Applying a System Dynamics model to forecast future medical workforce in the Emilia-Romagna Regional NHS, Italy

AIES 2013 Trento 22/11/2013

Francesca Senese, Roberto Grilli, Corrado Ruozi (**ASSR**)
Paolo Tubertini, Andra Lodi, **Dipartimento di Ingegneria dell'Energia Elettrica e dell'Informazione**, **Università di Bologna**
Mazzocchetti Angelina - **Servizio statistica e informazione geografica -RER**

Rationale for Human Resource for Health (HRH) planning:

- The labour market and the demand for health workforce are affected by new technologies, scientific advances, societal demands and new organizational models;
- HRHs expenditure represents approx. **42,3%** of General Government Health Expenditure in the WHO-European Region (expenditure includes: compensation, basic, postgraduate and permanent education of HRH);
- Planning HRHs requires to gather a wide range of **stock** and **flow** data to model the **supply** side and a even broader array of data to proxy the **demand** of health services and population **needs;**
- **Needs-based modeling** is recommended in Health Systems where there is social and political commitment to Universal Health Coverage (UHC), which implies that delivery of healthcare is aligned on needs;
- Being a complex logistic task and requiring to test different 'what if' scenarios, **Computer Simulation techniques** are effective tools to forecast HRHs future needs.

Background on medical HRH in Emilia-Romagna

- Having a supply constraint given by the ***numerus clausus*** medical specialist grants are supported by national and regional funds;
- Minus 10% nation grants a.y. 2012-2013 and increased pressure is posed onto regional funding of medical specialist training as a mean of devolution;
- Regional funding currently covering up to 18% of medical education in the four regional Universities, approximately 3 millions € a year;
- Regional investment in higher medical education requires the definition of the n. and typology of specialists needed in the future as well as their likelihood of being needed and retained by the public sector;

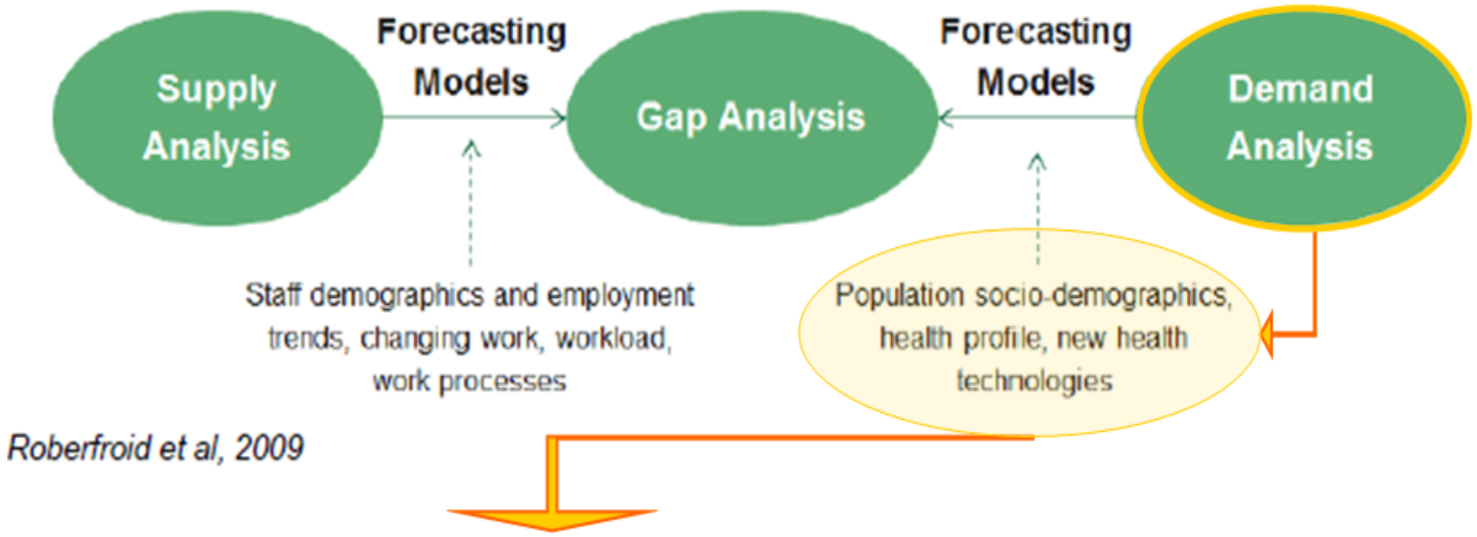
→ How to allocate regional supplementary grants?

Study objectives:

- Modelling the wider regional medical labour market and appraising current imbalances;
- Defining plausible scenarios of future workforce requirements approaching a 'needs-based' model;
- Testing cost-efficiency scenarios according to different 'specialty-mix' allocations of a given budget.

Modeling HRH

- The future of HRHs is clearly uncertain!!
- High quality intelligence should be used to support robust decisions.
- Methodologically, HRHs forecasting have to project supply and demand into the future analyzing the breaches obtained through multiple scenarios (gap analysis).



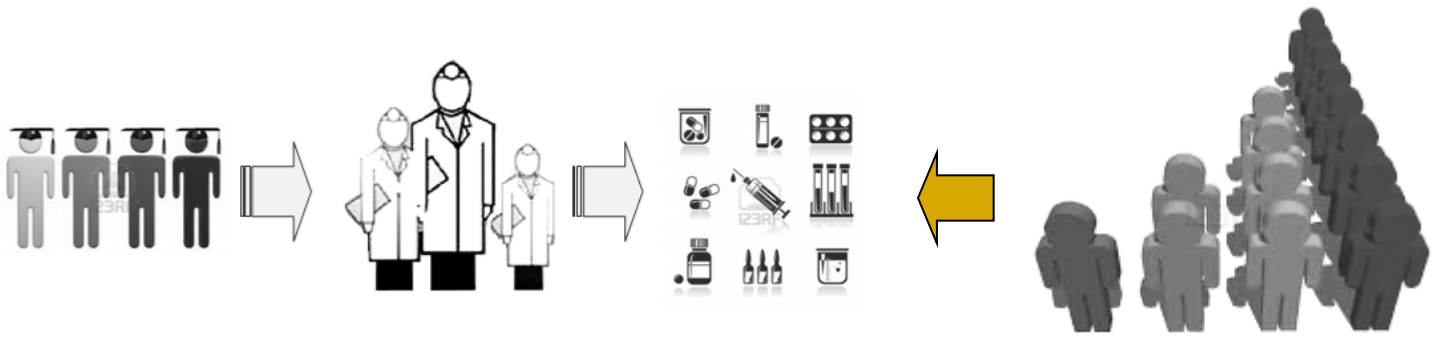
- modeling supply is relatively easy;
- capture all the possible factors affecting future HRHs demand is difficult, in particular, the ones representing **health and service needs**;
- demand scenarios risk to project current mismatches into the future.

Methodology

Our working hypothesis relies on the assumption that future Regional medical workforce requirements and prioritization of regional grants have to be defined in correlation with:

- Demographic and service utilization changes;
- IN / OUT patient consultation rates;
- Possible structural constraints (hospital beds).

Therefore, we used mixed-methods design to develop a demand-based approach to forecast future needs of medical specialists and Operations Research Techniques to model system behavior.



I) Supply side modeling: active medical specialists and newly trained ones

Stocks	Medical specialists employed in Emilia-Romagna: - Regional NHS (includes University, fix-termed); - Medical ambulatory specialists (specialty, sex, age FTE); - Private sector (Aiop 23 structures).
Outflows	Estimates of age and sex specific conditional probability of being 'active' or 'inactive' due to: - retirement (sex-age specific rates); - switched to private sector and; - other reason.
Inflows	Newly trained medical specialist 'as is' Ministerial allocation of contracts to Emilia-Romagna; Length of training: 4-5-6 years

II) Demand side modeling

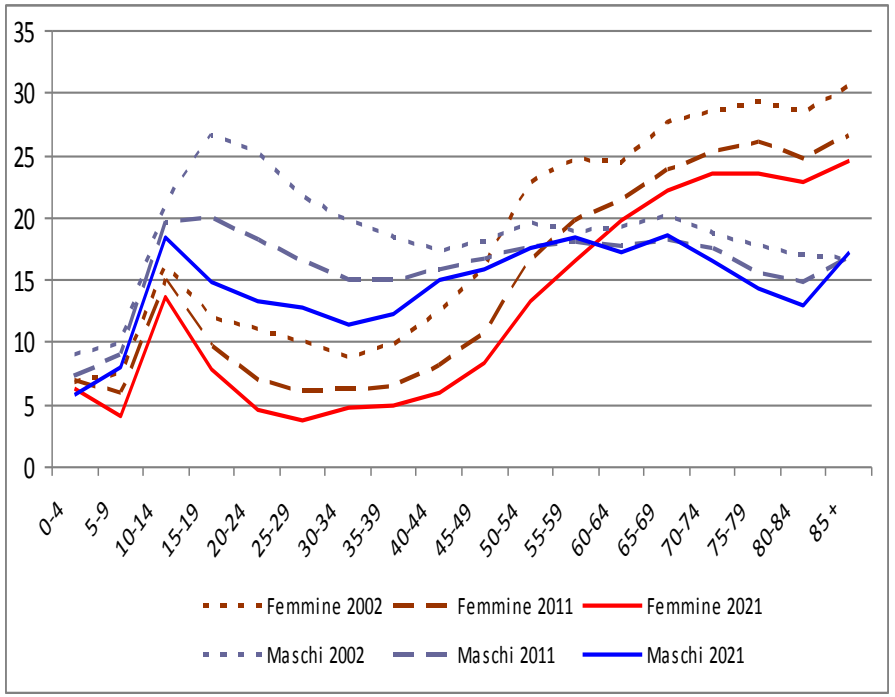
- In depth analytics into regional clinical databases (outpatient consultation and hospitalization by patient sex and age) for the period 2002-2011 in order to built demand scenarios to 2030;
- Exploitation of regional demographic forecasts to 2030;
- Selection and discussion with experts of demand drivers of future requirements for each medical specialties.

Service utilization analysis and projection to 2030

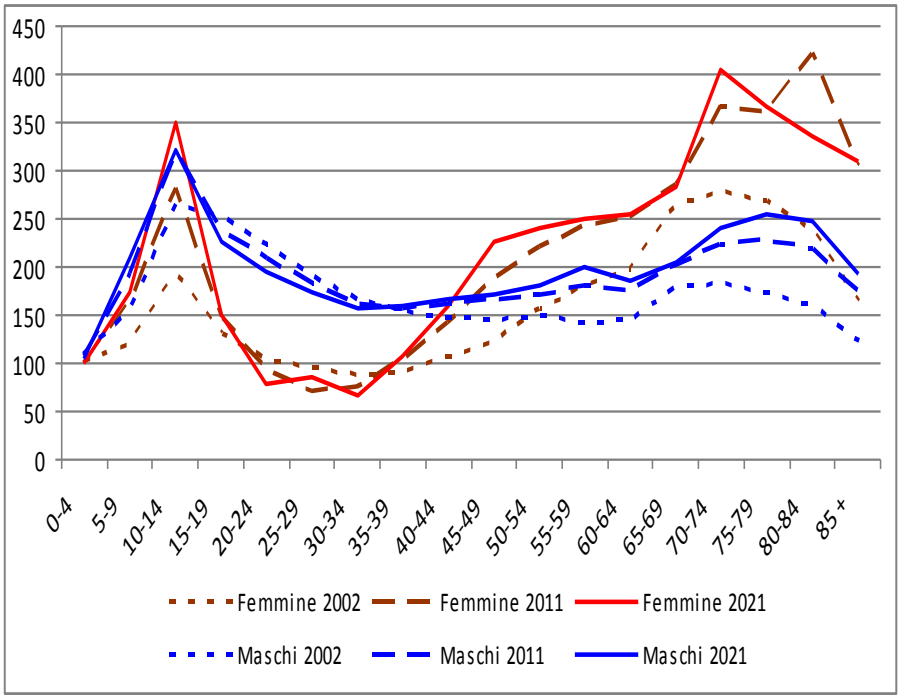
2002 - 2011	2011 - 2030
Demography **Sex – 5 years age groups**	**Demographic projections** **Sex – 5 years age groups**
IN/OUT patient consultations by specialty	**Expected volumes of ASA & SDO demanded by the population**
ASA / **SDO (HOSPITAL DISCHARGES)**	**'physicians-to-service' & 'physicians-to-population' ratios**
Specialists involved	**Possible constraints to n. of specialists requires: HOSPITALS BEDS at 2011**
	Specialists required 2011-2030

Ex. Orthopedic age-sex specific utilization rates 2002-2011-2021 for outpatient visits and hospital discharges

Tassi di ospedalizzazione consuntivi 2002, 2011 e stimati al 2021 per sesso e fasce d' età quinquennali (1000 ab.), disciplina di Ortopedia e traumatologia



Tassi ASA consuntivi 2002, 2011 e stimati al 2021 per sesso e fasce d' età quinquennali (1000 ab.), disciplina di Ortopedia e traumatologia



Tassi complessivi *1000 abitanti di utilizzo ASA e SDO di ortopedia, confronto 2011-2021

	ASA				SDO			
	2011		2021		2011		2021	
Specialità	F	M	F	M	F	M	F	M
Ortopedia e traumatologia	205,9	186,3	213,0	191,6	14,5	15,3	12,5	13,7

Demand scenarios:

Scenario 1: *status quo* 2011 of specialty mix & demographic change:

Deterministic scenario: Specialty mix in 2011 was appropriate and demand for specialists will by driven by demographic change to 2030

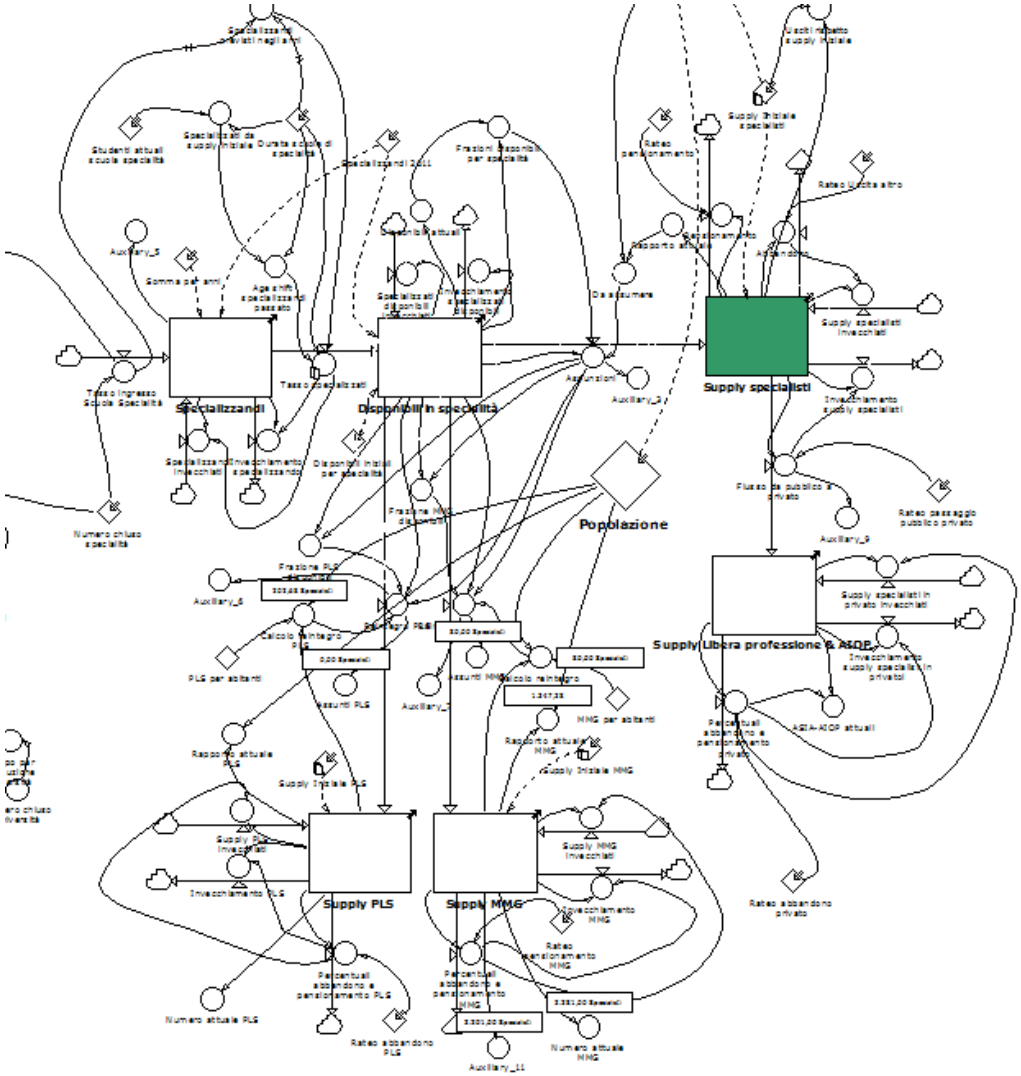
Scenario 2: *trendlines* utilization ASA + SDO 2011-2030

Pessimistic scenario: No structural costraints, demand increases combining population specific sex and age group trend and ASA + SDO estimated rates. Population growth and demand of services drives specialists demand with no possibility by health providers to determine the number of specialists required. Hospital discharges slightly dicrease yet out-patient consultations rise significantly

Scenario 3: deospedalizzazione
***'Core'* HOSPITAL AND out patient activity ASA**

Constrained and de-hospitalization scenario: Hospital beds constraint in inpatient services, ambulatory care expected to increased. Using specialists-to-hospital beds standards the 'core' of hospital specialists won't change. Outpatients consultations will drive instead demand for specialists in outpatient settings.

System Dynamics model

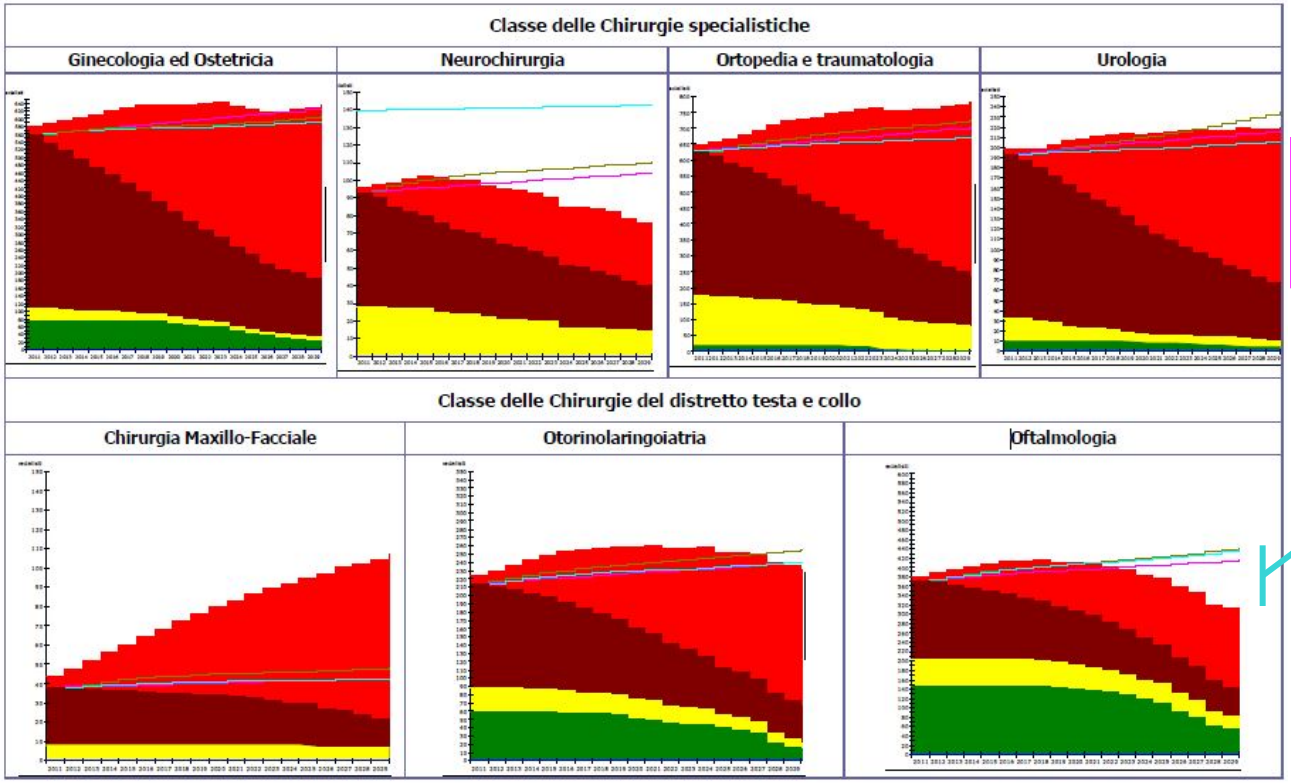


System Dynamics simulation model projects to 2030 (for each of the 61 medical specialties):

- baseline medical stock (y. 2011) and its expected leaves (outflows);
- number of newly trained medical specialists available according to an ‘as is’ scenario (last observable academic y. 2011-2012);
- demand for medical specialists according to demand scenarios.

System Dynamics outputs

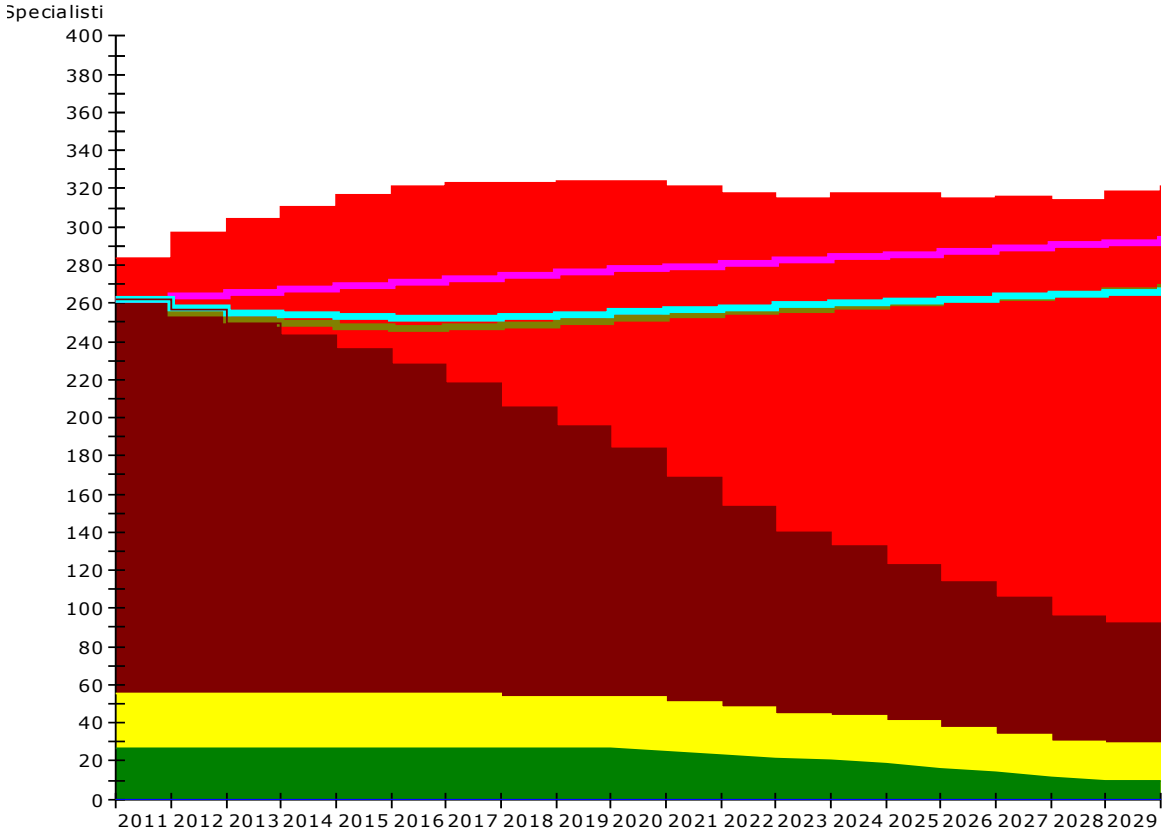
Outputs, analyzed on a yearly basis, can be split in two main categories:



Occupational breaches: slack between demand of specialists and employed ones

Training gap: slack between demand of specialists and available ones (employed + trained)

Physical medicine and rehabilitation



Demand scenarios

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock SSR	207	202	195	188	181	172	163	152	141	130	118	106	95	89	82	77	72	66	63	59
Stock sumaisti	35	35	35	35	35	35	35	35	35	35	32	29	27	25	23	19	17	13	12	12
Stock Aiop	28	28	28	28	28	28	28	27	27	27	26	25	24	24	22	21	20	19	19	18
Offerta (diplomati+Stock)	292	305	312	318	325	329	331	331	332	332	328	324	321	323	322	318	319	316	321	324
Scenario 1: Popolazione	270	272	274	276	278	279	281	283	285	286	288	290	291	293	294	296	298	299	301	303
Scenario 2: ASA+SDO	270	263	259	257	255	255	255	256	258	259	261	263	265	266	268	270	271	273	275	276
Scenario 3: PL & ASA	270	265	262	261	260	260	260	260	262	263	265	266	267	268	270	270	271	272	273	274

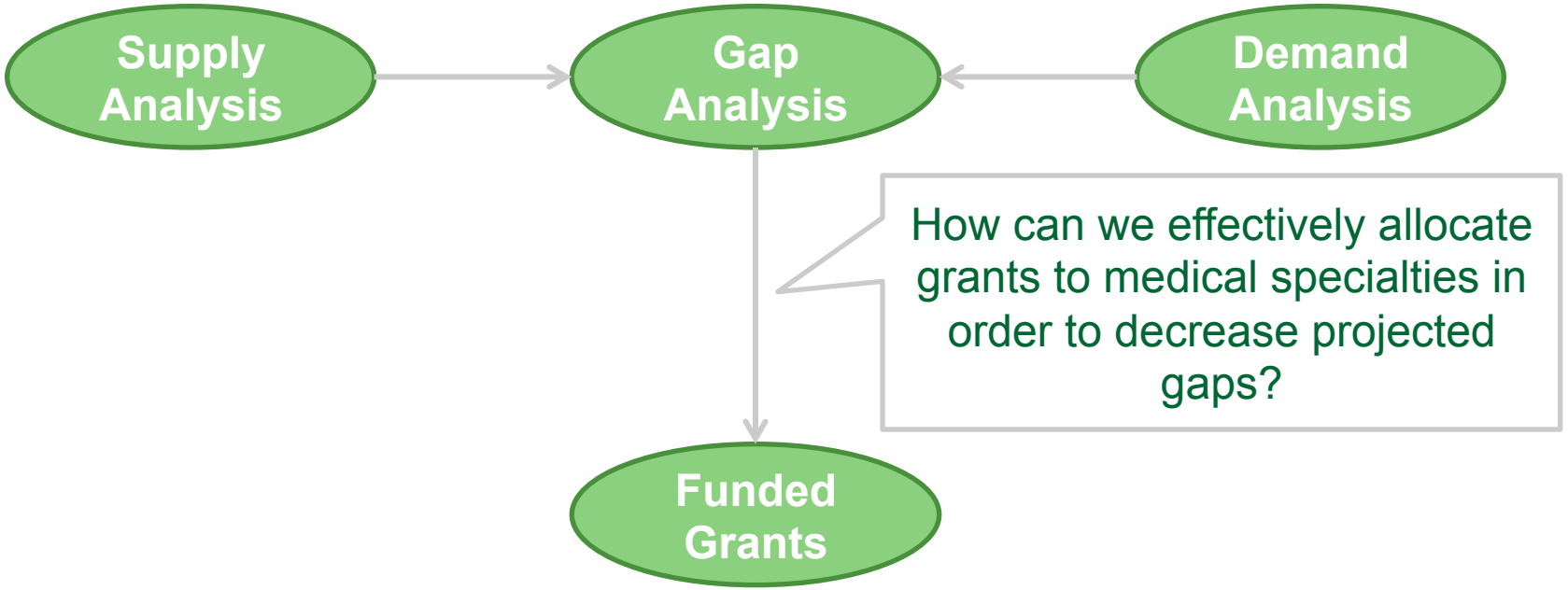
Regional demand scenarios vs. MIUR 'as is' training in 2030: e.g. Area MEDICA

Demand scenarios

		Occupazione AREA MEDICA 2011							Incremento % DOMANDA 2030 rispetto al 2011			Fabb. Formativo rispetto a contratti MIUR *'as is'*		
		SSR	SUMAI	Aiop	tot. 2011	Range occupazionale SSR	Range occupazionale Aiop	Range occupazionale Aiop	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Clinica Gen.	Geriatria	198	20	19	237	84%	8%	8%	20%	31%	16%	+	+	+
	Medicina dello sport	5	27	4	36	14%	75%	11%	12%	38%	12%	+	+	+
	Medicina di comunità	0	2	0	2	0%	100%	0%	12%	0%	0%	0	0	0
	Medicina interna	970	6	21	997	97%	1%	2%	12%	15%	10%	-339	-373	-317
	Oncologia medica	190	6	6	202	94%	3%	3%	12%	26%	13%	+	+	+
	Medicina d'Emergenza-Urger	590	0	5	595	99%	0%	1%	12%	11%	10%	-252	-243	-240
Neurosci. Comporta mento	Neurologia	181	28	24	233	78%	12%	10%	12%	33%	21%	+	-24	+
	Neuropsichiatria infantile	134	32	5	171	78%	19%	3%	18%	37%	38%	+	-23	-25
	Psichiatria	520	7	63	590	88%	1%	11%	11%	5%	4%	-62	-24	-18
	Psicologia clinica	1	5	13	19	5%	26%	68%	12%	77%	77%	+	-11	-11
Med. Specialistica	Allergologia ed Imm. clinica	0	6	2	8	0%	75%	25%	12%	20%	28%	+	+	+
	Dermatologia e Venereologia	84	49	17	150	56%	33%	11%	12%	16%	13%	+	+	+
	Ematologia	172	0	4	176	98%	0%	2%	12%	33%	24%	+	-37	-20
	Endocrinologia e malattie del	79	34	15	128	62%	27%	12%	12%	33%	33%	+	+	+
	Gastroenterologia	129	4	26	159	81%	3%	16%	12%	34%	26%	+	+	+
	M.cardiovascolari (cardiologi	429	45	79	553	78%	8%	14%	12%	40%	16%	+	-50	+
	M.dell'apparato respiratorio	138	7	18	163	85%	4%	11%	12%	27%	18%	+	+	+
	Malattie infettive	107	0	2	109	98%	0%	2%	12%	17%	8%	+	+	+
	Nefrologia	136	3	6	145	94%	2%	4%	12%	46%	28%	+	+	+
	Reumatologia	22	11	3	36	61%	31%	8%	12%	35%	34%	+	+	+
	Tot./media	**4085**	**292**	**332**	**4709**	**67%**	**21%**	**11%**	**13%**	**29%**	**21%**	**-653**	**-784**	**-631**

Training gap with respect to MIUR grants

Grants allocation: main idea



- The allocation of grants can be seen as a **combinatorial problem** that can be modeled and solved using Integer Programming (optimization) techniques;
- The goal of the allocation model is to identify among all the possible funding alternatives the most effective one.

Grants allocation: the IP model

S	Set of medical specialties: $i \in S$ and $\|S\| = 62$;
T	Time horizon: $t \in 2011, \ldots, 2030$
d_i	Duration of Specialization school i
$FabE_{it}$	Need of specialits of type i at year t
$Supply_{it}$	Supply of specialits of type i at year t employed at 2011
$Trained_{it}$	Supply of specialits of type i at trained till year t
p_i	Priority coefficient of specialty i
gap_{it}	Training gap for specialits of type i at year t: $gap_{it} = max(FabE_{it} - Supply_{it} - Trained_{it}, 0)$

$$MinZ = \sum_{i \in S} \sum_{t \in T} p_i * y_{it}$$

$$\sum_{i \in S} x_{it} \leq Grants \qquad \forall t \in T \tag{1}$$

$$\sum_{l=2011}^{t} x_{il} + y_{it} = gap_{it} \qquad \forall t \in T, \qquad \forall s \in S \tag{2}$$

$$\sum_{l=2011}^{t} x_{il} \leq gap_{it} \qquad \forall t \in T, \qquad \forall s \in S \tag{3}$$

$$x_{it} \geq 0 \qquad integer \qquad \forall t \in T, \qquad \forall s \in S \tag{4}$$

$$y_{it} \geq 0 \qquad integer \qquad \forall t \in T, \qquad \forall s \in S \tag{5}$$

The IP model minimizes overtime the training gap taking in consideration, for each specialty:

- priority, defined as a clinical complexity index (intensive, high, medium, low);
- yearly maximum number of Grants that can be funded;
- training gap compared to 2011 stock (magnitude of the gap).

Grant allocation: scenarios

The IP model can be used as a Decision Support System considering two main scenarios:

- We take as an input the number of grants that will be funded by the national Ministry of Health (reproducing 2011-2012 funding policy) and we consider as decision variables only Regional supplementary grants;

- We consider the situation in which we can decide how to allocate both regional and national grants dedicated to Emilia-Romagna.

Allocation of 23 regional grants per year (2011 -2024) according to 3 demand scenarios

Medical Specialties	Number of Grants			Percentage		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Medicina d'urgenza e di pronto soccorso	70	34	70	21,74%	10,56%	21,74%
Ginecologia ed Ostetricia	10	0	0	3,11%	0,00%	0,00%
Neurochirurgia	38	44	65	11,80%	13,66%	20,19%
Oftalmologia	19	0	22	5,90%	0,00%	6,83%
Otorinolaringoiatria	0	7	0	0,00%	2,17%	0,00%
Urologia	0	17	0	0,00%	5,28%	0,00%
Pediatria	40	40	35	12,42%	12,42%	10,87%
Medicina interna	35	0	17	10,87%	0,00%	5,28%
Neurologia	0	35	7	0,00%	10,87%	2,17%
Neuropsichiatria infantile	0	24	26	0,00%	7,45%	8,07%
Psichiatria	70	44	38	21,74%	13,66%	11,80%
Ematologia	13	50	34	4,04%	15,53%	10,56%
Gastroenterologia	0	10	0	0,00%	3,11%	0,00%
Malattie dell' apparato cardiovascolare (cardiologia)	0	8	0	0,00%	2,48%	0,00%
Malattie infettive	4	9	0	1,24%	2,80%	0,00%
Radiodiagnostica	0	0	4	0,00%	0,00%	1,24%
Patologia Clinica	22	0	4	6,83%	0,00%	1,24%
Igiene e Medicina Preventiva	1	0	0	0,31%	0,00%	0,00%
TOTAL	322	322	322	100,00%	100,00%	100,00%

Allocation of overall regional grants (2011 -2024) according to demand scenarios vs. 'as is' MIUR

Cumulative results table

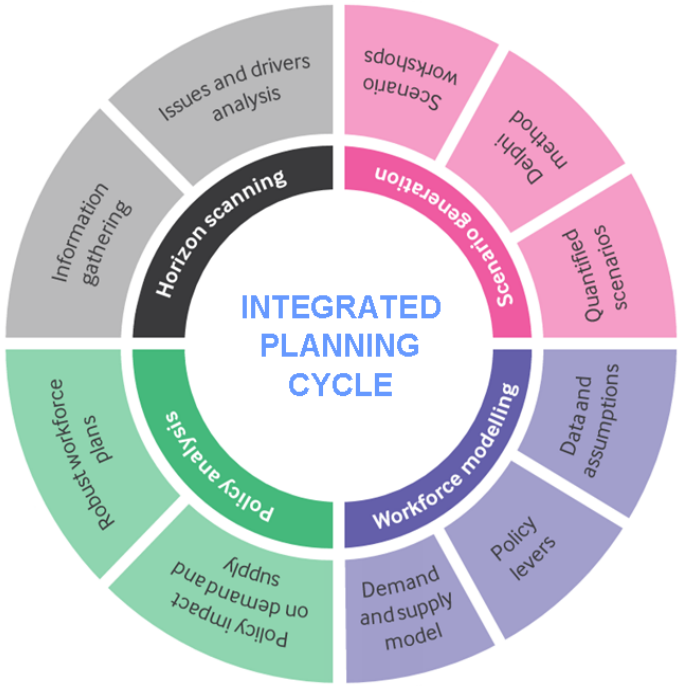
Medical specialties	Scenario 1	Scenario 2	Scenario 3	As-is scenario MIUR	As-is scenario MIUR & Regional grants
TOTAL	6561	6963	6705	6358	6680
% gap w.r.t. Health Ministry grants	3,2%	9,5%	5,5%		
% gap w.r.t. Health Ministry grants & Regional Grants	-1,8%	4,2%	0,4%		

By Medical AREAS

Medical classes	Number of grants				Allocation w.r.t. As-is scenario		
	Scenario 1	Scenario 2	Scenario 3	As-is scenario MIUR	Scenario 1	Scenario 2	Scenario 3
Surgical	1492	1584	1456	1617	-7,7%	-2,0%	-10,0%
Medical	3343	3815	3400	2743	21,9%	39,1%	24,0%
Services	1726	1564	1849	1998	-13,6%	-21,7%	-7,5%
TOTAL	**6561**	**6963**	**6705**	**6358**	**3,2%**	**9,5%**	**5,5%**

Should RER plan future medical training according to both population needs and regional NHS demand?

Workforce intelligence is just a component of an integrated planning cycle of HRH



STRENGHTS of MODEL PROPOSED

- Draws data from regional databases, making it replicable every year;
- Bottom-up process;
- Allows involvement of several actors offering a common ground, figures and scenarios to negotiate future medical training;
- Can lead to savings and increased returns of regional investment in medical training.

CRITIQUES of HRH MODELLING

- 'Tight planning' of HRHs is perceived as symptom of '**dirigiste**' approach vs. strategic;
- Difficult engagement of health professionals and University;
- Is emphasis best placed on identifying policy solutions to **overcome HRHs shortages** instead of integrated planning?

Translational impact and future developments

- The study can change the rationale for assessing Regional future medical requirements and the negotiation of supplementary grants accordingly;

- It offers nationwide valuable measures of ‘physicians-to-service’ & ‘physicians-to-population’ ratios.

Future developments might see the introduction of ‘specialist-to-service’ standards and the modeling of other health professionals (nurses, physiotherapists, etc,).