Chapter 5
Two Illustrative Examples: Brussels and Porto

C. Carnevale, F. Ferrari, R. Gianfreda, G. Guariso, S. Janssen, G. Maffeis, A.I. Miranda, A. Pederzoli, H. Relvas, P. Thunis, E. Turrini, P. Viaene, P. Valkering and M. Volta

5.1 Introduction

To evaluate in practice how IAM can be used to formulate and improve current air quality plans, this chapter reports on the application of one of the existing IAM tools, to two test cases: one is the Brussels Capital Region in Belgium and the other the region of Porto in the North of Portugal. The two cases are representative for the two options that are available for the decision pathway in the IAM framework as presented in Chap. 2: the scenario evaluation and the optimisation. Before presenting the peculiarities and the results obtained for the two test cases, this chapter briefly describes the specific features of the IAM tool used, namely RIAT+.

C. Carnevale · A. Pederzoli · E. Turrini · M. Volta (✉)
Università degli Studi di Brescia, Brescia, Italy
e-mail: marialuisa.volta@unibs.it

F. Ferrari · R. Gianfreda · G. Maffeis
Terraria srl, Milan, Italy

G. Guariso
Politecnico di Milano, Milan, Italy

S. Janssen · P. Viaene · P. Valkering
Vlaamse Instelling voor Technologisch Onderzoek n.v. (VITO), Mol, Belgium

A.I. Miranda · H. Relvas
Universidade de Aveiro, Aveiro, Portugal

P. Thunis
European Commission, Joint Research Centre (JRC), Directorate for Energy, Transport and Climate, Air and Climate Unit, Ispra, Italy

5.2   The RIAT+ System

The RIAT+ system was developed during the EU OPERA project (www.operatool.eu) and it is intended to help regional decision makers select optimal air pollution reduction policies that will improve the air quality at minimal (industrial and/or external) costs. To achieve this, the system incorporates explicitly the specific features of the area of interest with regional input datasets for the:

- Precursor emissions of local and surrounding sources;
- Abatement measures (technical and non-technical) described per activity sector and technology with information on application rates, emission removal efficiency and cost;
- The effect of meteorology and prevailing chemical regimes through the use of site-specific source/receptor functions.

The system runs as a stand-alone desktop application and can be downloaded from the OPERA project website (http://www.operatool.eu/download/). The package is distributed with a personal, non-exclusive and royalty-free license and has been applied in various regions, such as Emilia-Romagna (Carnevale et al. 2012) and in Alsace (Carnevale et al. 2014).

The RIAT+ software implements both the possible decision pathways introduced in Chap. 2 in the light of the classical DPSIR (Drivers-Pressures-State-Impact-Responses) scheme, adopted by the EU:

- **Scenario analysis**, where emission reduction measures are selected on the basis of expert judgment or Source Apportionment and then tested through simulations of an air pollution model.
- **Optimisation**, where the set of cost effective measures for air quality improvement are automatically selected by solving a multi-objective optimization problem.

To allow both approaches to be implemented in a fast and handy way (i.e. to be able to support a real-world discussion about possible options) a key feature of RIAT+ is a S/R model used to relate emissions (pressures) to a suitable air quality indicator, AQI (state). In principle, such a S/R model should be a full complex chemical transport model, but in practice this would be impossible for the computational burden that such models imply. So, within RIAT+, the relations between emissions and air quality indicators are expressed by means of Artificial Neural Networks (ANNs), that, in turn, are tuned to replicate the results of deterministic air quality model. ANNs are often referred to in this context as "surrogate models". The reason for this choice is that neural networks are known to be suitable to describe a nonlinear relationship between data, such as those theoretically involved in the formation of air pollution. Their identification procedure requires two steps: (1) the definition of the specific structure, and (2) the calibration of the parameters to the specific application. The selected structure of the ANNs must be able to retain what are considered to be the essential features of the original model. As the value

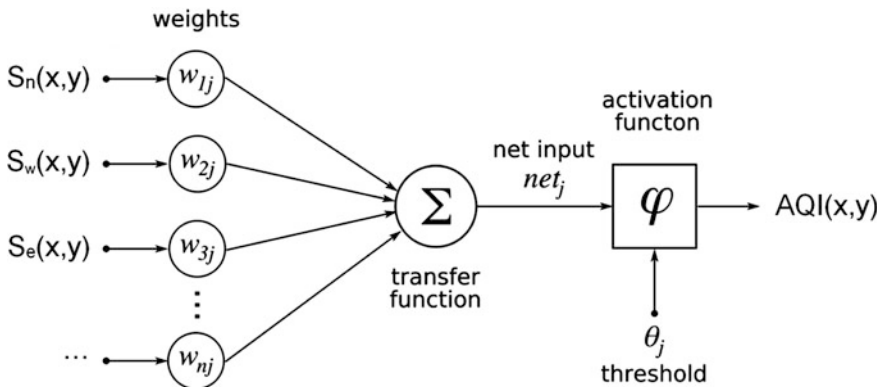**Fig. 5.1** *Quadrant shape* input configuration

Fig. 5.2 A sketch of an elementary neuron

of an air quality index is not only dependent on the local precursor emissions but also on surrounding emissions, the surrogate models must consider the influence of these surrounding emissions and the prevalent wind direction. This is achieved by considering a quadrant shape input configuration as shown in Fig. 5.1 where the emissions $S_j(x, y)$ are summed according to these quadrants, the dimension of which depends on the specific area and pollutant under study, and then used to compute the AQI value in position (x, y). Such a calculation is performed using a network of connected elements (neurons), the structure of which is sketched in Fig. 5.2.

The development of the surrogate models thus means: first, the definition of the input variables and of the form of the so-called "activation function" φ, generally a strongly nonlinear function of its argument, which is in turn a weighted sum of the input values; second, the determination of all the model parameters (namely, the weights w_{ij} and the threshold θ_j).

This second step (training) is performed by imposing that the surrogate model represent, as much as possible, a set of CTM calculations that are representative of the range of emissions/AQI that may be entailed by the plan to be developed. The process of selecting such configurations to be simulated by the CTM is usually
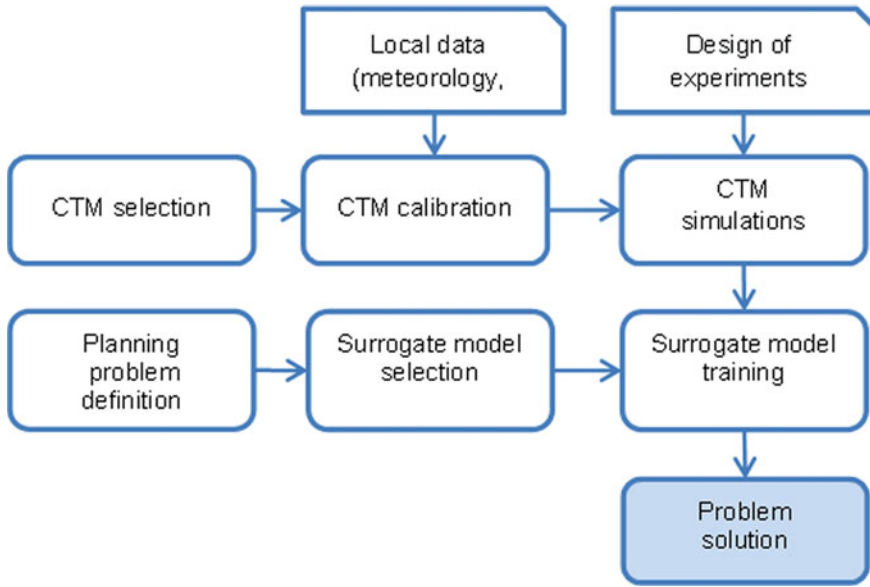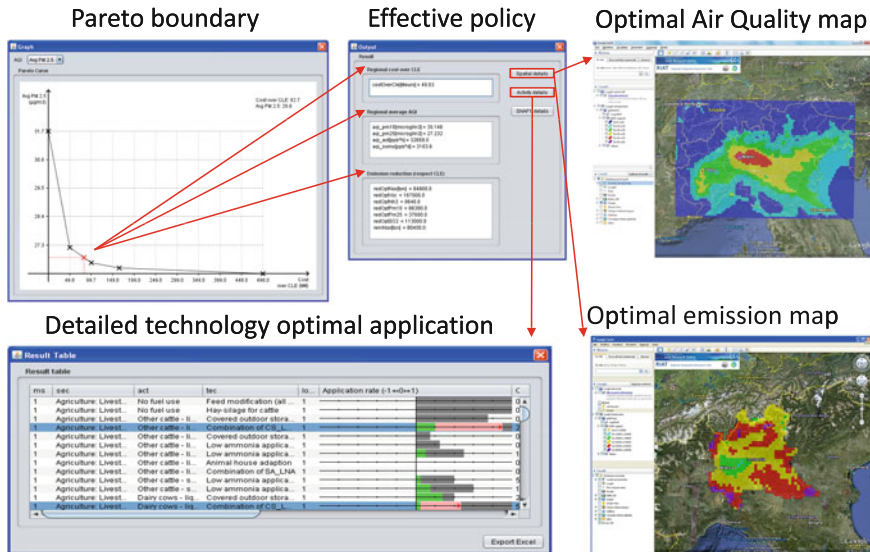
Fig. 5.3 RIAT+ solution procedure

Fig. 5.4 RIAT+ output

referred to as the 'Design of Experiment'. On the one hand, these simulations have to be limited in number due to their computational time, but, on the other hand, they must be able to represent as closely as possible the cause-effect relationship between precursor emissions and the considered AQIs.

The overall solution procedure implemented in RIAT+ is presented in Fig. 5.3, which shows how local data, CTM simulation and problem statement are combined to determine the overall results. These can in turn be analysed under different views: values and costs of measures in different sectors, spatial distribution of emissions and AQIs, efficient trade-offs between costs and AQIs (see Fig. 5.4).

RIAT+ IAM system has been used in support of air quality planning in Brussels Capital Region (Belgium) and in the Great Porto Area (Portugal). The results of such applications are briefly sketched in the next sections.

5.3 Brussels Capital Region

The Brussels Capital Region (BCR) has an area of 161 km^2 and is home to more than 1.1 million people. The region consists of 19 municipalities, one of which is the Brussels Municipality, the capital of Belgium. The location of the BCR in Belgium is shown in Fig. 5.5.

For the BCR, Brussels Environment, BIM (http://www.ibgebim.be) is responsible for the study, monitoring and management of air, water, soil, waste, noise and nature (green space and biodiversity). BIM proposed a list of 13 measures to improve air quality, approved by the Brussels authorities and consisting of nine measures related to vehicle traffic and four to domestic heating. For these abatement measures, BIM provided order-of-magnitude estimations of the costs and emission reductions. These were screened to determine the effect of the different measures using RIAT+ in the scenario mode.

Fig. 5.5 Location of the BCR (*dark area*) in Belgium

5.3.1 Proposed Abatement Measures

Traffic

Reduction measures related to traffic are mainly non-technical, meaning that they involve a change of the traffic flows more than a change in the emission standards. The main actions that were analysed are:

- The introduction of a low emission zone (LEZ) extended to the entire capital region or only the inner part of Brussels municipality. Two possibilities were tested: a restriction only for Heavy Duty Vehicles (HDV) with emission standard prior to Euro 5; or a restriction also for passenger cars with diesel engine before Euro 5 and gasoline before Euro 2. Emission and cost data related to these cases were derived from a TM-Leuven (2011) study. Reduction entailed by these plans ranged, for instance for PM2.5, between 10 and 40 % with respect to the CLE scenario.
- Reduction of the car parking lots available in Brussels by 25,000. This measure is assumed to reduce the number of commuters entering Brussels every day and discourage the local inhabitants from using cars to drive to work. The estimate of BIM/IBGE (2012) is that 140,000 commuters enter Brussels in every weekday and 225,000 residents use their vehicle to get to work. Given that the estimated distance travelled is about 9 km for residents and 13 km for the others, and assuming that the reduction of parking places entails a corresponding reduction of trips, this measure would mean a reduction of 129 M km a year with a 1.5 % reduction of the traffic emissions.
- The implementation of mobility plans encouraging public transport for all the sites hosting more than 1000 people and all events involving more than 1000 participants. This is assumed to equal a 3.7 % reduction of the traffic sector, with a correspondent reduction, for instance, of 2.6 % of PM10 emissions.
- A modal shift from car to bike for commuting. This follows existent plans to move from the current 1.9 % of commuting trips by bike to 20 % by 2018. An English study indeed showed that each new cyclist corresponds to a 500 € gain per year for society, mainly through the reduction of costs in health care (Cycling England 2007). This would correspond to a further reduction of commuting private traffic by 4.8 %.
- The introduction of a urban toll. This can be implemented according to different schemes: a toll of 12 €/day within BCR; one of 3 €/day in the larger Brussels Regional Express Network (RER); a price of 7 c€/km in the RER zone. The first scheme is estimated to reduce NOx emission by 18 % with respect to CLE 2018, the second by 11 %, the third by 9 %. According to a STRATEC (2014) study, the net present value of the costs for implementing these scheme ranges from 250 M€ for the first two, to about 2500 M€ for the third.
- Eco-driving. To make eco-driving the standard on roads, it should be first taught during the various formations of the road users (driving license, taxi driver permit, training of bus and truck drivers, etc.); but we must also regularly sensitize drivers by information and awareness tools, particularly within

enterprise transport plans. Following AIRPARIF (2012), it is assumed that about 25 % of all drivers are susceptible to a more eco-driving style, implying 7 % less fuel use, and hence a 1.7 % reduction of emissions. Assuming a full scale eco-driving campaign similar to that implemented in the Netherlands (ECODRIVEN 2008) will result in a rough estimate of 180 k€ annually. This implies a net present value, discounted over a time period of 6 years (e.g. 2014–2020) on the basis of a 5.7 % interest rate, of about 1 M€.

- Stimulating the use of Compressed Natural Gas (CNG) as car fuel. While this is a more technical measure, it seems that in Belgium is more a psychological problem than a lack of infrastructure. It is necessary to implement incentives and information campaigns and to increase the number of points of sale sufficiently to make CNG a viable alternative as in many other countries. With respect to the 2010 situation (FEBIAC 2013), it was assumed that 540,000 (10 % of the fleet) could run on CNG in 2020, substituting 6.3 % of current diesel cars and 3.7 % of gasoline cars. Since the average mileage is 15,500 km/year, this would mean a decrease of 7.6 % of NOx emitted by cars.

Domestic heating

The reduction of emissions in the thermal energy sector was planned along both technical and non-technical actions.

- Maintenance of residential heating appliances. This measure consists of a periodic inspection of boilers, according to the requirements listed in the PEB (Performance Energétique des Bâtiments) guidelines. In particular, in this study, the measure was only applied to residential boilers, with a power in excess of 20 kW, which corresponds, to 95 % of all boilers in the residential sector. Specifically, the periodic inspection of boilers consists of cleaning all components of the boiler and flue system, the burner setting and compliance verification requirements. Oil-fired boilers should be checked annually while natural gas boilers should be checked every three years. The adoption of this measure is assumed to reduce NOx emissions by 72 ton, SOx by 33 ton, VOC by 9.3 ton, and PM2.5 by 3 ton in 2020. According to the estimate of VITO (2011) the adoption of this action may cost around 18 M€/year.
- Improving building isolation. This measure aims to stimulate the construction and building renovation programs by demonstrating that it is possible to achieve excellent energy and environmental performance while opting for economically justifiable solutions and promoting high architectural quality. It provides building owners the opportunity to be ambitious, and allows to generate a number of exemplary buildings that have a lasting effect on the Brussels construction market through the experience obtained. Between 2007 and 2013, 520,000 m^2 of buildings were renovated with an improved isolation in the Brussels area.
- Local plan for energy management and energy audits. This measure is mainly constituted by an analysis of existing or renovated building owned by large real estate companies to define where energy-saving maintenance is needed, and is

mandatory under city government regulations. It is estimated to reduce NOx emission by about 24 ton in 2020, VOC emissions by slightly more than 3 tons and only by 0.6 ton PM2.5. The cost has not being evaluated since they are part of CLE 2020.

5.3.2 The 2010 Scenario

The starting situation for the simulations was a reconstruction of 2010 situation based on the emission inventory of the previous year. For the two sectors involved, namely domestic heating (SNAP code 2) and traffic (SNAP 7) the emissions are listed in Table 5.1.

Table 5.2 reports all the reductions per each pollutant and each measure that can be obtained by their full adoption.

The air quality modelling system AURORA (Mensink et al. 2001; Lauwaet et al. 2013) was used in Brussels capital region to simulate the transport, chemical transformations and deposition of atmospheric constituents at the urban to regional scale. It consists of several modules. The emission generator calculates hourly pollutant emissions at the desired resolution, based on available emission data and proxy data to allow for proper downscaling of coarse data. The actual CTM then uses hourly meteorological input data and emission data to predict the dynamic behaviour of air pollutants over the study area. This results in hourly three-dimensional concentration and two-dimensional deposition fields for all species of interest. For the BCR, AURORA was set up for a domain of 49 × 49 grid cells at 1 km resolution. For the vertical discretisation, 20 layers were used for a domain extending up to 5 km. The layer thickness increases from 27 m for the bottom layer to 743 m for the top layer. For the boundary conditions, the results of an AURORA run were used for a domain covering Belgium at a resolution of 4 km. The same boundary conditions were used in all runs. For the meteorological inputs, the ECMWF ERA INTERIM data with a resolution of 0.25° were used and interpolated to the model grid. The emissions are based on the CORINAIR emission inventory, which were spatially disaggregated using the Emission MAPping tool (E-MAP) developed by VITO (Maes et al. 2009). This tool downscales national emission inventories using a set of proxy data, such as land use information or the road network. The carbon bond CB05 chemical mechanism (Yarwood et al. 2005) was used.

Table 5.1 Emissions (ton/year) in the BCR for the base scenario

Sector	NOx	CO	SOx	VOC	PM2.5
Domestic heating	2266	3899	586	299	71
Traffic	2026	1581	5	5	130

Table 5.2 Emissions reduction (%) wrt the base scenario

Measure description	Emission reduction (%)				
	NOx	SOx	VOC	PM2.5	PM10
Eco driving	1.7	1.7	1.7	1.7	1.7
Modal shift	2.4	0.0	2.4	3.4	3.4
Transport plans	1.9	0.0	1.9	2.6	2.6
Urban toll	18	19	23	15	15
Parking places	0.8	0.0	0.8	1.1	1.1
Boiler maintenance	3.2	5.6	3.1	4.2	4.2
Exemplary buildings	0.2	0.0	0.2	0.1	0.1
Energy efficiency large bldgs	0.3	0.3	0.3	0.3	0.3
Energy audits	1.4	1.1	1.5	1.0	1.0

The model results were validated by comparison to the observed values at the measurement stations inside the domain. The methodology proposed by FAIRMODE (see: Thunis et al. 2012, 2013; Pernigotti et al. 2013) was adopted. Briefly put, the methodology accounts for observation uncertainty in the evaluation of model results and proposes a method to decide whether model results are acceptable. In Fig. 5.6 the target diagram for the NO_2 results is shown. For the results to be acceptable the method requires that they lie within the unit circle. In this sense, evaluating a target diagram is much the same as looking at a darts board, the aim being to have all points as close to the centre as possible. In the present case, all stations are well within the unit circle, except for the single point corresponding to a suburban traffic station where the underestimation of observed values (bias) is bigger although still within the acceptable range. The correspondent diagram for PM10 shows a slightly worse model performance.

Fig. 5.6 Validation analysis of AURORA model results for NO_2. The markers correspond to the situation of 18 measurement stations (CMRSE is centered root-mean-square error)
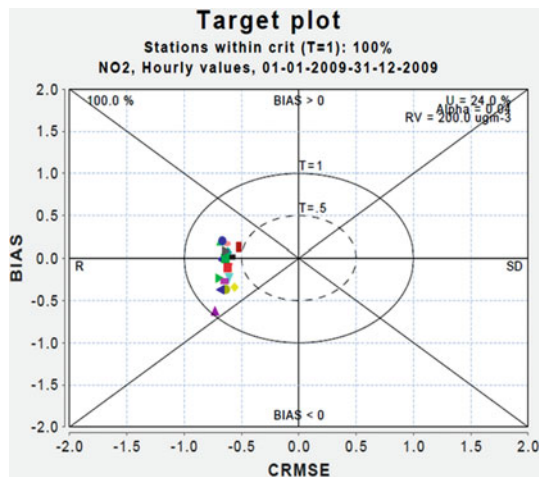
5.3.3 Design of Experiments and Source/Receptor Models

For the Design of Experiment phase, three levels of emission within BCR were distinguished: base case (B), high emission reductions (H) and low emission reductions (L). They correspond to the following assumptions:

- The B emission level corresponds to the CLE2020 emissions, increased by 20 %.
- The H level is obtained by projecting the 2009 regional emission inventory to 2020 with the projected application rates of all technologies (as predicted by the GAINS inventory).
- The L level (low emission reductions) is obtained as the average of B and H.

The emission levels for the model grid cells outside the BCR were also changed according to the changes inside the BCR, while for the boundary conditions of the 49×49 km domain, the average emission variation from the 2009 inventory projected to CLE2020 of the BCR domain cells was applied to the emission inventory covering all Belgium.

To determine the emission reduction scenarios for the ANN training, the three levels B, H, L were combined to produce 14 different emission sets.

The selected Air Quality Indexes (AQIs) were: yearly average of PM10 concentrations and yearly average of NO_2 concentrations. The emissions surrounding individual model grid cells were aggregated according to the quadrants in Fig. 5.1 with a dimension of 14 cells for PM10 and of 20 cells for NO_2.

The ANNs ability to reproduce CTM results was checked in different ways. For instance, Fig. 5.7 shows the results of the differences between other scenarios and the low reduction case.

The ANN is well capable of reproducing the CTM behaviour for NO_2 but has more difficulties with reproducing the PM10 concentration changes. This is
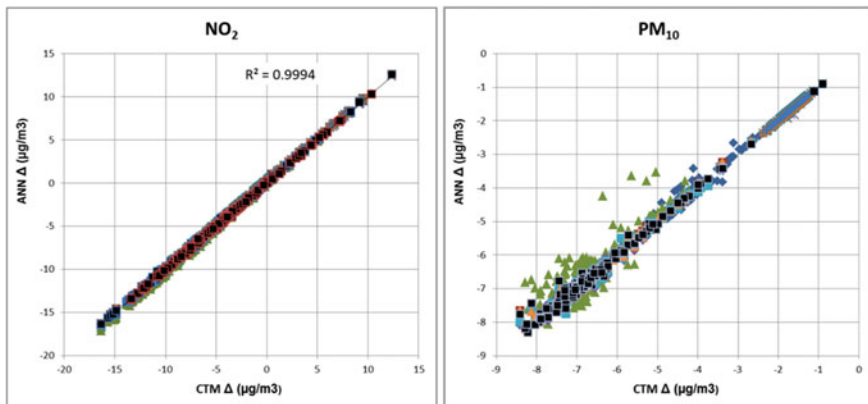

Fig. 5.7 Comparison of ANNs and CTM (AURORA model) results for NO_2 and PM10

especially true for a model run in which only the NOx emissions are changed (represented by small triangles in the figure). For this last case, the average normalised bias amounts to 3.6 % with extreme values of up to 33 % whereas for all the other scenarios the average normalised bias is less than 0.25 %.

5.3.4 Results

The application of RIAT+ allows to quickly compute the impacts of any combination of measures. In particular, for BCR, the concentration patterns were examined, together with the distribution of YOLLs assuming a uniform population density in the area.

Even assuming all the measures are in place, the emission changes are limited, and thus, unsurprisingly, also the concentration changes are limited (see Fig. 5.8). The average estimated changes for PM10 are for most measures less than 0.1 $\mu g/m^3$. This is within the range of model uncertainty, so these results should be considered with caution. As YOLLs are mainly dependent on PM10 concentration, their value should also be interpreted conservatively. All this said, RIAT+ estimates the impact of all measures to be worth well more than ten million euros per year.

Looking at individual measures, the 'toll' seems the most effective, while other traffic measures, such as LEZ, seem less relevant because a large part of old EURO vehicles will already be replaced by newer types in 2020.
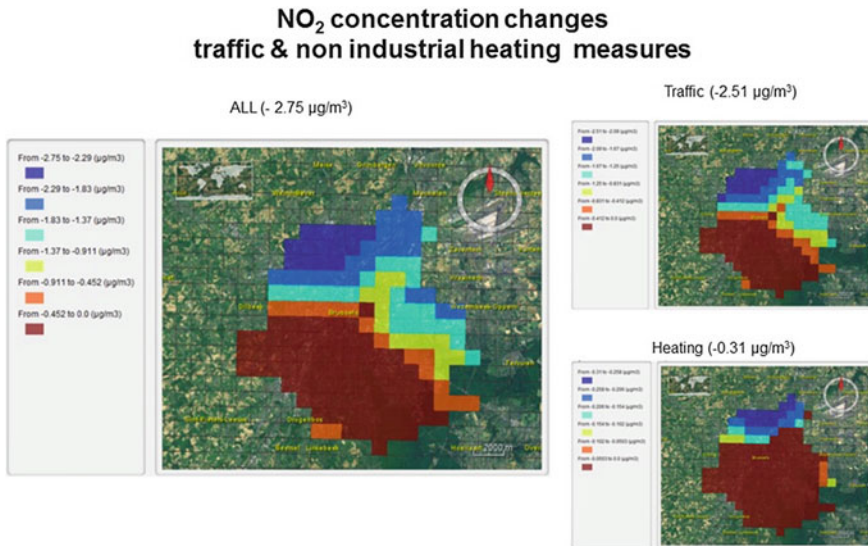

Fig. 5.8 Average NO$_2$ concentration changes due to the application of different set of measures

5.4 Great Porto Area

The Great Porto Area is a Portuguese NUTS3 (Nomenclature of Territorial Units for Statistics) sub region involving 11 municipalities. It covers a total area of 1024 km^2 with a total population of more than 1.2 million inhabitants. Figure 5.9 shows the location of the Greater Porto Area in Portugal and in its northern region.

This region of Portugal is one of the several EU zones that had to develop and implement an air quality plan (AQP) to reduce PM10. AQP was initially designed using a scenario approach considering the implementation of an a priori defined set of abatement measures (Borrego et al. 2011, 2012). This allowed to identify the most relevant emission sectors: industrial combustion, residential combustion and road traffic.

5.4.1 Proposed Abatement Measures

A list of possible abatement measures, including costs and emissions effects was compiled using the GAINS database for Portugal. This database includes: activity details (unabated emission factor, activity level…) and technology details (removal efficiency, CLE and potential application rate, unit cost) for the years 2010, 2015, 2020 and 2025. The reference scenario for March 2013 was considered and 103 «triplets» (sector-activity-technology) were associated to the emission inventory. They are related to: Combustion in energy and transformation industries (SNAP 1) (20 measures); Non-industrial combustion (SNAP 2) (4 measures); Combustion in manufacturing industry (SNAP 3) (23 measures); Production processes (SNAP 4) (7 measures); Solvent and other product use (SNAP 6) (10 measures); Road Transport (SNAP 7) (25 measures); Other mobile sources and machinery (SNAP 8) (14 measures). They are basically all end-of-pipe measures. Technologies for food and drink industry production processes and for construction activities were not included as they are not present in the GAINS database.

Fig. 5.9 Location of the Great Porto area in Portugal and model grid used
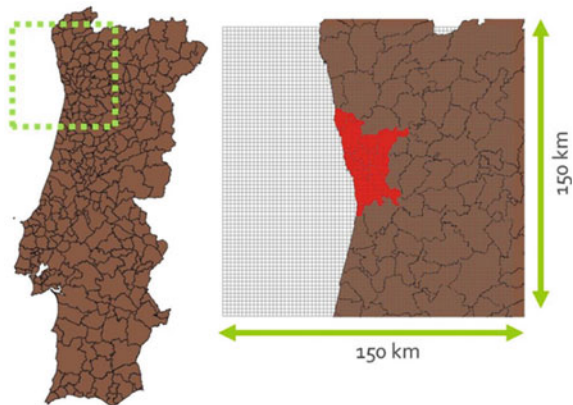
5.4.2 The Chemical Transport Model

The Air Pollution Model (TAPM) (Hurley et al. 2005) was used for the simulation of different mitigation scenarios. It is a 3-D Eulerian model with nesting capabilities, which predicts meteorology and air pollution concentrations. It simulates the transport, dispersion and chemistry of atmospheric pollutants, at both local and regional scale, and it is suitable for long term simulations (e.g. a full year) since it is not strongly time-demanding in terms of computational efforts. Point, line and area/volume source emissions are considered. The model has two components: the meteorological prognostic and the air pollution concentrations component. The meteorological module of TAPM is an incompressible, optionally non-hydrostatic, primitive equation model with terrain-following coordinates for 3D simulations. The results from the meteorological module are one of the inputs to the air pollution component. The gas-phase chemistry mode of TAPM was used, which is based on the semi-empirical mechanism called Generic Reaction Set (GRS), including also the reactions of SO_2 and PM, having 10 reactions for 13 species. The TAPM model was applied to the Great Porto Area (150 km × 150 km) for one entire reference year (2012) with a 2 km by 2 km spatial resolution (see Fig. 5.9) using disaggregated emissions from the Portuguese 2009 emission inventory, which is the most recent available. Its results were compared to the measured values at the monitoring stations inside the model domain. As in Brussels case, we used the methodology proposed by FAIRMODE for the validation.
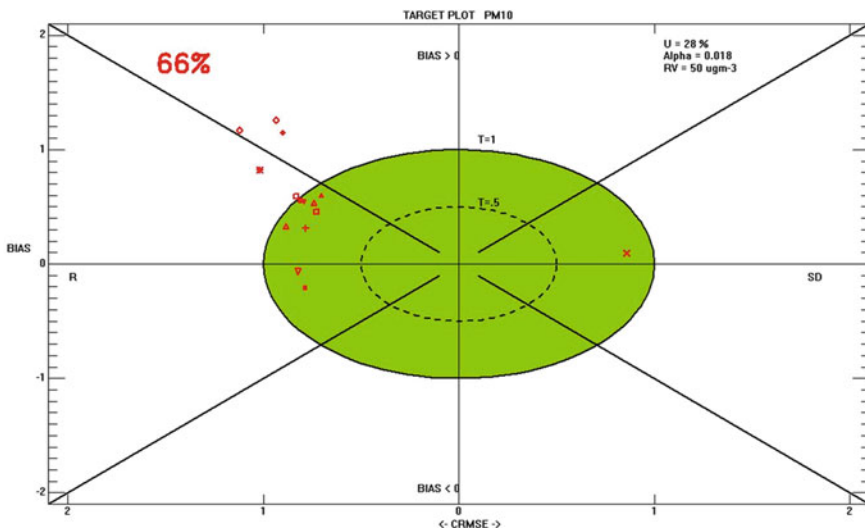

Fig. 5.10 Target diagram for the observation stations for PM10 inside the model domain for 2012

In Fig. 5.10 the target diagram for PM10 results is shown. In this case, modelling results comply at 66 % with the unit circle criterion, even if the overall BIAS is around 33 % of the average value and the average correlation between modelled and actual values is about 0.5.

The four non-complying stations have high values of BIAS and Root Mean Square Error (RMSE), which could be related to an overestimation of background values. The target diagram for NO_2 shows that 69 % of the values comply with the unit circle criterion, while values are similar to PM10 for the other performance indicators.

5.4.3 Design of Experiments and Source/Receptor Models

Ten emission sets were defined to train the RIAT+ Artificial Neural Networks for the Great Porto Area. These scenarios have to contain all possible relationships between precursor emissions and the various air quality indices. Ideally, the number of scenarios is determined by checking the incremental improvements to the ANN results of adding additional scenarios to the training dataset.

Starting from the 2009 Portuguese emission inventory, three different emission levels were considered: B (base case), L (low emission reductions) and H (high emission reductions).

The B (base) case considers the evolution of 2009 emissions taking into account the fulfilment of CLE2020 increased by 15 %. The H (high reduction) case is associated to the Maximum Feasible Reduction of emissions in 2020 (MFR2020), further decreased by 15 %. These bounds guarantee that the optimal plausible reductions will lie within those present in the training dataset. The L (low reduction) scenario results from averaging B and H emission values.

The procedure to implement these S/R models requires two steps. In the first step the best ANN structures were chosen on the basis of maximum correlation and minimum RMSE, considering a series of different possible configurations (i.e. different network structure, activation function and number of cells). Then, in a second step the best structure was applied to the whole domain. The quality index considered in this application was the PM10 annual mean. Table 5.3 presents the best ANNs parameters selected for PM10 Neural Network.

To validate the results from the ANN, output values are compared to the results calculated by the CTM. The scatter plot in Fig. 5.11 shows the comparison for an independent validation set which consists of 20 % of the available grid cells not used in ANN training. The good performance of the ANN, with a Normalised RMSE of 0.34 and a correlation coefficient of 0.95 confirms that the ANNs have a sufficient capability to simulate the nonlinear S/R relationship between PM10 mean concentration and the emission of its precursors.

Further analyses confirmed this conclusion. For instance, the average correlation between TAPN and the ANN surrogate model in terms of AQI variations with respect to the base scenario is about 0.93.

Table 5.3 ANN best parameters for PM10 annual mean index

| ANNs features	Value
Nodes in the input layer	16
Hidden layer transfer function	Log-Sigmoid
Nodes of the hidden layer	20
Output layer transfer function	Linear
Nodes in the output layer	1
Training function	Levenberg-Marquardt backpropagation
Radius of influence (n° of cells)	4
Training set (n° of cells)	6784
Validation set (n° of cells)	1696

Fig. 5.11 ANNs performances evaluated in terms of scatter plot between ANNs and TAPM results for PM10
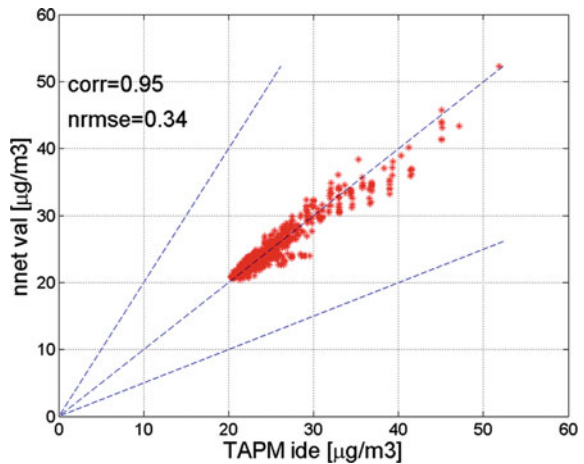
5.4.4 Results

RIAT+ was applied in the optimization mode and Fig. 5.12 shows the Pareto optimal (efficient) solutions over the Great Porto domain. The horizontal axis of the figure shows the implementation costs (over CLE) of abatement measures expressed in M€, and the vertical axis reports the corresponding efficient AQI value. It shows that a PM10 mean concentration of 28.8 µg/m3 can be reached by adopting emission reduction technologies costing around 7.6 Million € per year (see point C). Points A and Z represent the extreme cases where no actions or maximum feasible reductions are implemented. The other points of the Pareto Curve are intermediate solutions.

Fig. 5.12 Pareto curve of
mean yearly PM10
concentrations
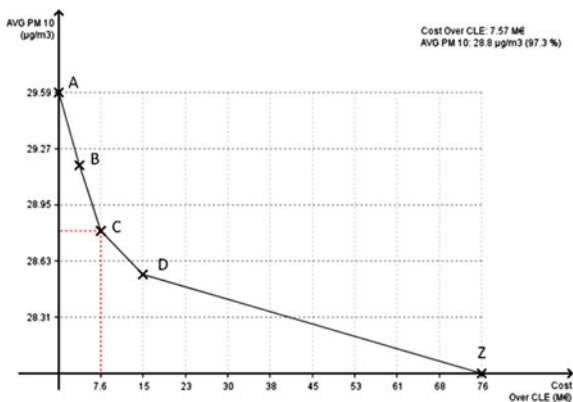
The solution corresponding to point C of the curve, for instance, would be
reached mainly acting on non-industrial sector activities (SNAP 2). Road transport
(SNAP 7) and other mobile sources and machinery (SNAP 8) could also contribute
to the required reduction of PM concentrations. More precisely, the major invest-
ment should be in measures related to new and improved fireplaces. These results
are consistent with the ones obtained by Borrego et al. (2012): in Portugal, 18 % of
PM10 emissions are due to residential wood combustion, which may deeply impact
the PM10 levels in the atmosphere. According to the Portuguese emission inven-
tory, this macro sector is the second most important in terms of PM10 emissions,
after macro sector 4 (industrial processes), in the Great Porto area.

Figure 5.13 presents the spatial distribution of the expected reductions of PM10
concentration levels, for the Point C of the Pareto curve. The largest reductions of
PM10 emissions and concentration levels are expected over the Porto municipality
where the population density is higher.

The analysis of RIAT+ results for the selected solution, which implies annual
costs around 7.6 M€, shows that some areas can still be expected to exceed the
PM10 annual limit value (40 μg/m^3).

Finally, Fig. 5.14 presents the relation between investment cost and benefit
measured as reduction of external cost (in term of reduced YOLLs). The ratio
between benefits and internal costs significantly decreases when Point B is reached.
In other words, the additional gain in health benefits is smaller per additional €
invested. However, as it can be seen from the figure, investment costs are always
lower than external costs (i.e. below the Y = X line) until point Z. This indicates
that acting on emission to reduce PM10 concentrations is always beneficial from a
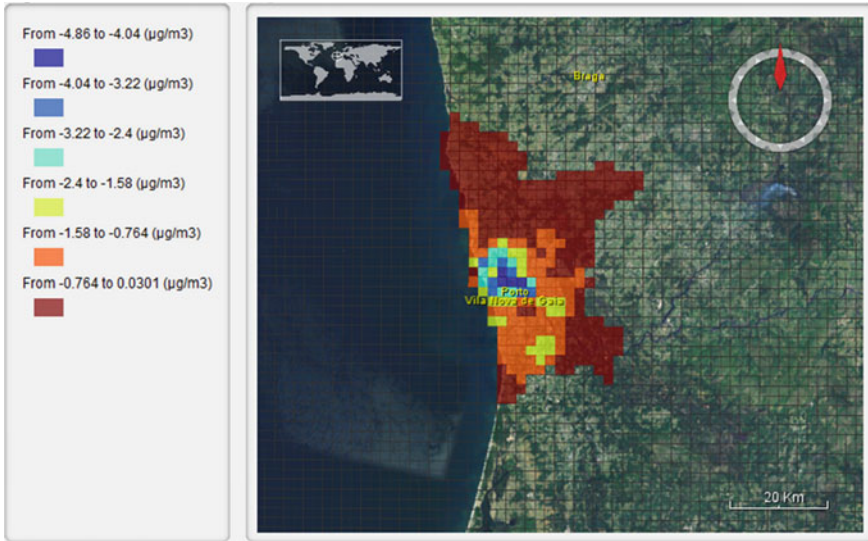socio-economic point of view.

Fig. 5.13 RIAT+ estimated concentration reductions ($\mu g/m^3$) correspondent to point C of the Pareto curve
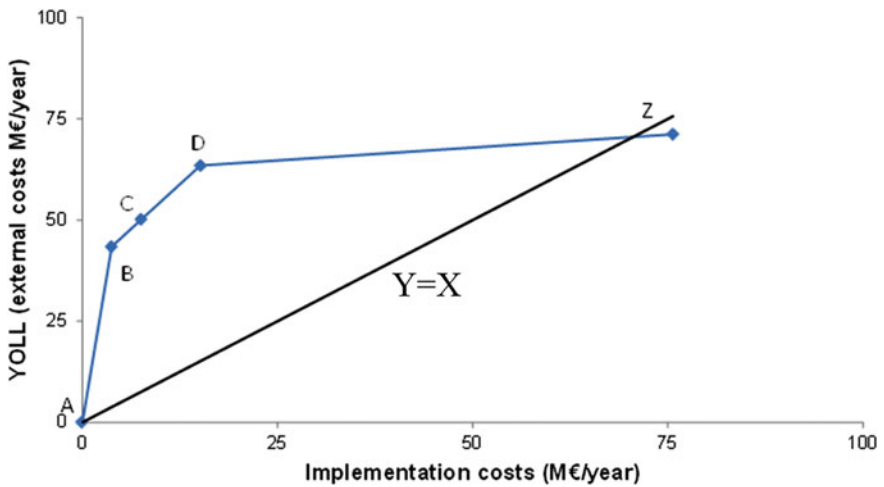

Fig. 5.14 Cost-benefit analysis (implementation vs. external costs)

5.5   Conclusions

From the experiences of application of a comprehensive IAM system (RIAT+) to the test cases of Brussels Capital Region and the Great Porto area a number of conclusions can be drawn.

The list of options for abatement measures is restricted not only by what is technically and economically feasible but possibly even more by political and social acceptance. IAM tools should therefore be further extended to take into account the implications of political and social acceptance at an early stage of the decision process (see also Laniak et al. 2013).

Existing tools can be practically applied in an integrated assessment of air quality not only to consider compliance to the concentration limits but also to efficiently take into account internal and external costs (e.g. health impact) of different available abatement options.

The biggest task when implementing such a comprehensive IAM is—as is also the case in regular air quality modelling applications—to obtain high quality input data on local emissions and the cost and effectiveness of possible abatement measures. When such data is lacking, one can still rely on existing European inventories and databases with data on abatement measures such as EMEP and GAINS well keeping in mind the assumed validity of such data for the region of interest and the implications for the results obtained using the IAM.

If an IAM system uses S/R relationships (artificial neural networks, linear regression, …) to relate emission changes to air quality changes, such relationships should be carefully tested to ensure that they not only correctly replicate the concentration values obtained through more complex modelling tools (e.g. CTMs) but also capture the dynamics i.e. the concentration changes calculated by the model for which they are a surrogate.

In the Brussels case, a lot of effort was put into defining and evaluating specific measures while the impact on air quality of these measures is rather limited due to the dimension of the area selected. A first screening step such as a simple scenario to check the importance of the impacts should be done before using a complex methodology, as the latter has limited added value in such cases.

In the Porto case, a list of available technologies from an existing database was used and the main sectors were selected and identified. Nevertheless, a more local list of measures needs to be decided and discussed with stakeholders and policy makers. With the optimization approach, it was possible to quickly identify the sectors and the entity of optimal investment costs to achieve a given air quality objective and the corresponding benefits.

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