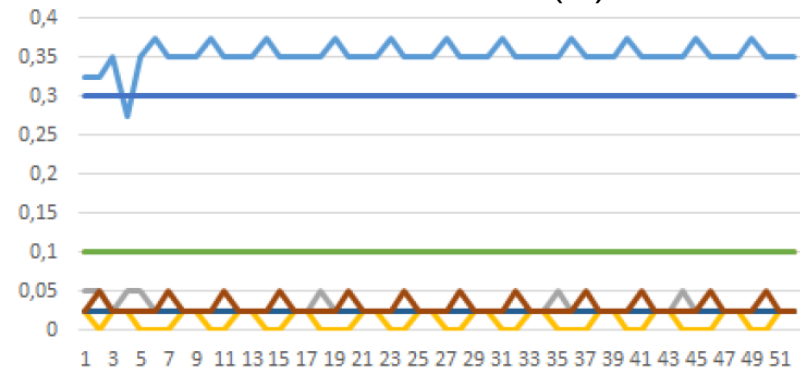
Waiting list (%)



Specialty capacity (%)



Allocated slots (%)



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



More flexibility regarding capacity



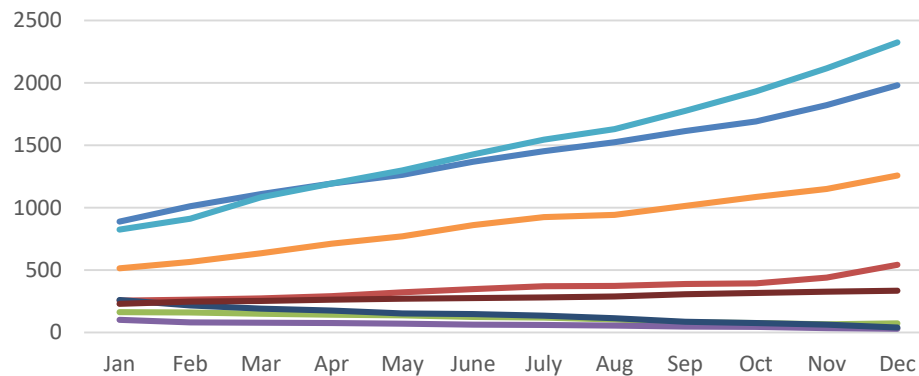
Better compliance supply vs demand



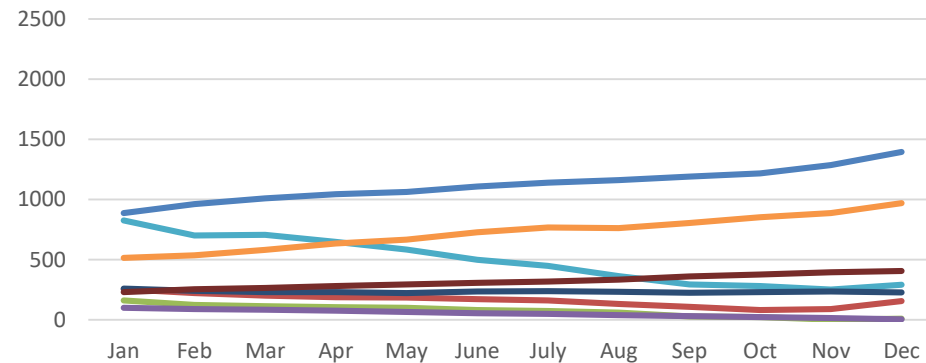
About 95% slots assigned

■ Increased Capacity: Evolution of the waiting list

WL Evolution - Real Instance*



WL Evolution - Increased Capacity



* Assuming 100% utilization

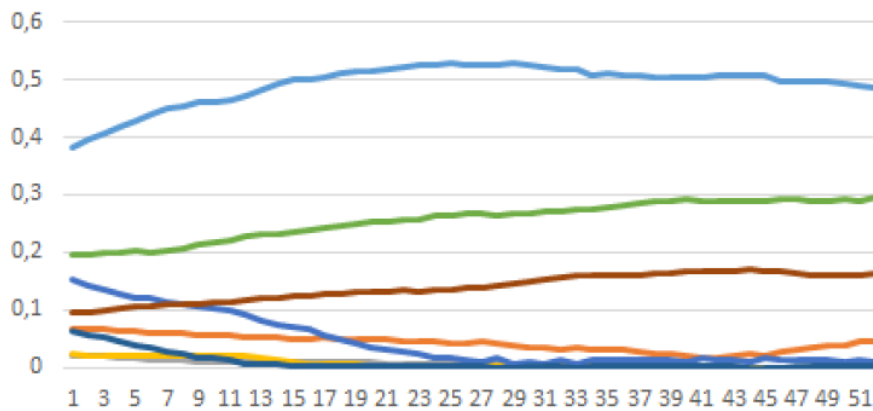
- ✓ WL reduces for large demand specialties
- ✓ Ophthalmology, General surgery, Orthopedics (lower decrease)

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

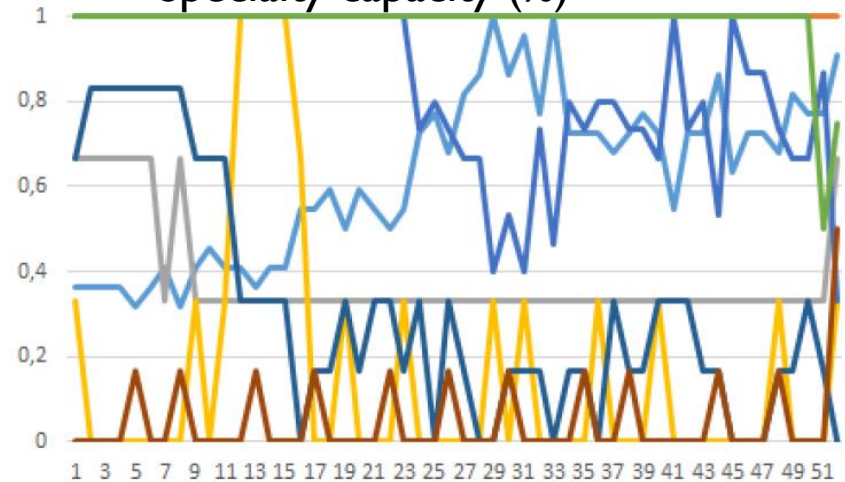
— General — Plastic — Pediatric — Stomatology
— Ophthalmology — Orthopedics — ORL — Urology

■ Increased Capacity + No Stability Constraints

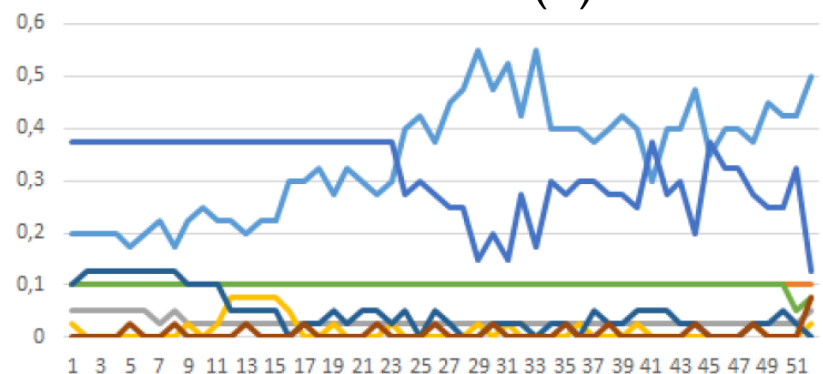
Waiting list (%)



Specialty capacity (%)



Allocated slots (%)



More flexibility to chase demand



Potential to schedule more patients



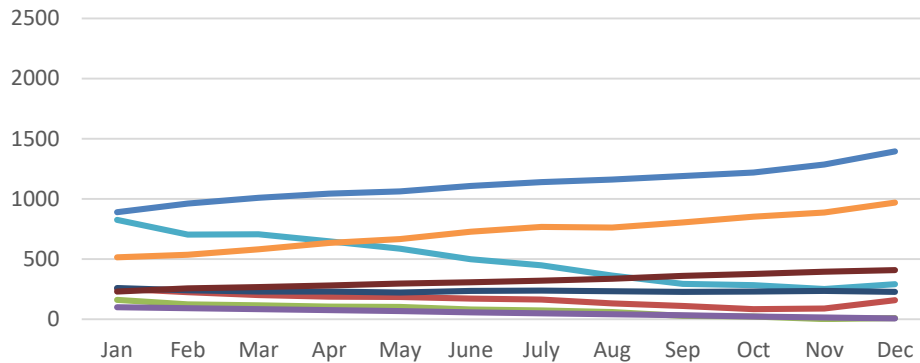
About 95% slots assigned



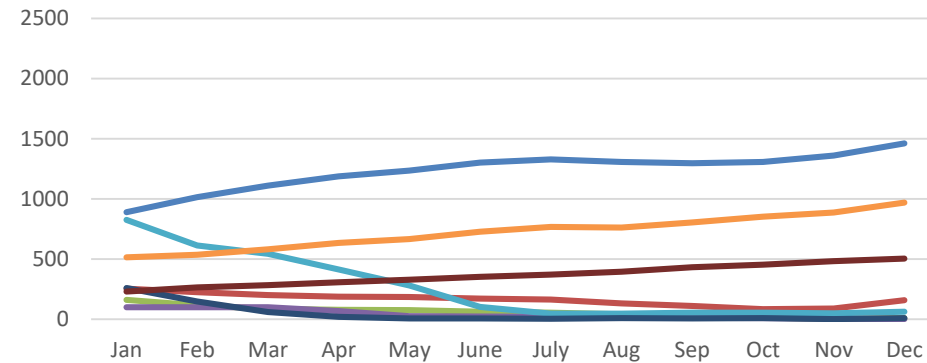
Doctors not satisfied

■ 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)
- ✓ Schedules more patients
- ✓ Tradeoff nb of surgeries vs surgeons satisfaction



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
2020

UNIÃO EUROPEIA
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de Desenvolvimento Regional