NON LINEAR DECISION MODELS TO MITIGATE AIR QUALITY EFFECTS ON HEALTH IN NORTHERN ITALY

C. CARNEVALE[1], E. Pisoni[1], M. Volta[1], F. Wagner[2]

[1] Department of Information Engineering, Brescia University, Italy

[2] Atmospheric Pollution and Economic Development Program, IIASA, Austria

PROBLEM FORMULATION

$$\min_{\theta} J(\theta) = \min_{\theta} \left[AQI(E(\theta)) \quad C(E(\theta)) \right]$$

Internal Costs

Air Quality Index

$$\theta \in \Theta$$

Set of feasible decisions

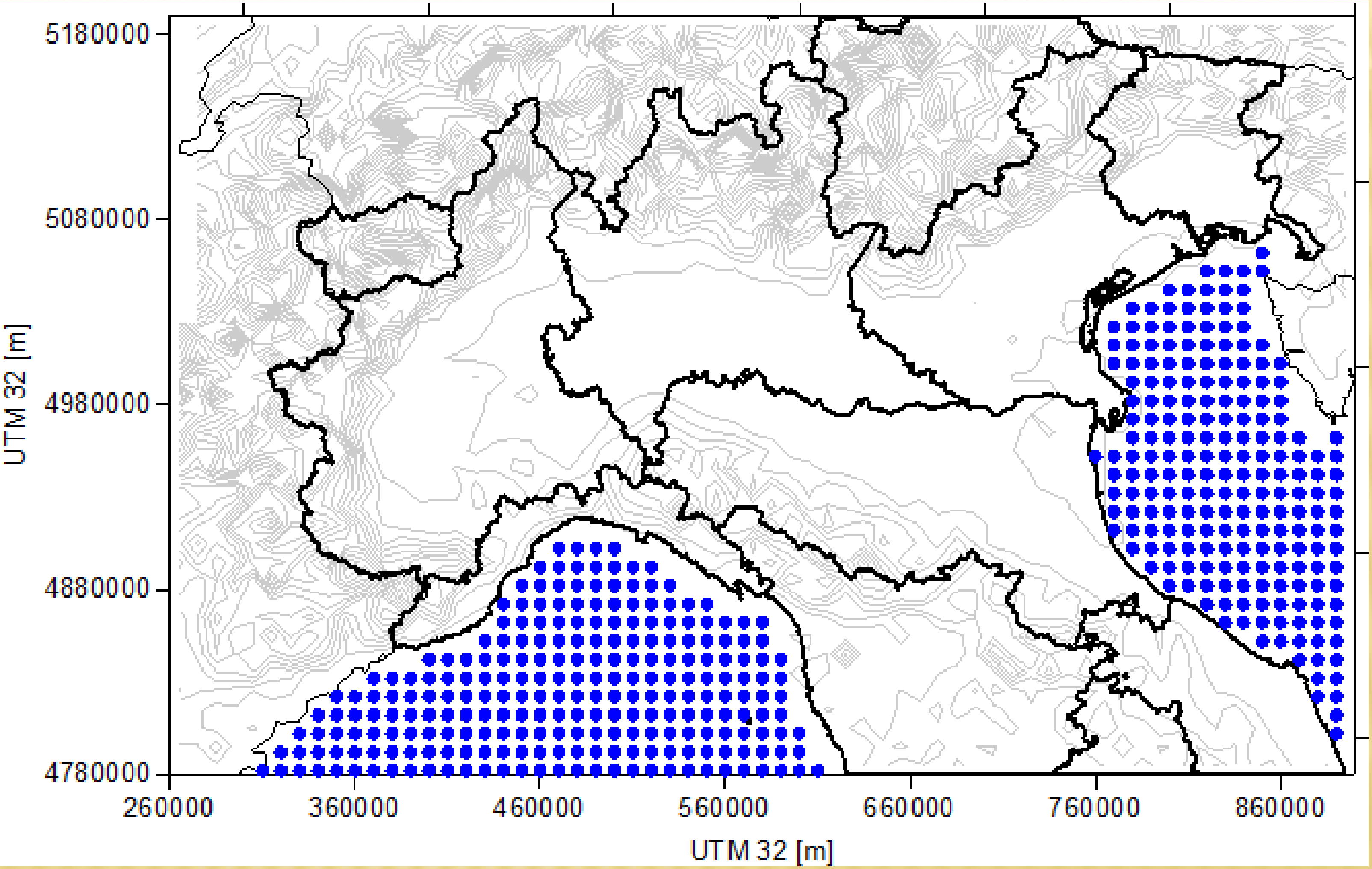
Set of decision variables (precursor emission reductions)

$$E$$

Basecase emissions

PISONI E; CARNEVALE C; VOLTA M. (2009). Multi-criteria analysis for PM10 planning. ATMOSPHERIC ENVIRONMENT. 4833- 4842. 43

CASE STUDY



5180000
5080000
4980000
4880000
4780000
UTM 32 [m]
260000
360000
460000
560000
660000
760000
860000
UTM 32 [m]

OBJECTIVE 1: AIR QUALITY INDEX

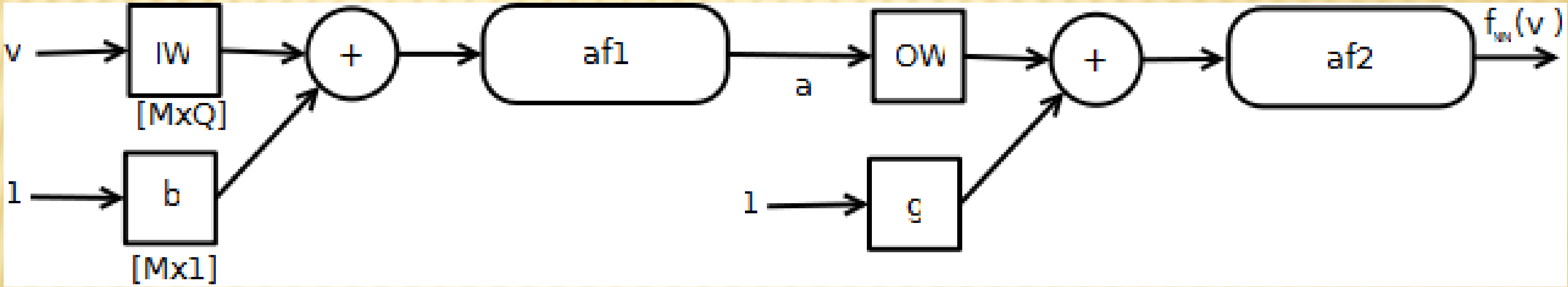
- Air Quality Index: **PM10** mean concentrations
- Emission-concentration = **nonlinear** link
- Source-Receptor models:
  - **Artificial Neural Networks** (ANNs)
- Identification dataset: **TCAM simulations**

CARNEVALE C; FINZI G; PISONI E; VOLTA M. (2009). Neuro-fuzzy and neural network systems for air quality control. ATMOSPHERIC ENVIRONMENT. 4811- 4821. 43

CARNEVALE C; DECANINI E; VOLTA M. (2008). Design and validation of a multiphase 3D model to simulate tropospheric pollution. SCIENCE OF THE TOTAL ENVIRONMENT. 166- 176. 390

ANNS ARCHITECTURE

- **Feed Forward** network
- **Input:** (ring of cells) precursor emissions
- **Output:** (cell) AQI



ANNS IDENTIFICATION

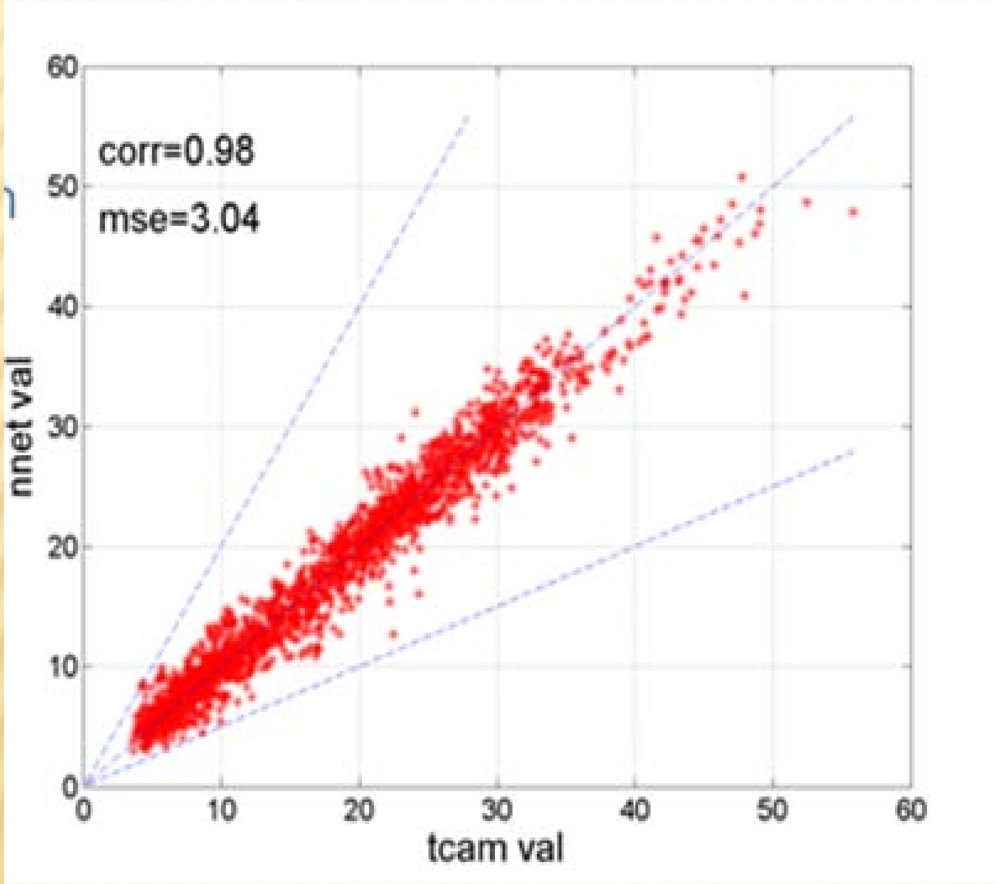
- Emission reductions [%]:
  - C&Epackage MRR (2020)
  - NEC2007BASELINE

SCENARIOS	NOX	VOC	NH3	PM	SO2
1	30.89	27.26	21.45	26.70	35.85
2	61.78	54.52	42.90	53.40	71.70
3	61.78	27.26	21.45	26.70	35.85
4	30.89	54.52	21.45	26.70	35.85
5	30.89	27.26	42.90	26.70	35.85
6	30.89	27.26	21.45	53.40	35.85
7	30.89	27.26	21.45	26.70	71.70
8	30.89	54.52	21.45	53.40	35.85
9	61.78	54.52	21.45	53.40	71.70
10	61.78	27.26	42.90	26.70	35.85

- 11 TCAM simulations:
  - 2004
  - $10x10km^2$

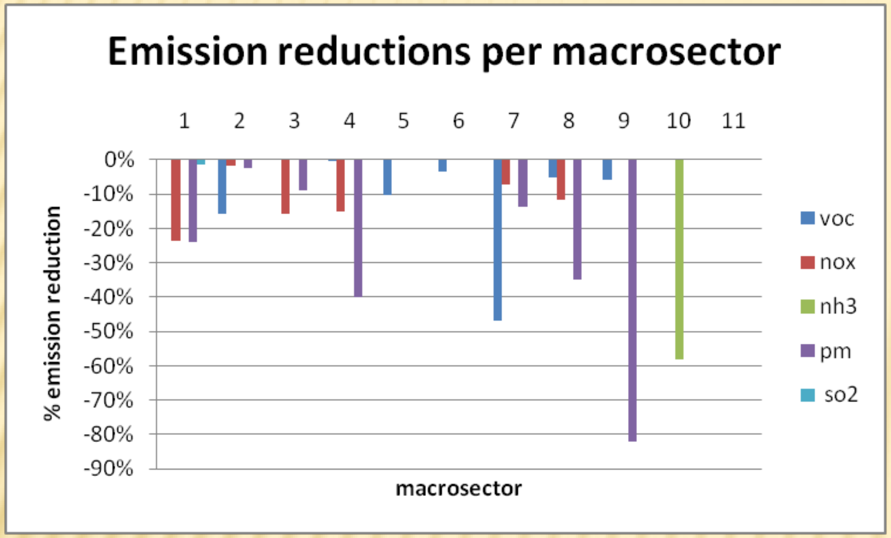
QUITSAT project (2006/10) , Italian Space Agency

SOURCE-RECEPTOR MODELS: RESULTS



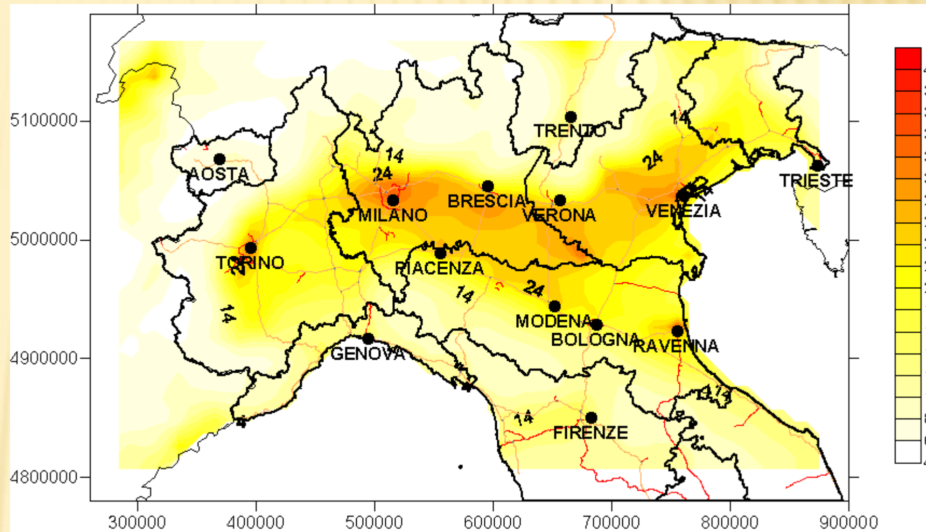
TCAM mean (µg/m³)	17.63
ANNs mean(µg/m³)	17.59
correlation	0.98
Mean Error (µg/m³)	-0.05
Mean Absolute Error (µg/m³)	1.31
Normalized Mean Absolute Error	0.07

SOURCE RECEPTOR MODELS: RESULTS

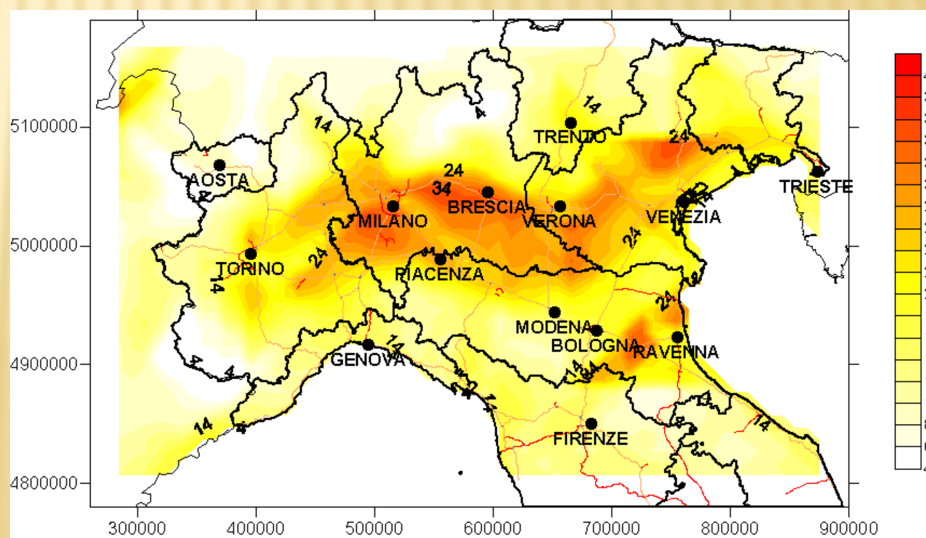


	TCAM (mg/m3)	ANNs (mg/m3)
Mean PM	13.33	15.29

TCAM



ANNs



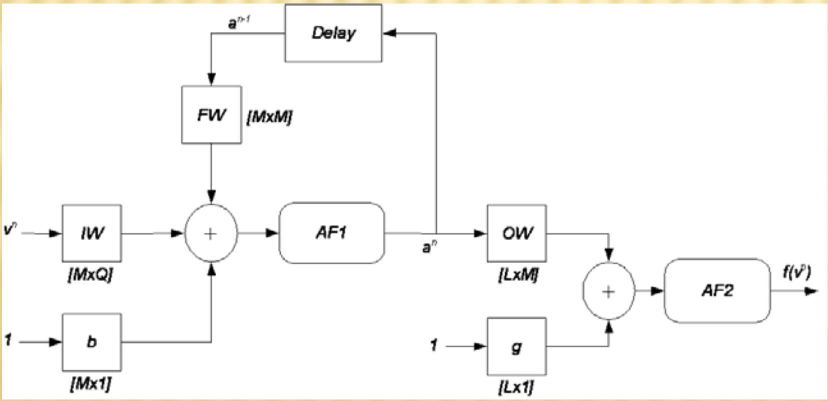
OBJECTIVE 2: INTERNAL COSTS

- Internal costs: precursor **emission reductions**
- **Technical measures**
- **Macrosectors**
- Emission-cost functions
  - **Artificial Neural Networks** (ANNs)
- Identification dataset:
  - 1000 **scenarios simulated by GAINS** for Italy

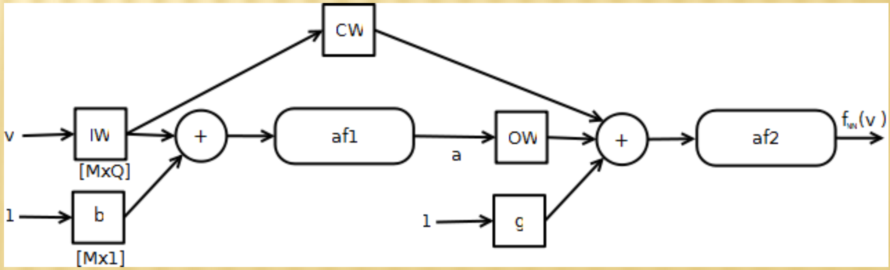
EMISSION-COST MODELS

- ANNs **Input:**
  - Optimized emissions [kton] of the 5 precursors, sampled using a uniform distribution, between CLE2020 and MFR2020
- ANNs **Output:**
  - Optimal costs over CLE2020 [Meuro/ton]

Elman NN



Cascade-forward



BEST PERFORMING ANNS ARCHITECTURE

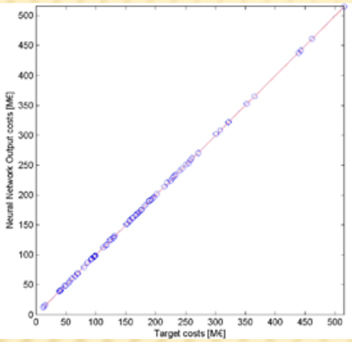
MACROSECTOR	*INPUT FUNCTION*	*OUTPUT FUNCTION*	*TRAINING*	*NEURONS*	*ANNs input (EMISSIONS)*
1	poslin	poslin	trainlm	19	SO2, NOx, pPM, NH_3
2	tansig	poslin	trainlm	17	SO2, NOx, pPM, NH_3, VOC
3	logsig	poslin	trainlm	25	SO2, NOx, pPM, NH_3
4	poslin	poslin	trainlm	17	SO2, NOx, pPM, VOC
5	logsig	poslin	trainbfg	15	pPM, VOC
6	poslin	poslin	trainlm	17	VOC
7	logsig	poslin	trainlm	17	NOx, pPM, NH_3, VOC
8	poslin	poslin	trainbfg	25	SO2, NOx, pPM, NH_3, VOC
9	tansig	poslin	trainlm	21	SO2, NOx, pPM, NH_3, VOC
10	poslin	poslin	trainlm	20	SO2, NOx, pPM, NH_3, VOC

COST ANNS: RESULTS

MACROSECTOR	Normalized Mean Error [%]	Normalized Mean Absolute Error [%]
1	-0,23	0,65
2	0,15	2,05
3	0,13	1,05
4	0,03	0,06
5	0,002	0,003
6	0,22	1,52
7	-0,27	2,13
8	**0,44**	**7,55**
9	-0,50	1,78
10	-0,06	0,52

COST ANNS: MACROSECTOR RESULTS

1



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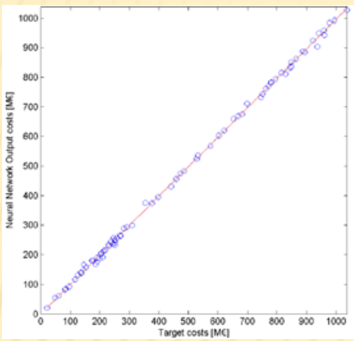

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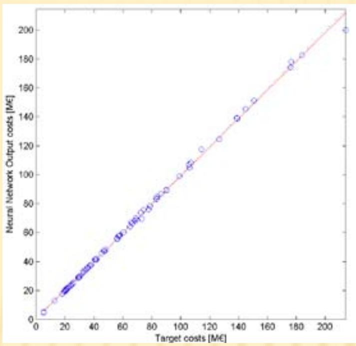

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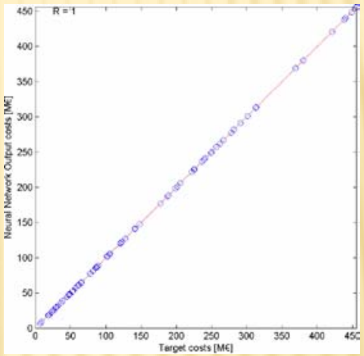

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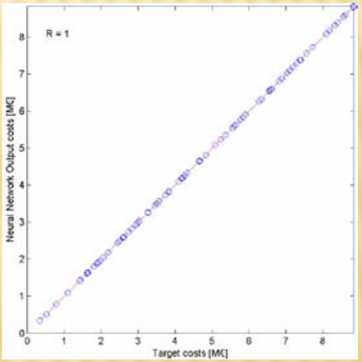

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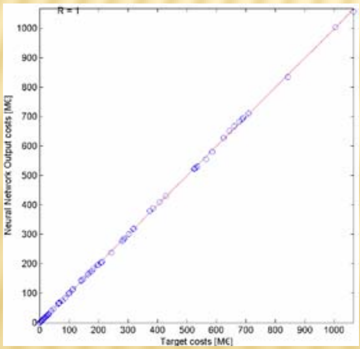

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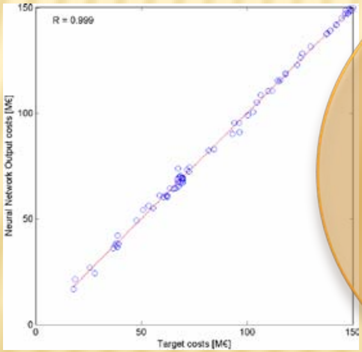

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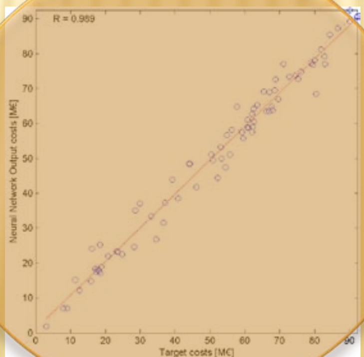

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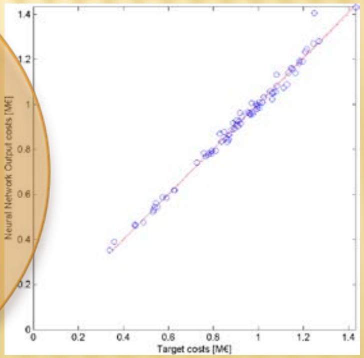

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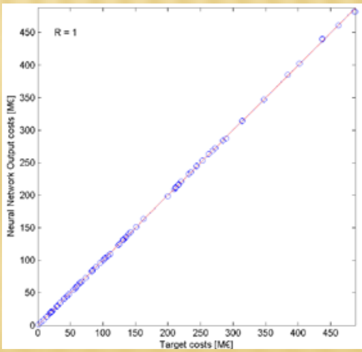
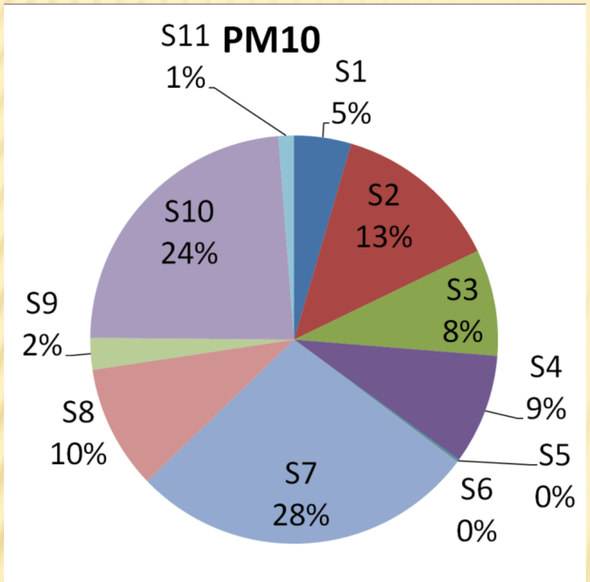
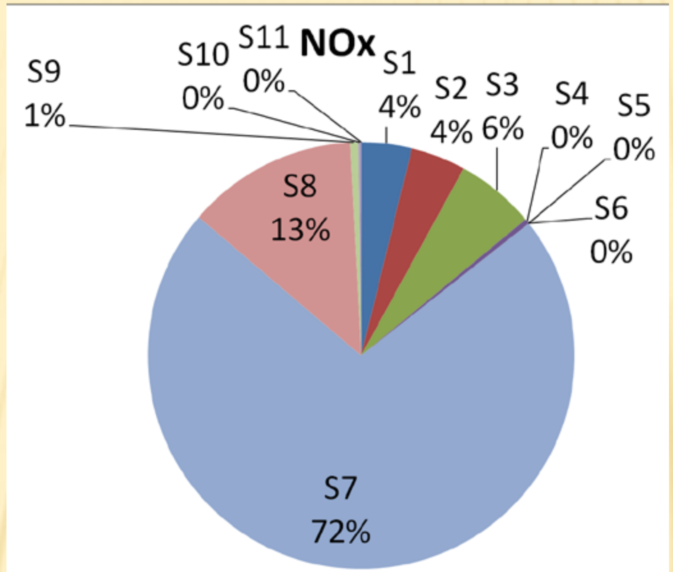
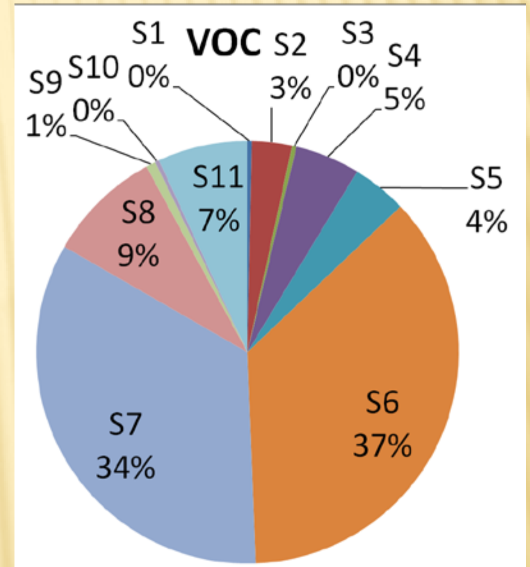
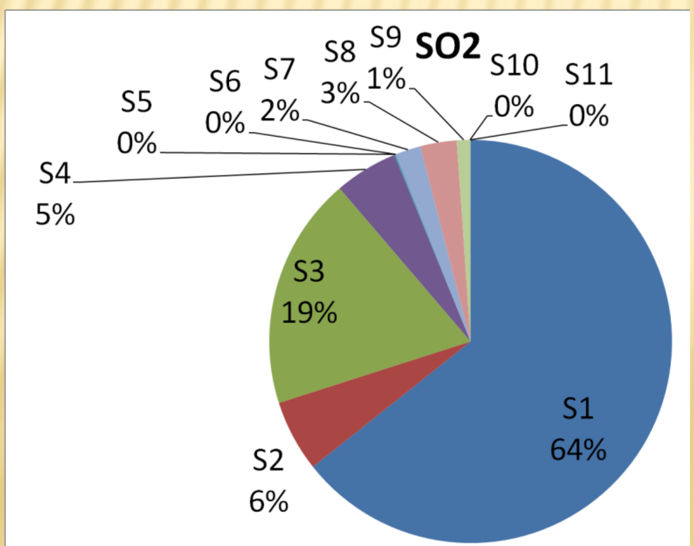


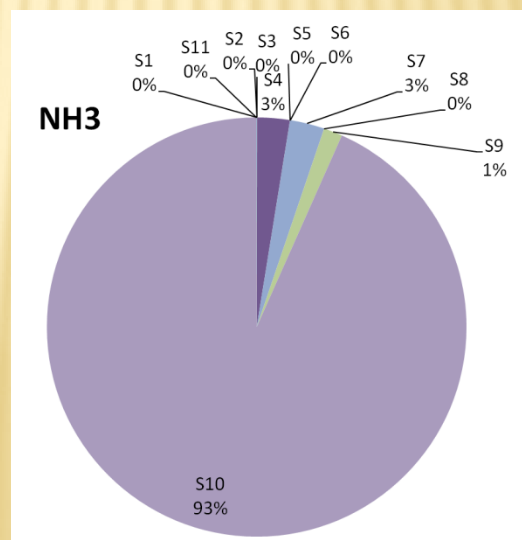
MACROSECTOR EMISSIONS





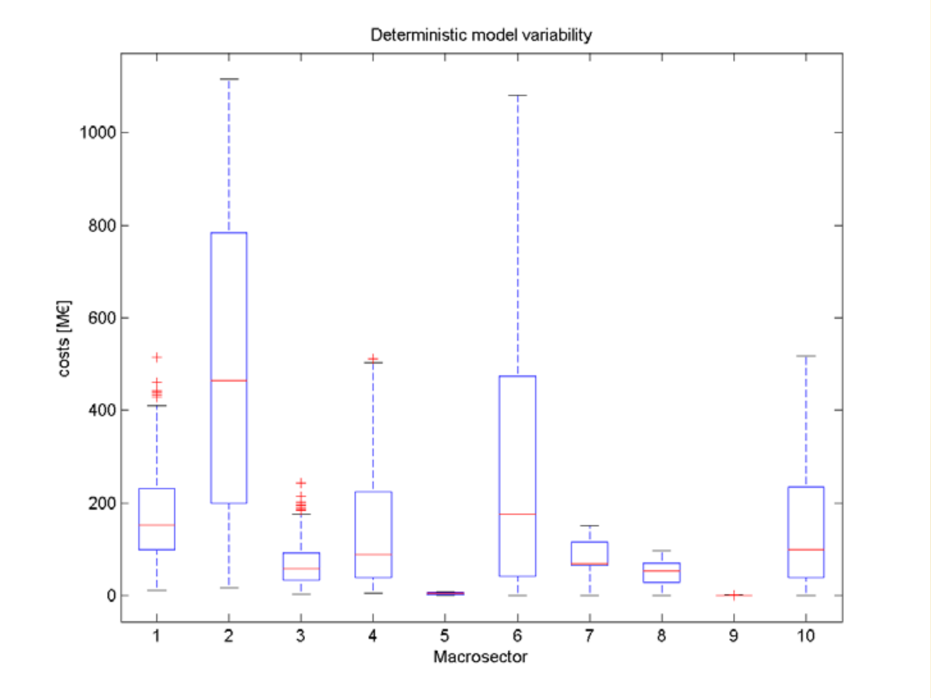




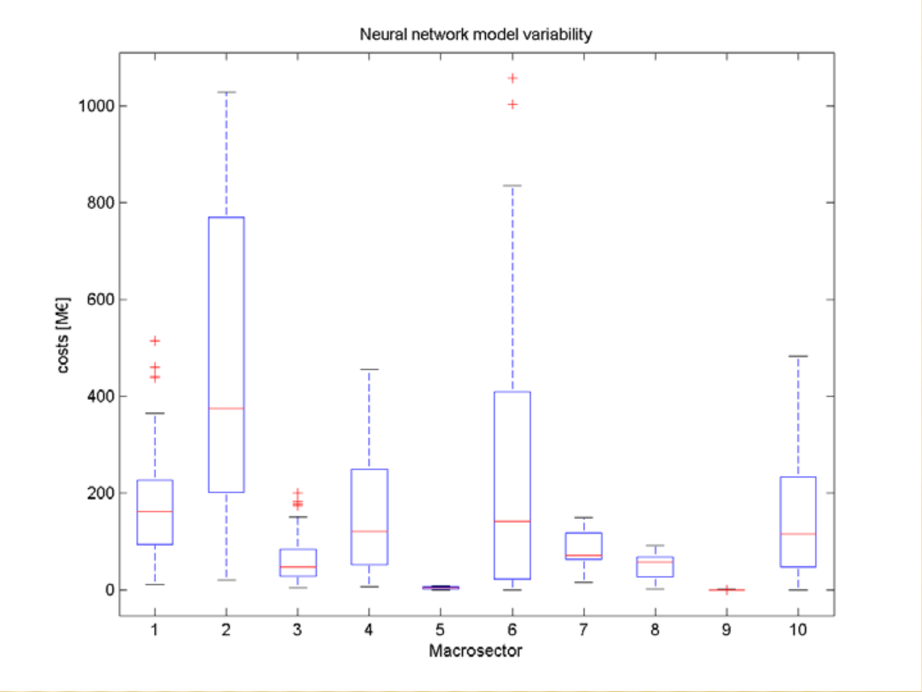


COST ANNS: RESULTS

GAINS



ANNs



DECISION PROBLEM SOLUTION

- Weighted sum method:

$$\min_{\theta} J(\theta) = \min_{\theta} \left[\alpha \cdot AQI(E(\theta)) + (1-\alpha) \cdot C(E(\theta)) \right]$$

$$0 \leq \alpha \leq 1$$

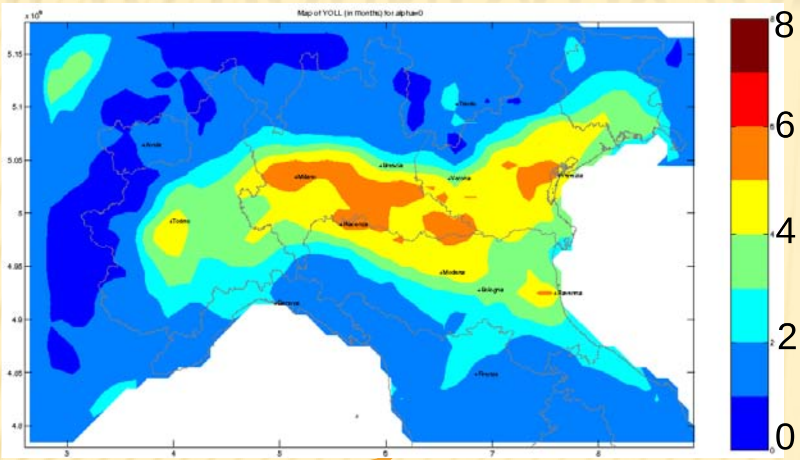
- Constraints:

	1	2	3	4	5	6	7	8	9	10	11
VOC	0,00	0,66	0,00	0,37	0,02	0,35	0,00	0,00	0,06	0,90	0,00
NOx	0,52	0,27	0,58	0,50	0,00	0,00	0,62	0,77	0,50	1,00	0,00
NH3	0,41	0,02	0,76	0,00	0,00	0,00	0,08	0,47	0,00	0,34	0,00
PM10	0,65	0,75	0,20	0,50	0,00	0,00	0,00	0,00	0,29	0,78	0,00
SO2	0,70	0,22	0,42	0,61	0,00	0,00	0,00	0,77	0,36	1,00	0,00

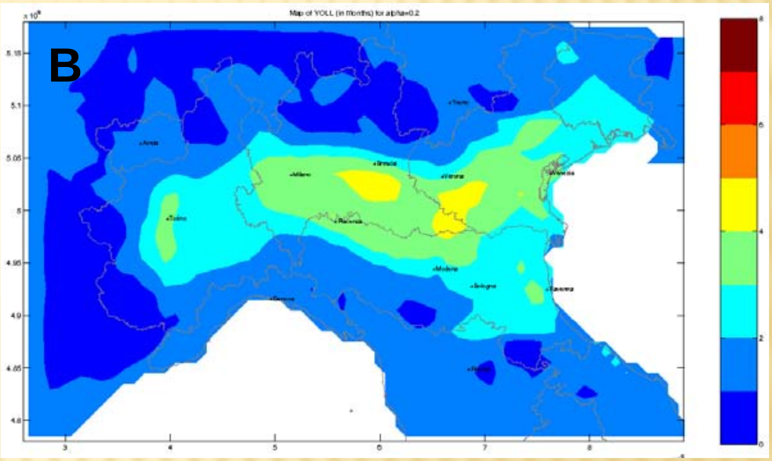
- Multi-pollutant technologies

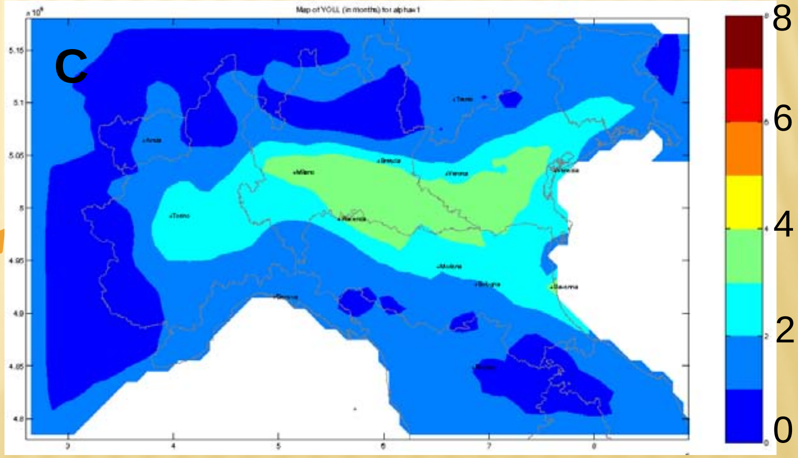
PARETO BOUNDARY (OVER CLE2020)

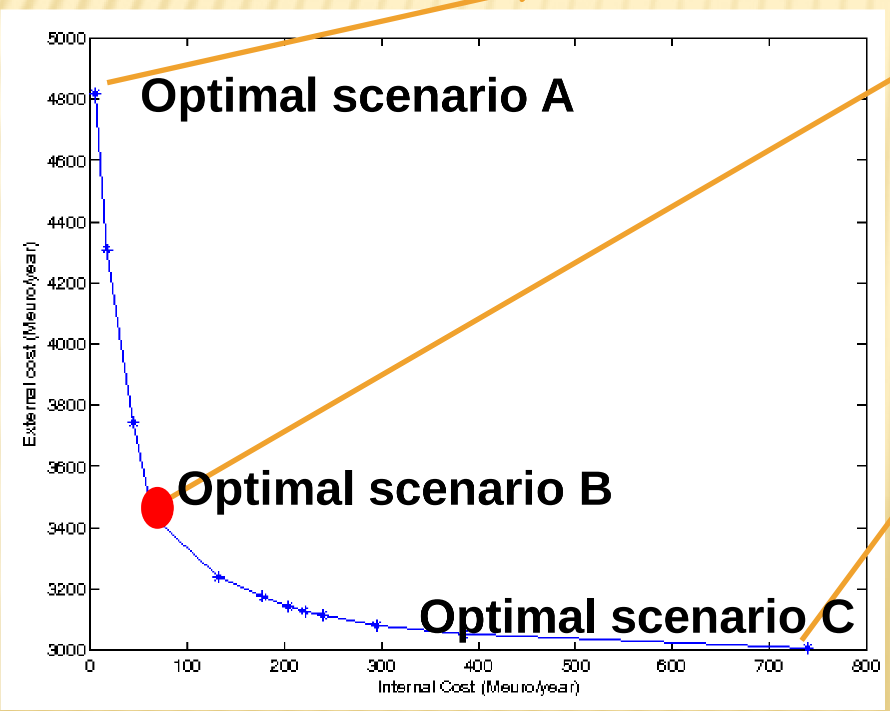
A



months of lost life

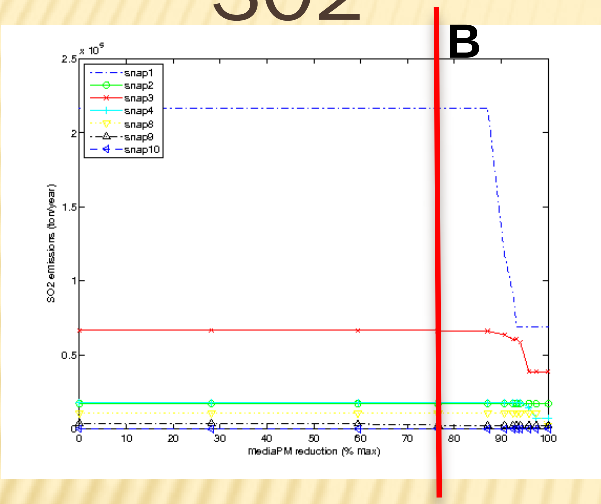




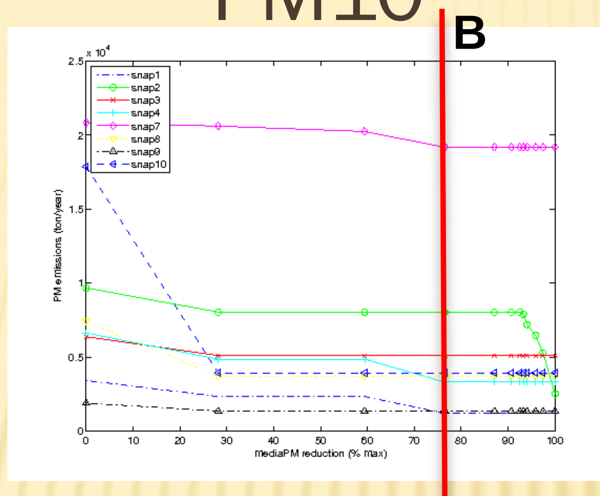


OPTIMAL POLICIES (OVER CLE2020)

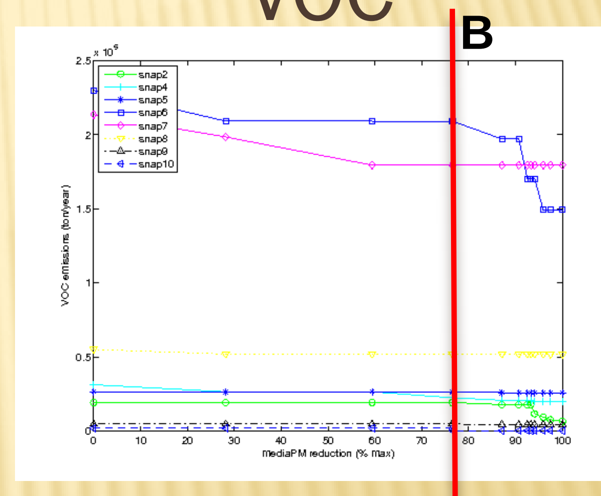
SO2



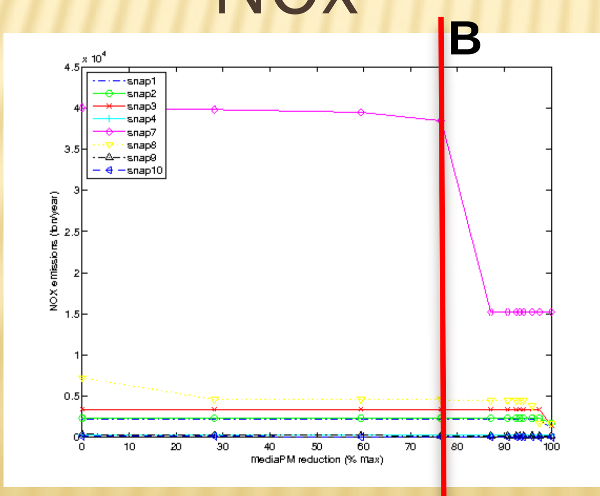
PM10



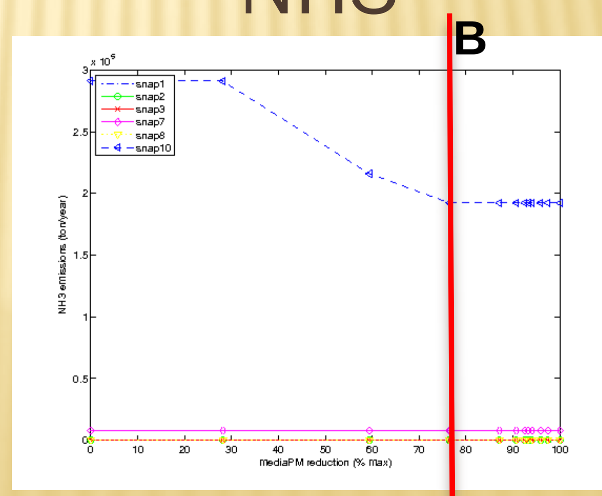
VOC



NOx



NH3



CONCLUSIONS

- A **decision model** has been formalized to control PM10 exposure in Northern Italy
- Emission-AQI and Emission –Cost: **non-linear functions**
- AQI and internal costs are simulated by ANNs
- **TCAM** (11) and **GAMES** (1000) simulations
- Optimal policy analysis
- Comparison between the solutions of the proposed methodology and the GAINS ones?

SENSITIVITY ANALYSIS

1. the **sensitivity** of the effective policies to
   - ✓ uncertainty of the inputs
   - ✓ different problem formulations, optimization algorithms, planning objectives, emission-concentration relationships, spatial scales …
2. the definition of a set of **indexes** and a **methodology to measure the sensitivity** of the decision problem solutions.

the absolute "optimal" policy is not known	intercomparison	indexes

3. **methods** and tools to **support** air quality authorities in the application of IAMs