Integrated assessment of direct and indirect impacts on health of active mobility measures

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Introduction and context

Particulate matter (PM), is still a major problem in some European areas, where high concentration levels represent a continuing threat to human health. In these areas, behavioral measures could be a viable option to abate PM precursor emissions beyond levels reachable with end-of-pipe measures application. Integrated Assessment Modelling (IAM) is a methodology that allows to evaluate the the socio-economical and health impacts of Air Quality policies. This work presents the MAQ model, an Integrated Assessment Model, designed to select efficient Air Quality policies. The model has been applied to assess **fuel savings, greenhouse gases emission reduction, direct and indirect health impacts** of **active mobility (AM) measures** (i.e. cycling or walking).

Materials and approaches

MULTI-DIMENSIONAL AIR QUALITY MODEL

The MAQ model [1] is based on a multi-objective approach. It aims at minimizing, in a given domain, one or more **Air Quality Indexes** (AQIs), representing the impacts on air quality of a policy, namely a set of measures (decision variables) and its **implementation cost** (IC), while satisfying a set of constraints. The problem can be formalized as follows:

$$\min_{\Theta}\left[AQI(\Theta), IC(\Theta)\right]$$

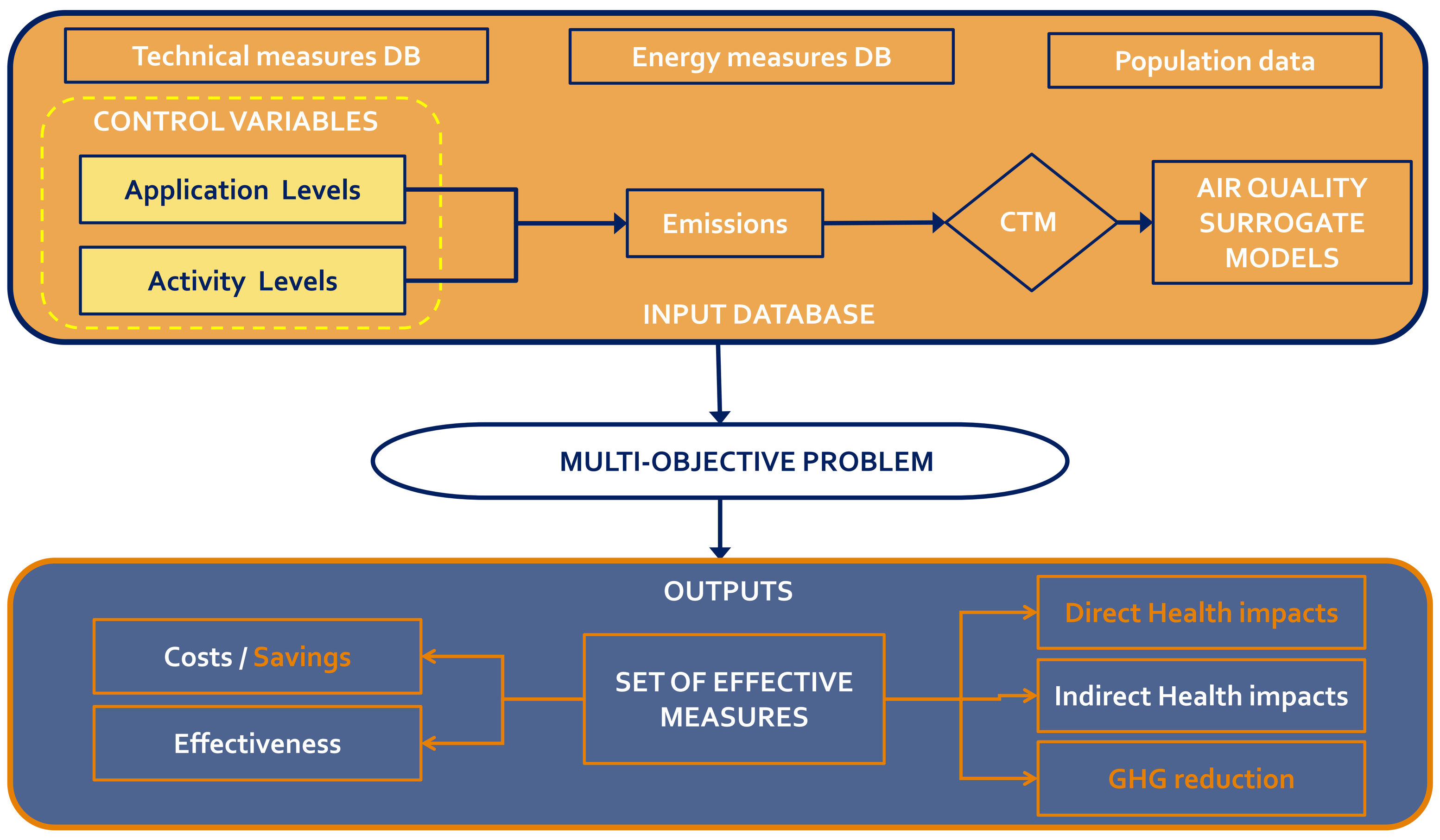
subject to

$$\xi(\Theta) \leq 0$$

$$\eta(\Theta) = 0$$

where:

- Θ is the set of decision variables, including end-of-pipe and technical measures i.e. the feasible emission reduction measures;
- AQI is the Air Quality Index, it is linked to the decision variables affecting the precursor emissions E(Θ) though a non-linear relation;
- IC is the cost due to abatement measures implementation;
- η and ξ are in general non-linear functions constraining the decision variables.



HEALTH IMPACT ASSESSMENT

INDIRECT HEALTH IMPACTS of PM exposure, in terms of Years of Life Lost (mortality) and morbidity impacts, is calculated following the **ExternE methodology** [2].

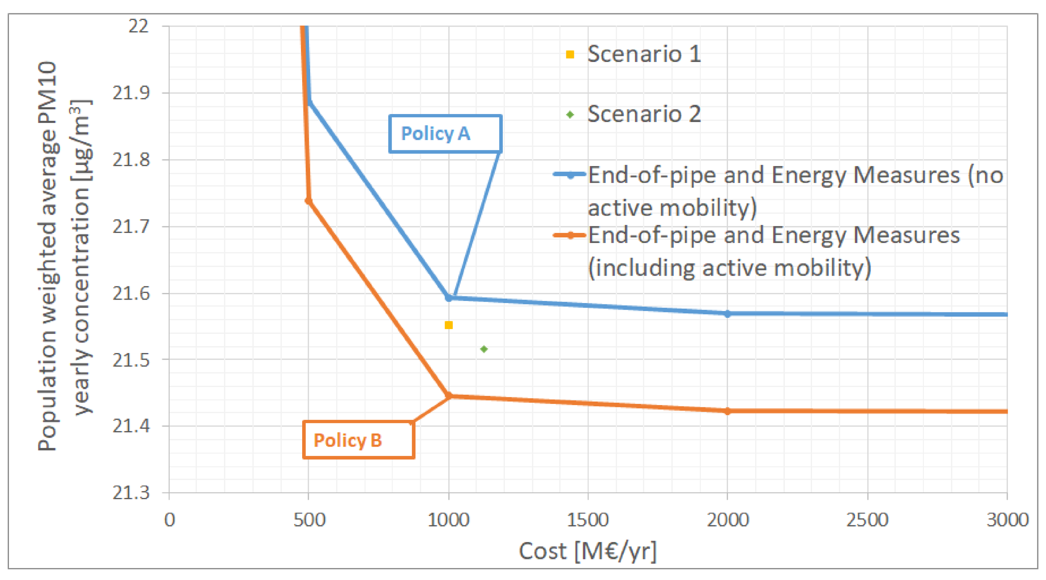
DIRECT HEALTH IMPACTS due to AM measures have two different effect:

1. A reduction in YOLLs due to increased levels of physical activity [2]
2. An increase of YOLLs due to increased breathing rates [3]

Materials and approaches

The methodology is applied to Lombardy, a region in Northern Italy. The efficient emission reduction policies are described by the Pareto Curve, on the horizontal axis the internal costs are displayed in millions of euros per year, while on the vertical axis the AQI estimated is shown (see Figure below). Policy B is an extreme scenario where all the commuters decide to adopt AM measures at a very low social cost, the cost of an information campaign (0.02 M€/PJ). Two additional scenarios closer to reality can be developed starting from Policy A (not considering active mobility measures) and:

- assuming only a third of the commuters adopt AM measures at a cost equal to the communication campaign (Scenario 1)
- two thirds of the commuters may choose to adopt AM measures if payed for the increased time spent travelling (14.1 €/hr [4]). (Scenario 2).

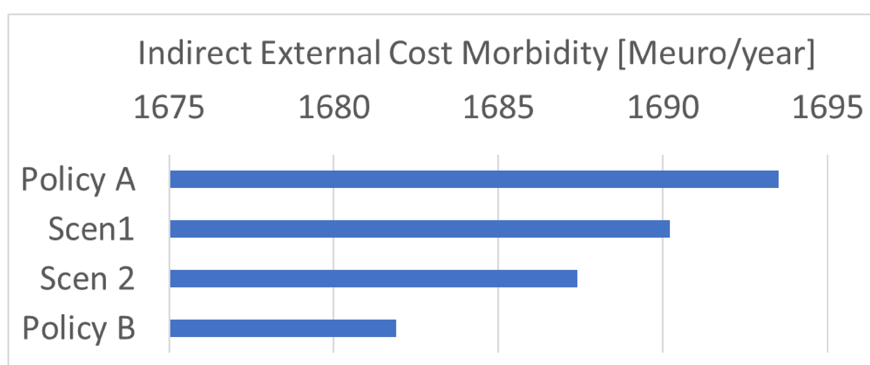


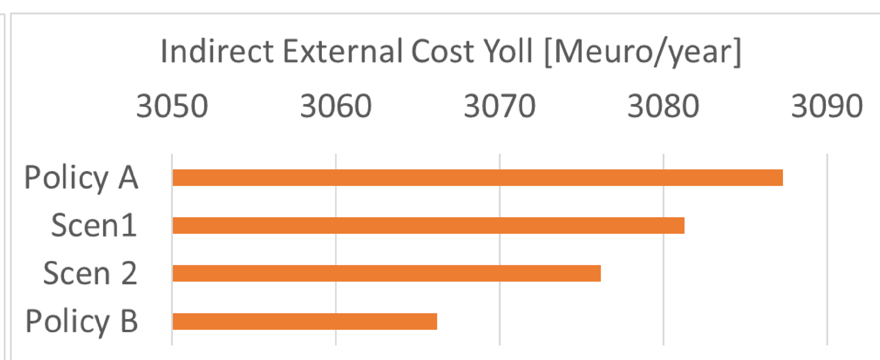
The abatement policies are applied, not only to road transports, but throghout different activity macro-sectors to maximize efficency. The table below shows the measures implementation costs for a selection of CORINAIR macro-sectors.

Scenario	MS 1	MS 2	MS 3	MS 6	MS 7	MS 8	MS 10
Policy A- End-of pipe	44.70	-6.03	0.72	536.52	6.06	6.33	94.11
Policy A- Energy	10.55	258.44	0.00	0.00	19.20	4.61	0.00
Policy B- End-of pipe	44.71	-6.05	0.63	536.52	6.16	6.34	94.11
Policy B- Energy	10.30	261.12	0.00	0.00	18.71	3.64	0.00

The costs and savings for the different scenarios with respect to road transport sector are summarized in the following table. The table also reports the overall CO2eq emission reductions.

Scenario	End-of-pipe measures cost [M€/yr]	Energy measures cost [M€/yr]	Tot. Savings [M€/yr]	AM Savings [M€/yr]	CO2eq reduction [kton/yr]
Policy A	6.1	19.2	1270.3	-	1146
Scenario 1	6.1	19.86	1622.73	352.43	1359
Scenario 2	6.1	145.5	1975.17	704.87	1416
Policy B	6.2	18.7	2360.2	1072.65	1482





The following table lists the direct and indirect health impacts od the Scenarios.

	Policy A		Scenario 1		Scenario 1		Policy B	
	Bike	Walk	Bike	Walk	Bike	Walk	Bike	Walk
Commuters adopting AM [M people]	0	0	0.33	0.82	0.66	1.65	0.95	2.35
Direct impact per commuter (YOLL loss) [months per commuter]	-	-	-50	-24	-50	-24	-50	-24
Direct impact per commuter (YOLL loss) [months per commuter]	-	-	5.14	0.54	5.14	0.54	5.14	0.54

Transferability

This approach can be applied to different areas throughout the globe, from the regional to the metropolitan scale in order to assess user defined sets of end-of-pipe, energy and behavioral abatement measures. This flexibility allows the system to be applied by a range of different actors ranging from regional/municipal decision makers to industry, where the approach can be applied to assess the cost effectiveness of innovations in terms of air quality indicators.

References

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