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At regional and Local scales

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# WP 4 Guidance on integrated air quality and health assessment systems

VITO

Guidance document evaluation Tier1

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# Summary

In this deliverable the guidance provided in deliverable D4.1 for APPRAISAL ('First draft version of the Guidance document') is assessed in a confrontation with 8 practical examples of existing Air Quality Plans or related studies. From the analyses a number of improvements to the existing document were identified.

## Version History

| Version | Status | Date | Author(s) |
|---|---|---|---|
| 0.1 | First Draft | 12/05/2014 | Peter Viaene, Wouter Lefebvre (VITO) |
| 0.2 | Second Draft | 19/05/2014 | Peter Viaene (VITO), Evangelia Fragkou and Ioannis Douros (AUTH), Ana Miranda, Hélder Relvas and Joana Ferreira(UAVR), Nadège Blond (CNRS), Alain Clappier (UdS), Piotr Holnicki and Zbigniew Nahorski (SRI), Katarzyna Juda-Rezler and Magdalena Reizer (WUT), Niko Karvosenoja (SYKE) |
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| 1.1. | First Review | 30/06/2014 | Priscilla Declerck, Olivier Brasseur (IBGE/BIM), Arno Graff (UBA), Peter Viaene (VITO |
| 1.2 | Final | 10/07/2014 | Piotr Holnicki and Zbigniew Nahorski (SRI), Katarzyna Juda-Rezler (WUT), Peter Viaene (VITO), Marialuisa Volta (UNIBS) |

## Summary of Changes

| Version | Section(s) | Synopsis of Change |
|---|---|---|
| 0.1 | All | New document |
| 0.2 | All | Added contributions on guidance evaluation based on specific AQP |
| 1.0 | All | Minor corrections after review |
| 1.1 | All | Changes in accordance with reviewers' comments, additional input CNRS added |
| 1.2 | All | Final after updates |

# Contents

# 1 Introduction

The main objective of work package 4 is to deliver a state of the art guidance document on Integrated Assessment (IA) applications that can be used by all stakeholders. The first draft version of this guidance document (D4.1) was written based on the insight gained during the extensive review process in work package 2 and the design for an IAs presented in work package 3 which focused on the Driver/ Pressure/ State/ Impact/ Response (DPSIR) scheme to describe an IA methodology.

In the second part of work package 4 the guidance put forward in D4.1 is evaluated using practical examples. In the original proposal a two tiered approach was envisioned in which a 'simple' and a more 'detailed' approach to IA were distinguished and the guidance in WP4.2 would be tested according to these two approaches. During the elaboration of the previous work packages it became clear that two distinct tiers (simple/ complex) do not exist but that the different existing applications of IA combine different levels of complexity for the different DPSIR blocks dependent on the available data and tools but also on the complexity required by the IA ('fit for purpose'). In the first step in the evaluation of the guidance we'll focus on existing AQPs with the aim to both reveal the differences between 'practical application' which is what was applied in setting up the air quality plans and what we have now listed in our guidance document. These differences will hopefully show us what is missing in the air quality plans but also - and that is maybe more important – where the guidance document itself is lacking information or could be improved.

# 2 Analysis of the Air Quality Plans and the guidance document

In the following chapters the analysis of the different AQPs is presented according to the following common structure:

- Description of the AQP so that the reader can identify the case and has an idea of the specific case characteristics;
- Details on how the different aspects that are addressed for the DSPIR blocks in the guidance document are taken into account in the AQP that is being tested. The analysis starts with a radar plot that summarizes the level of complexity for each of the DPSIR blocks;
- List of what is missing to raise the level of complexity of the individual DPSIR blocks in the AQP. This not only considers the benefit of adding the extra complexity but also whether the additional complexity is really needed in the particular case as sometimes even a simple solution could be enough and increasing the complexity unnecessarily would incur additional costs in elaborating the plan without providing any real benefit;
- Additional guidance (if any) that is missing in the guidance document (D4.1) and that would be welcome based on the analysis of the AQP. This is mainly to be able to extend the guidance document afterwards with those bits of advice that are currently lacking.

Before continuing with the analysis of individual AQPs we'll briefly describe the levels of complexity that have been distinguished for the different DPSIR blocks and how these are presented in the radar chart.

## 2.1 Levels of complexity and the radar chart

The radar chart was introduced in deliverable D2.8 that describes the database entry finalization. This chart graphically represents the level of complexity for each of the DPSIR blocks based on the answers to the questionnaire. For each of the five blocks five levels of complexity have been defined:

- Level 0 – not possible to assign level based on input from questionnaire ('no level')
- Level 1 - the block is not considered in the AQP
- Level 2 - low
- Level 3 - medium
- Level 4 – high

Four of these levels correspond to an actual level of complexity. The fifth 'zero level' or 'no level' case corresponds to the case where it is not possible to assign a level based on the answers in the questionnaire So in the 'no level' case the AQP has maybe considered the block but it was not possible to assess the complexity based on the input from the questionnaire. The chart therefore distinguishes a total of 5 different levels. An example of a radar chart is shown in Figure 1. The example is for an assessment study in which no attempt was made to determine the set of abatement measures that are required to improve air quality. The main effort in the study was to determine the drivers, emissions and the state while from the answers to the questionnaire it was not clear whether health impact was assessed (0 level).

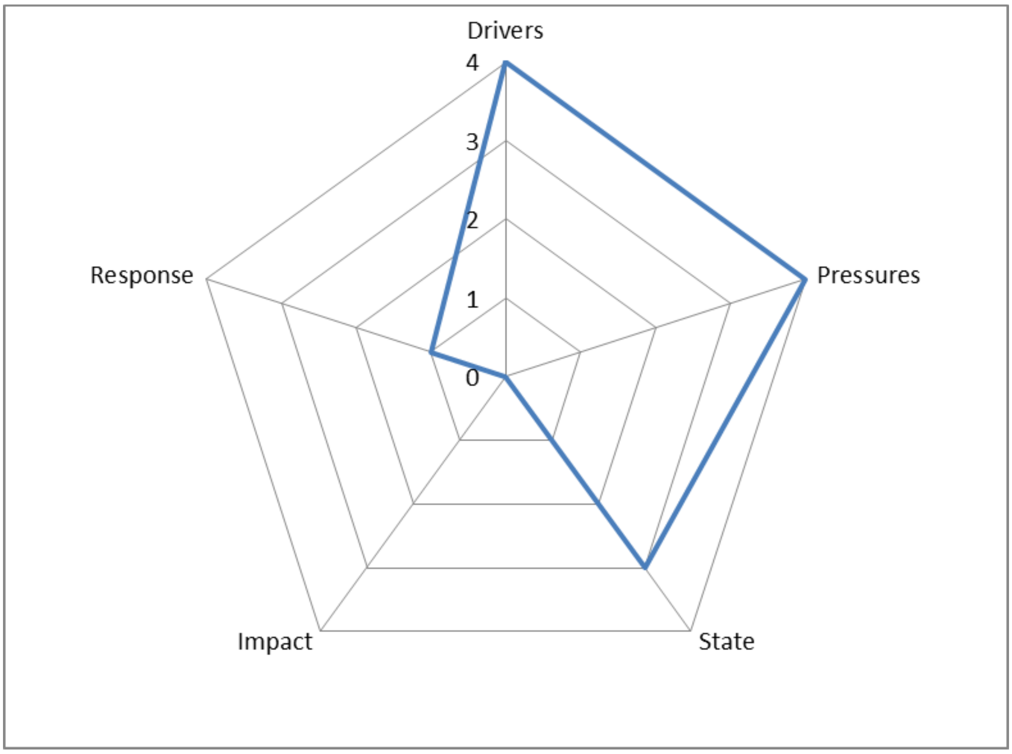


**Figure 1 Example of a radar chart**
**(levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

The different levels of complexity that are distinguished for the DPSIR blocks are listed in Table 1. For the Driver block the complexity depends on whether the different levels (national, regional and local) are included as well as potential synergies between these different levels. For Pressure blocks the distinction is based on whether the activities and emissions were derived using a top down or a bottom-up approach or a combination of these two. The level of complexity for the block that describes the state (concentration /deposition) is determined by how the state is derived (using a model?) and whether the different scales ranging from the regional to the local scale were considered. Detail in the spatial and temporal resolution for the exposure and population data is also what matters for the complexity of the Impact block. For the Response block, finally, the degree to which an objective, quantitative choice of the abatement measure(s) is made will distinguish a simple from a more complex methodology.

**Table 1 levels of complexity distinguished for the different DPSIR blocks**

| DPSIR block | Level | Description |
|---|---|---|
| Driver | 1 | not implemented |
| | 2 | top-down approach, using coarse spatial and temporal allocation schemes |
| | 3 | bottom-up approach with generic (i.e. national/aggregated) assumptions |
| | 4 | bottom-up approach with specific (i.e. local/detailed) assumptions |
| Pressure | 1 | not implemented |
| | 2 | emissions estimated for rough sectors on a coarse grid using a top-down methodology |
| | 3 | combination of bottom-up and top-down methodology |
| | 4 | emissions calculated with the finest resolution in space and time available (fine grid), using a bottom-up method and the highest level of detail in the SNAP sectors |
| State | 1 | not implemented |
| | 2 | measurements and geo-statistic interpolation are used |
| | 3 | one single deterministic model is used |
| | 4 | a downscaling nested models chain is used |
| Impact | 1 | not implemented |
| | 2 | coarse description of exposure provided either by measurement or modelling of AQ (e.g. average mean annual exposure for a city), simple population description |
| | 3 | similar to level 1, but with spatial detail in the STATE description |
| | 4 | a detailed temporal and spatial resolution for exposure and population data |
| Response | 1 | not implemented |
| | 2 | expert judgment and scenario analysis |
| | 3 | source apportionment and scenario analysis |
| | 4 | optimization |

## 2.2 AQP for Antwerp (VITO)

### 2.2.1 Description of the AQP

This study (Lefebvre et al., 2011) for the zones 'port of Antwerp' (BEF01S) and 'Antwerp' (BEF02A) was mainly intended to assess the benefits of different sets of measures to improve air quality and reduce noise levels. Currently these two zones are considered hot spots with problems in terms of exceedances of the $NO_2$ and PM limit values in the EC Directive. Based on this study the City of Antwerp wants to establish an action plan to decrease the population exposure to both air pollution and noise.

With about half a million inhabitants Antwerp is the largest city in the Flemish region. The city hosts the second biggest sea port in Europe and is a major transport hub with a six lane motorway bypass that encircles much of the city centre and runs through the city's residential area. In 2013 the city was declared to be the second most congested city in the world by Forbes.

### 2.2.2 Elaboration of the DPSIR blocks

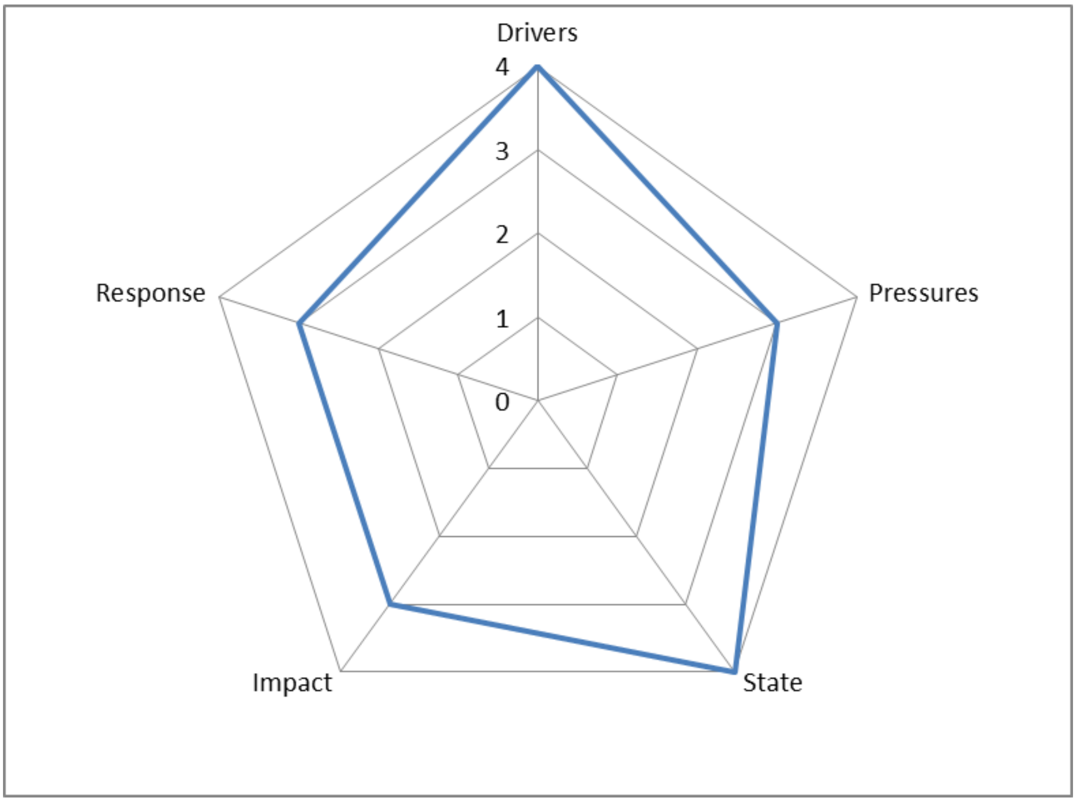


**Figure 2 Radar chart for the AQP for Antwerp**
**(levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

### 2.2.3 Drivers/Pressures

Previous studies had identified the harbour industry and road transport as major sources of $NO_x$ and PM. The study focuses on these two sectors and the proposed measures that are evaluated only relate to these two sectors. For traffic the emissions were calculated using the MIMOSA model (Mensink et al. , 2000) which in the version used for this study relies on COPERT 4 (COPERT 4, 2007) and generates hourly emissions for a road network based on traffic volume, road characteristics and fleet composition. For the industrial emissions a detailed bottom up emission inventory with stack level data was used which was compiled by the Flemish Environment Agency. For the other emissions a top-down approach was used in which the EMEP emissions were spatially disaggregated using the EMAP tool (Maes et al., 2009). The study also considered elementary carbon (EC) for which the emissions were determined as a sector dependent fraction of the $PM_{2.5}$ emissions.

#### 2.2.4 State

To determine the $NO_2$, PM and EC concentrations a nested chain of models was used. The background contribution was determined as hourly concentrations at a resolution of 3 km using the AURORA model which is an Eulerian chemical transport model (Lefebvre et al. , 2011). The concentrations due to the local traffic/industry emissions were calculated with a Gaussian plume model for a higher resolution irregular grid and combined with the background concentrations using a procedure to avoid double counting. These concentrations were then further refined to street level using the OSPM (Berkowicz et al., 2008) street canyon model.

#### 2.2.5 Impact

For the health impact assessment the high resolution concentration maps were combined with a detailed population density map for Antwerp based on individual address information. This data also allowed for an assessment of differences in population exposure with age. The analysis was based on yearly average concentrations, the focus being on long term health impacts. The concentration results were also used to determine the concentrations at locations that were deemed to be more vulnerable for air pollution such as schools, retirement homes and hospitals. Finally, DALYs (Disability Adjusted Life Years) were calculated based on the PM concentrations in accordance with the Clean Air for Europe (CAFE) Programme.

#### 2.2.6 Response

In a first step a list of economically and/or politically feasible measures was drafted by the Antwerp environmental authority which was then extended and screened based on expert opinion and previous experience with respect to the effectiveness of the individual measures. Besides this list of measures, a list of hotspots based on previous studies was also provided for which the measures should be applied. The measures were then grouped into three packages:

- measures that could be easily implemented on a short term;
- in addition to the measures listed in 1, two specific additional measures are considered: a low emission zone and a congestion charge;
- the measures listed in 2 are complemented with measures specifically for the industry in the harbour.

For each of these packages with measures, differences in concentration and exposure were calculated (scenario calculations). The study also calculates the cost benefit for some of the measures. The study however did not entail an optimisation procedure so that this level is 2 as it combined expert judgment with source apportionment information that was obtained from previous studies.

#### 2.2.7 Possible improvements to the DPSIR blocks used in the AQP

This study did not explicitly consider uncertainty in the quantification of the activities and the emissions through Monte Carlo analysis. As a follow-up to the study the model chain was validated and a good agreement between modelled and measured concentrations was found which is at least an indication that probably the uncertainty on the activities and emissions is not that big in this case.

A possible improvement to the impact analysis would be to also consider a higher temporal resolution for the exposure calculation and to consider the dynamic exposure taking into account the whereabouts of the population. Accounting for dynamic exposure however seems to have only a minor effect on the final model outcome (Dhondt et al.,2012).

With respect to the choice of the response this study did not use an optimisation approach to determine the optimal set of abatement measures. In view of the high resolution modelling required to obtain a street level concentration assessment it is unclear whether the detailed numerical modelling involved in the assessment is compatible with an (iterative) optimisation approach which would require deriving a simplified Source/Receptor model. There is also no explicit source apportionment in the study but the identification of major sources was based on previous studies. This study also is clearly and consciously (as required by the authorities) limited to the set of measures that the Antwerp authorities have to their disposal. As more than half the road transport emissions are from the highway and the measures considered in the study have a negligible effect on highway traffic there is a clear necessity for additional measures to limit emissions on (Antwerp) highways, however such measures are beyond the jurisdiction of the local authorities.

### 2.2.8 Missing guidance

Guidance is needed most for improving the emission estimates. The guidance document could be extended with references to data sources with characteristics of emissions (flue temperature, stack heights, temporal profiles) and data needed for emission projections (economic constraints on different sectors)

## 2.3 AQP for Athens (AUTH)

### 2.3.1 Description of the AQP

The Air Quality Plan under study was developed as part of a wider effort of the Greek Ministry of Environment, Physical Planning and Public Works to comply to the EU legislation 1996/62/EC regarding ambient air quality levels. In this framework, the Ministry has funded the preparation of development plans for the abatement of air pollution in urban areas in Greece. A relevant programme was funded between the years 2003 and 2005 for the development of an Air Quality Plan for the urban area of Athens, which was jointly undertaken by two consulting companies, namely ENVECO S.A. and EPEM. The official title of the programme was “Development of an Operational Plan for the Abatement of Atmospheric Pollution in the City of Athens”.

The city of Athens is located in a basin of approximately 450 $km^2$. This basin is surrounded on three sides by fairly high mountains (Mt. Parnis, Mt. Pendeli, Mt. Hymettus and Mt. Aegaleon), while to the SW it is open to the sea. Industrial activities take place both in the Athens basin and in the neighbouring Thriasion plain. The Athens basin is characterized by a high concentration of population (about 40% of the Greek population), accumulation of industry (about 50% of the Greek industrial activities) and high motorization (about 50% of the registered Greek cars). Anthropogenic emissions in conjunction with unfavourable topographical and meteorological conditions are responsible for the high air pollution levels in the area.

The programme for the abatement of air pollution in the urban area of Athens was divided into three phases:

**Phase 1**: This phase included the collection of emission data from all sources contributing to air pollution in the urban area of Athens (transport, industry, central heating) and the application of a dispersion model for the reference year of 2002, in order to assess the spatial distribution of pollutants complementarily to the measured concentration data from the stations of the monitoring network.

**Phase 2**: The second phase included the application of an air quality dispersion model for predicting the air pollutant levels in the urban area of Athens for the years 2005, 2008 and 2010.

**Phase 3**: In this final phase, a Decision Making System was developed in order to evaluate the efficiency of abatement measures in terms of complying with the requirements of the EU Directive.

### 2.3.2 Elaboration of the DPSIR blocks

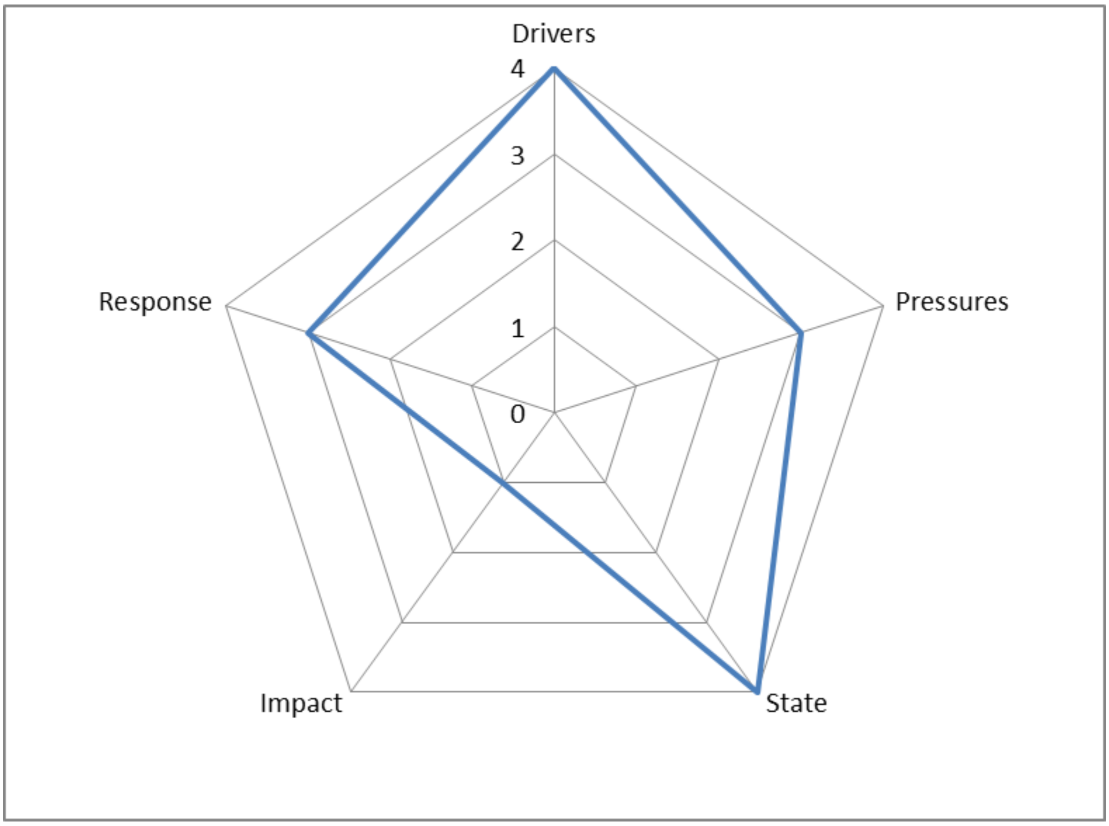


**Figure 3: Radar chart for the AQP for Athens**
**(levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

### 2.3.3 Drivers/Pressures

The main sectors contributing to pollutant emissions were considered in the AQP, based on existing studies, for example the 2002 Annual Report on Air Quality in Athens. The main drivers identified included industry, central heating and transport. However, in terms of $PM_{10}$, an additional source apportionment study was performed which included sources particularly linked to $PM_{10}$ emissions, such as long-range transport and resuspension.

Within the frame of the development of the AQP, the Greek Ministry of Environment funded the compilation of an emission inventory which was compiled for the Greater Athens Area, for the reference year 2002, taking into account emissions from:

1. Stationary air pollution sources like, industry, domestic heating and oil stations,
2. Mobile sources, such as, road traffic and emissions from ship, airplane and train lines.

Pollutants included were CO, $NO_2$, $NO_x$, $O_3$, $SO_2$, Benzene, $PM_{10}$ and Pb, for most of which EU legislation sets up specific air quality limit values that have to be met up to 2005 and 2010. Regarding stationary air pollution sources, an on-site measurement campaign was undertaken including 1000 industrial units from 48 industrial sectors. An emission factor database adapted for Greece was also prepared. Concerning the emission inventory for road traffic emissions, the CORINAIR methodology and the COPERT software were applied. A detailed emission inventory was the result of this effort, based on a bottom-up approach.

Emission rates for pollutants from transport and industry were derived from the National Emission Inventory (Ministry of Environment), while biogenic emissions were based on existing published results. The emission rates for tyre wear, brake wear and road abrasion were calculated based on the CEPMEIP database, while the construction activity was approached from satellite images and traffic resuspension emissions from literature data.

### 2.3.4 State

In this AQP both air quality assessment as well as a source apportionment methodology for $PM_{10}$ were applied.

Regarding the urban air quality assessment, it can be concluded that this was addressed in an advanced complexity level. The Eulerian OFIS urban scale dispersion model was used for the spatial assessment of pollutant levels in the study area and for the development of maps allowing the identification of heavily polluted areas within the study domain. OFIS simulates concentration changes due to the advection of species and chemical reactions in each cell of the computational domain.

In order to account for the contribution from local emission sources, the OSPM combined plume and box model was used for simulations of air pollution from traffic in urban streets.

The influence of meteorological patterns on $PM_{10}$ concentrations was analysed, particularly in regard to long-range $PM_{10}$ transport from other areas (e.g. the Saharan desert). The contribution of natural sources was assessed using a combined methodology of satellite images, LIDAR measurements, measurements from the national monitoring network and modelling results using the SKIRON/Eta transport and deposition model.

Concentrations of pollutants were assessed using a chain of models adapted to different scales from the regional to the local scale. The Eulerian model OFIS takes into account regional background pollutant levels to account for the transfer of pollutants towards and away from the urban area. Furthermore, all important chemical transformation mechanisms are represented in the OFIS model, which is a pre-requisite for studying reactive pollutants such as ozone and particles. The OSPM street scale model accounts for increased concentrations at the local (hot-spot) scale due to local emissions. Both models have an appropriate spatial and temporal resolution to realistically describe pollutant dispersion at the scales of interest. Furthermore, both a sensitivity analysis in terms of emissions was conducted (emission reduction scenarios and sensitivity to natural background contributions) as well as an operational model validation against measurement data from the monitoring network in Athens. In conclusion: an advanced (Level 3) complexity level was used for concentration assessment.

### 2.3.5 Impact

The impact of the assessed pollutant concentration levels on health was not specifically addressed in the development of this AQP. This parameter was only indirectly considered, on the basis of exceedances of limit values for the protection of human health, according to the EU Directive.

### 2.3.6 Response

The simulations were performed for the urban scale as well as for the street scale model for several future emission scenarios, for the years 2005, 2008 and 2010, in order to examine future compliance with standards.

The results indicated that natural emission sources play a very important role in the calculation of PM concentrations and that their contribution leads to significant increase in the number of current and future exceedances. This could suggest that more strict policies regarding the anthropogenic part of PM emission need to be applied.

A source apportionment study was conducted for $PM_{10}$. The spatial and temporal distribution of $PM_{10}$ in the Greater Athens Area was assessed with the use of the Eulerian photochemical model REMSAD and sensitivity simulations were performed with the same modelling tool to identify and quantify source contribution.

An interesting point in the AQP for Athens was that different emission reduction scenarios were evaluated both for the urban scale (using the OFIS model) as well as for particular hot spots due to local traffic emissions (using the OSPM model). In this way it was shown that a further emission reduction is required in order to comply with standards at the local scale (i.e. to reduce number of exceedances), on top of the emission reduction that is necessary to comply with annual limit values.

An optimisation procedure was not performed. A thorough Multiple Criteria Analysis using the ELECTRE III method (Roy, 1968) was applied in order to identify the most suitable set of abatement measures. Parameters such as the public cost, public acceptance and socio-economic impacts were considered.

### 2.3.7 Possible improvements to the DPSIR blocks used in the AQP

In the AQP for Athens, it can be concluded that most of the DPSIR blocks were approached in an intermediate to high level of complexity. More specifically, emissions were calculated based on a bottom-up approach in most cases, in complementarity with data from the National Emission Inventory and other data from top-down emission studies and emission factors from scientific publications were adapted to the specific conditions of Greece to increase their representativity. However, uncertainties were not quantitatively calculated and in the case of the source apportionment study, the results were compromised due to scarcity of chemical speciation data and the low resolution of biogenic emission data. Also, an important issue in the source apportionment study for $PM_{10}$ was the lack of detailed information to calculate emissions from central heating, such as emission rates, boiler installations and its spatial variation, etc. The survey concluded that at that time, central heating did not significantly contribute to particulate pollution, however this contribution would be considerable during the cold season leading to increases of $PM_{10}$ emissions in the urban area of Athens. This issue is highlighted in the Guidance Document as an important source of uncertainty in the emission inventory, particularly in countries where biomass burning is used in a high degree for heating during the cold season. In conclusion: an intermediate (Level 2) complexity level was used for quantification of emissions.

Health impact was not explicitly accounted for in the development of this AQP. However, it can be argued that this is beyond the scope of an AQP aiming to ensure compliance with EU limit values. Health impact was also one of the parameters considered during the multicriteria analysis tool.

Abatement measures were examined in the AQP for Athens using both a scenario based approach as well as a source apportionment study for $PM_{10}$. The source apportionment study was efficient in identifying and quantifying all relevant emission sources, including trans boundary transport of pollutants. It was thus possible to suggest emission reduction based on abatement measures that would have the greatest impact on concentration levels. These measures mostly involved technical measures in regard to the transport sector. Furthermore, a multicriteria analysis was performed in order to take into account economic and social factors and recommend the most efficient pollutant reduction measures for the city of Athens. It can be concluded that a very thorough approach was used for the development of a response strategy to urban air pollution in Athens, but as an optimisation approach was not used in deriving the set of abatement measures the complexity level is 3 instead of 4. An uncertainty analysis was also not performed.

In the case of the source apportionment study, a thorough investigation was performed using an array of specialized modelling tools to account for the relative contributions of anthropogenic and natural sources. However, the REMSAD dispersion model used presented some limitations and disadvantages leading to an underestimation of the secondary fraction of $PM_{10}$ and chemical analysis data was scarce. Furthermore, it would be useful to include a source apportionment study for other legislated pollutants, including ozone and $NO_x$

In general, the AQP for Athens is in line with the guidelines presented in the Guidance Document for Integrated Assessment Modelling and addresses the DPSIR blocks at an appropriate complexity level for its purpose. The main limitations were that uncertainty was not explicitly considered at any stage and the lack of detailed and high resolution emission information for some sources that were taken into account in the source apportionment study. The impact of air pollution on human health was not explicitly addressed in the development of the AQP for Athens. A quantitative analysis of the health impacts is not performed.

### 2.3.8 Missing guidance

None

## 2.4 AQP for the Northern Region of Portugal (UAVR)

### 2.4.1 Description of the AQP

Air quality problems have been detected in the Northern Region of Portugal. The air quality monitoring network includes several background, traffic and industrial stations, with a total of 24 sites where $NO_2$, among other pollutants, is continuously measured. The analysis of the $NO_2$ air quality data (2002 - 2010) showed that the $NO_2$ annual limit value was surpassed at five air quality monitoring stations. All of them are classified as urban traffic stations and are located in two of the four agglomerations of the Northern Region: Porto Litoral and Braga

The air quality assessment indicated that traffic is responsible for an increase of more than 40 % compared to the $NO_2$ urban background value. A set of emission mitigation measures was defined. These measures were mainly focused on the traffic sector, however, the industrial and residential combustion sectors were also considered. The environmental benefits and impacts of these measures in improving $NO_2$ levels in the atmosphere were assessed through the application of an air quality numerical modelling system (TAPM model), which simulated the reference situation and a mitigation scenario based on estimated emissions reduction. The modelling results predict a decrease of 4–5 $\mu g.m^{-3}$ in the annual $NO_2$ levels over the study region, allowing three of the five air quality stations to be in compliance regarding the annual limit value. More details about this AQP can be found in Borrego et al. (2012).

It was found that the air quality stations that would be still non-compliant are strongly influenced by local emissions. In order to avoid $NO_2$ exceedances, additional measures would be needed, especially regarding the road traffic sector (for example, vehicle speed reduction and/or prohibiting the circulation of heavy-duty vehicles).

### 2.4.2 Elaboration of the DPSIR blocks and possible improvements

Greatest weaknesses in terms of the approach used in this AQP (Figure 4) are linked to the IMPACT block, since air quality impacts, namely the effects on human exposure and health, were not considered.

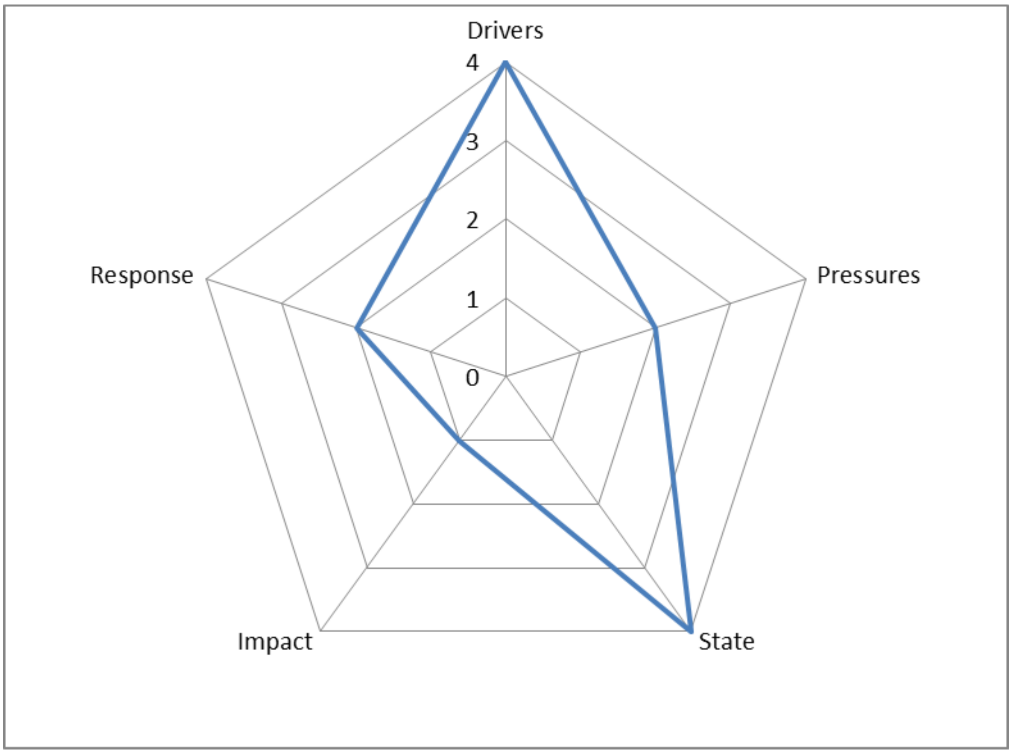


**Figure 4 Radar chart for the AQP for Northern Region of Portugal (levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

### 2.4.3 Drivers/Pressures

Complexity for the DRIVERS block is high because the Air Quality Plan (AQP) includes national, regional and local strategies trying to consider potential synergies between these different levels. PRESSURES, however, are considered at the "low" level of the Radar Chart, possibly because a top-down approach was used to estimate atmospheric emissions instead of combined approaches (bottom-up and top-down). Notwithstanding this coarse approach, temporal variations were applied to the annual emissions by SNAP activity sector. Anyway, the combined approach could provide better results, increasing the level of complexity.

### 2.4.4 State

In the case of STATE the level of complexity is high.. The TAPM air quality modelling application considered three domains using a nesting approach: the outer domain includes the Iberian Peninsula (D1), D2 covers the northern and centre regions and the inner domain contains the northern region (D3), with resolutions of 43.2, 14.4 and 4.8 $km^2$, respectively. In addition to the meteorological information, the air pollution module considers the air pollutant emissions from several sources, such as point sources, line sources, gridded surface anthropogenic and biogenic emissions. The background concentrations required by the model were obtained by estimating the average values of the background air quality stations of the study area for 2010.

### 2.4.5 Impact

In this Air Quality Plan the human health effects were not estimated, thus the IMPACT assessment block level is zero. The impact is indirectly considered, on the basis of exceedances of limit values for the protection of human health, according to the EU Directive.

### 2.4.6 Response

The level of complexity of the “RESPONSE” block is low. This result is a consequence of the scenario analysis methodology used instead of an optimization approach. The scenario analysis was performed by evaluating the effect of the emission reduction scenario on air quality using TAPM simulations. The list of measures was defined in close contact with stakeholders and these are mainly non-technological measures with a focus on the traffic, industrial and residential combustion sectors.

### 2.4.7 Possible improvements to the DPSIR blocks used in the AQP

For the drivers the AQP used a top down approach. This could be improved by using a combined bottom-up/top-down approach. For the STATE, the application of other air quality models might improve the achieved results. Refining the modelling application to estimate concentrations at street level could also be important, allowing to better identify the impacts of mitigation measures, especially those related to traffic.

Traditionally, modelling tools have addressed air quality assessment issues including dispersion and chemistry but have not extended their capability by incorporating exposure or other health indicators. Quantification of these health effects is however particularly important in designing Air Quality Plans. Knowing the amplitude of effects helps the decision makers to distinguish between details and main issues that need to be addressed, facilitating the clarification of trade-offs that may be entailed. In this particular case, it might be interesting to apply at least one methodology to estimate external costs (e.g. ExternE).

### 2.4.8 Missing guidance

There is no need for additional guidance.

## 2.5 Preliminary AQP for Emilia Romagna (Terraria)

### 2.5.1 Description of the AQP

This study was concerned with the Po Valley area and in particular with the Emilia-Romagna region. The aim of the study was mainly to assess the benefits of different sets of measures to improve air quality.

The Emilia-Romagna region is located in the south-western part of the Po Valley basin, a densely populated and heavily industrialized area, where meteorological conditions, due to the low wind intensity, cause the stagnation of the air masses, associated with peak pollution episodes of PM during winter time and high levels of ozone during the summer time. The daily Limit Value (LV) for $PM_{10}$ was exceeded every year since the enforcement of the EU directive (2005) with a slow decreasing trend of the $PM_{10}$ annual mean during 2001 – 2012. The $NO_2$ annual limit value shows some exceedances mainly in the traffic stations and a decreasing trend. Ozone health and vegetation protection limit values are systematically exceeded in all the stations with a stationary trend during 2001-2012. The data show also that the annual LV for $PM_{2.5}$ (obligation from 2015) can be exceeded with adverse meteorological conditions.

### 2.5.2 Elaboration of the DPSIR blocks

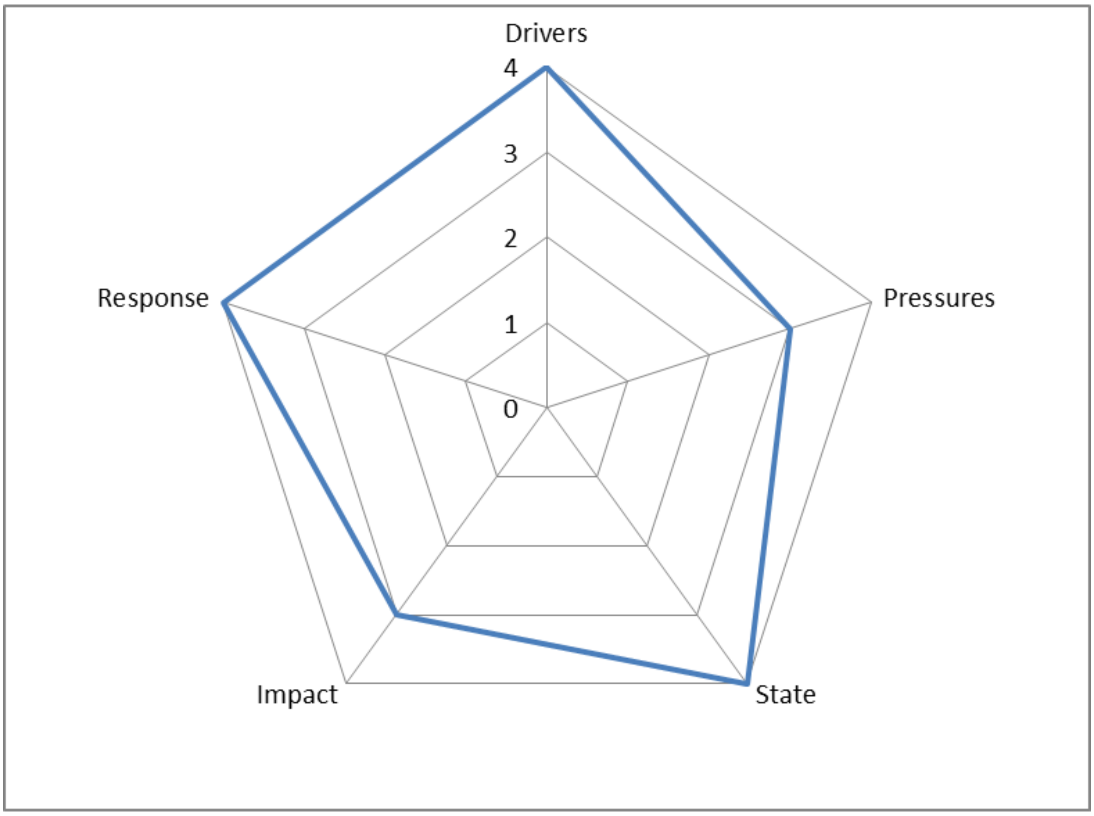


**Figure 5: Radar chart for the preliminary AQP for Emilia Romagna (levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

### 2.5.3 Drivers/Pressures

Sources of PM and ozone precursors, such as $NO_x$ and VOCs, are mainly related to road transport and combustion. Almost 60-65 % of particulate matter is of secondary origin and a large part of particulate matter and ozone pollution is due to regional background that is influenced by the transport of pollutants from the neighbouring regions of the Po

Valley basin. $NO_2$ exceedances are mainly due to local pollution, nevertheless the background concentration of $NO_x$ plays an important role in the production of the secondary aerosols. Ammonia (which is mainly emitted by agriculture) is an important precursor of PM in the Po Valley. Diesel trucks are responsible for a large part of $NO_x$ emissions. Emissions from wood burning and motor vehicles (exhaust and non-exhaust) are the main sources of $PM_{10}$.

The emission scenarios and the resulting air pollution simulations have been produced on a domain grid covering the Emilia Romagna region and the surrounding areas which influence the regional air pollution. The regional inventory of atmospheric emissions has been undertaken by ARPA Emilia Romagna on behalf of the Emilia Romagna Region, with reference to the year 2010 using INEMAR (INventario EMissioni in ARia - Air Emission Inventory) which is a database developed in order to derive a regional bottom-up atmospheric emission inventory for different activities (heating, road transport, agriculture, industry, etc.). The gridded emissions and proxy variables (year 2010) were prepared using the tool eFESTo which is part of the NINFA Regional Air Quality Modelling System. This input allows the RIAT+ tool (Regional Integrated Assessment Tool) to produce a spatial and seasonal disaggregation of the emissions inside the region.

The regional emission inventory approach is combined (top-down and bottom-up) and the emissions are detailed by macro sector-sector-activity and fuel (inside the Region); the point source emissions also have stack details.

### 2.5.4 State

To determine $NO_2$, PM and $O_3$ concentrations (Air Quality Index – AQI) a nested chain of Eulerian models (called NINFA) was used. Air pollution concentrations have been simulated for the year 2010 using NINFA which includes Chimere (version 2008c) an Eulerian chemical transport model. The range of scale was regional and urban; the spatial resolution was 5km by 5km, with 40 vertical levels; the output consists of hourly concentrations. The meteorological model used is COSMO17, with a prognostic approach. The background contribution was determined as hourly concentrations using the Prev'air model. The concentrations due to the local traffic/industry emissions were then further refined to street level.

Emission data (for $NO_x$, VOC, $NH_3$, $PM_{10}$, $PM_{2.5}$, $SO_2$) and AQI values (mean $PM_{10}$, mean $PM_{2.5}$, AOT40, SOMO35, mean $NO_2$, mean MAX8H $O_3$) have been then used to train Artificial Neural Networks and compute the Artificial Neural Networks (ANNs), which describe the relationship between emissions of the precursors and the AQI for each temporal period (year, winter and summer). The results confirmed that the neural network system is capable of reproducing the non-linear source-receptor relationship between emissions and precursors.

To train the ANNs 12 emission scenarios on the Emilia-Romagna domain were designed and used.

### 2.5.5 Impact

For the health impact assessment the high resolution concentration maps were combined with a detailed population map. The health impact assessment approach used was retrospective. The health impact relationship used dealt with the reference values associated to the relative risks, without thresholds. Population data used for the health impact functions originated from a cohort study. The air pollutants used in the estimation were: $PM_{2.5}$, Arsenic, Cadmium, Nickel and other. The exposure indicators were calculated based on air quality interpolated monitored data and air quality modelled data. For population the same spatial and temporal resolution of concentration were used. The indicator used was the morbidity (e.g. pneumonia cases, cardiovascular and respiratory diseases).

### 2.5.6 Response

In this preliminary phase of the Regional AQP, the RIAT+ tool has been used to assess measures and costs to improve air quality. Both technological and efficiency measure are taken into account in the optimization process. Analysing the yearly average $PM_{10}$ concentration on the whole Emilia Romagna a Pareto curve was obtained, with five points, each of which represents a different optimal combinations of reduction measures. Analysing emission reduction corresponding to a point of the Pareto curve, a significant reduction of $NH_3$ should be reached acting on agriculture macro sector, while $NO_x$ reduction should be obtained through transport and other mobile sources macro-sectors. Actions on residential heating should be promoted to reduce a large part of primary $PM_{10}$ emission.

RIAT+ gave also a detailed list of measures to obtain these reductions. The combination of different runs with single or multi-pollutant optimization objectives leads to the following list of priority measures to be implemented

- energy efficiency measures in the residential sector including improved fireplaces
- high efficiency oil and gas industrial boilers and furnaces in manufacturing industry
- significant replacement of old heavy and light duty diesel vehicles (i.e. Euro5 and Euro6), as well as an increase of the limited traffic zones and cycling paths
- replacement of oldest construction and agriculture vehicles

### 2.5.7 Possible improvements to the DPSIR blocks used in the AQP

This study did not explicitly consider the uncertainty on emissions and consequently neither on concentrations.

A possible improvement to the impact analysis could be a better estimation of costs for both technical and non-technical measures and a major regionalization of the GAINS technical measures database to better link a regional emission inventory to the European (GAINS) measure database. Health impact assessment should be improved using dynamic population data to better estimate human exposure.

### 2.5.8 Missing guidance

None

## 2.6 Research project for the Alsace Region (CNRS/UdS/ASPA)

### 2.6.1 Description of the AQP

Title: OPERA – Application of the RIAT+ model to define new strategies to reduce air pollution in the Alsace Region

Region: Alsace Region (France)

Reason/purpose: Test the RIAT+ system and see if it can help to modify/adapt the Regional Air Quality Scheme for Air, Climate and Energy.

### 2.6.2 Elaboration of DPSIR blocks

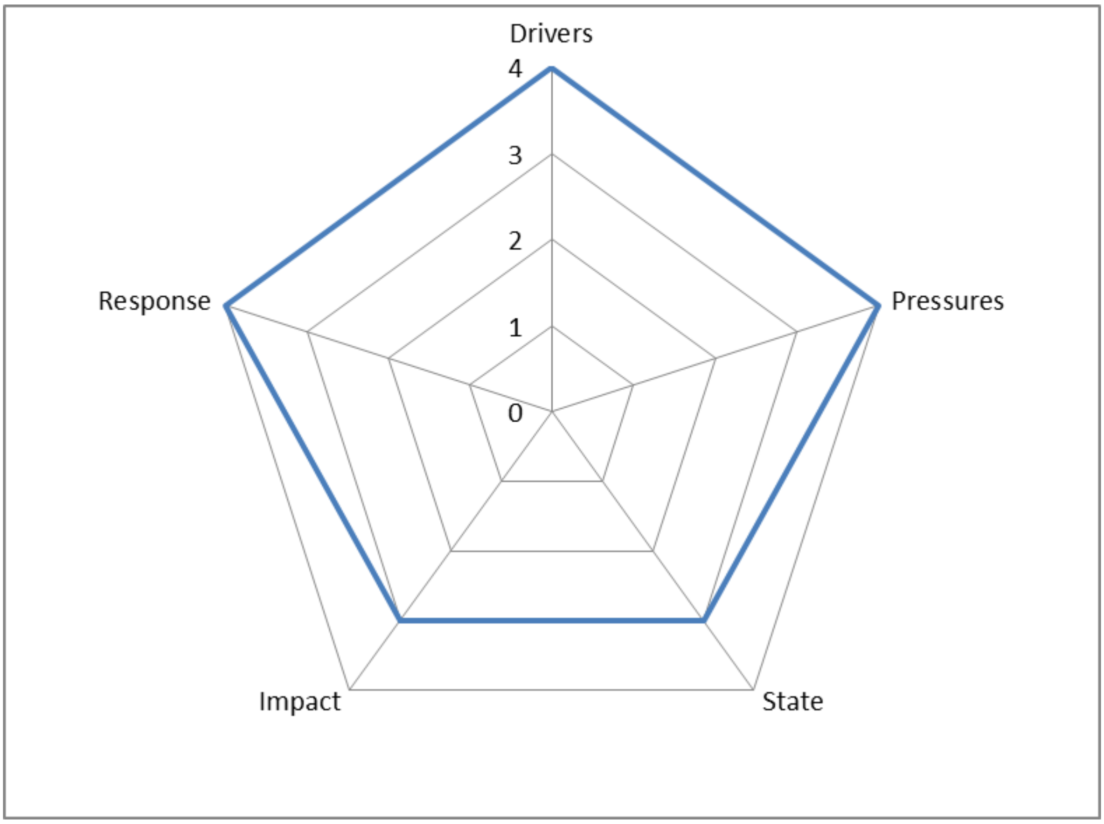


**Figure 6: Radar plot of the RIAT+ application on the Alsace Region (levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level**

### 2.6.3 Drivers

The information on drivers is collected by the local air quality agency, called ASPA. The nomenclature is based on SNAP (Selected Nomenclature for Air pollution EMEP/CORINAIR 1997) level 3 to describe the activities. Nevertheless the SNAP was extended in specific cases and sometimes codes defined by OFEFP (French Federal Office of Environment, Forest, and Landscape) in 1990 are used for polluting activities that are not considered in SNAP. For combustion activities (industry, transport, residential), a fourth level is applied in order to fulfil specific requirements using NAPFUE (Nomenclature for Air Pollution of Fuels EMEP/CORINAIR 1994).

The activity of fixed sources of fossil energy and biomass are computed using several sources of data mainly concerning the energy consumption. The Regional Direction of Industry, Research and Environment (DREAL) provides the energy consumption of several sources. The energy consumption of urban heating is directly provided by local heating production companies. Regional energy consumption data is provided by the Energy Observatory. Combustion emissions are spatialized to compute the activity for the service and residential sectors. The spatialization is done using the SIRENE database (information on companies) or specific surveys and energy needs. Data for the residential sector, including heating mode and temperature for each site, is provided by INSEE (National Institute of Statistic and Economic Studies). Activities in the residential use of machinery (lawn mower, chain saw, etc.) are described using gasoline consumption. Energy consumption data due to combustion for agriculture and forestry sector are given by the Energy Observatory, the statistics are collected by the ministry of agriculture. For specific machinery, the data are computed using the number of vehicles. The energy consumption per industrial process is estimated using ratios of the global energy consumption or production quantity (the ratios are estimated from statistics provided by professional syndicates, federations, or literature). The activities in industries with no direct fuel combustion (chemical synthesis, cast metal without combustion, wine and beer production, etc.) include refinery activities (computed using measures, estimation of the producer, statistic data), non-iron metal production (data are issued from producer data or computed using real or estimated production, or even numbers of employees given by SIRENE or another database), organic or inorganic chemistry (data given by DREAL or computed using real or estimated production, or even numbers of employees given by SIRENE or other database), processes relative to wood, paper, food and drink production (data given by DREAL, or calculated by quantity of production, number of employees, etc.), use of solvents (given by producers, surveys, estimated considering the activity when not known, computed using real or estimated production at regional or national scale). Activities to produce solvent use in residential and service sectors are usually estimated using population data and number of employees. Activities linked to waste treatment are given by producers or DREAL for incineration. Activities concerning fuel storage and distribution are computed using quantities of fuels stored and distributed given by the producers in case of point sources and issued from national statistics (CPDP, Energy Observatory or for natural gas GDF ,Gaz de France, a French company distributing gas). Road traffic activities include vehicle types and numbers, traffic fluxes are mainly provided by the Departmental Direction for Equipment/Facilities (DDE) and districts. Rail and river traffic activities are computed using data from respectively SNCF (French national railway company) and VNF (French national company of river traffic). Air traffic activities are calculated with LTO cycle (Landing take of) using traffic data provided by each of the airports. Activities on agriculture and forestry are calculated using statistics on animals and cultivation areas. Forestry activity is computed taking into account tree types, ambient temperature and radiation. The input data are given by the IFN (National Forestry Inventory) and ONF (National Office of Forests). Natural activities are estimated using inventories of natural surfaces.

Top-down and bottom-up approaches are both used to produce coherent inventories.

### 2.6.4 Pressure

DREAL provides emissions for only a few pollutants. The Alsace refinery also provides emissions for a few pollutants. Emission factors for processes related to wood, paper, food and drink production and use of solvents (COVNM) are extracted from: EEA - EMEP-CORINAIR-Emission inventory guidebook 2006, OMINEA (Organization and Methods for National Inventories for Atmospheric Emission in France – managed by CITEPA, http://www.citepa.org) – 2007; EPA – AP 42 Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources – 2007 ; OFEFP – Stationary sources – 2000 ; British inventory 2002 ; European IPPC Bureau – Best available techniques reference documents ; IPCC - Guidelines for National Greenhouse Gas Inventories – 2006; and other sources of EPA and DREAL. Emission factors for use in residential and service sectors are taken from OMINEA and OFEFP. Dumps' emissions from waste treatment are calculated using the ADEME dumps' inventory and data on individual characteristics (bio-gas recovery, ratio of organic waste, etc.). The computation method is based on the one proposed by OFEFP. Emissions from water treatment, mud spreading, composting are computed using data from ADEME and methods from IPCC, EMEP-CORINAIR and OFEFP depending on the pollutant. Emission factors for fuel storage and distribution are estimated by measurements or simulations. Road traffic emissions are estimated using COPERT IV EMEP-CORINAIR. Emission factors to compute Air traffic emissions are taken from OACI (International civil aviation organization), STNA (Technical service of French aviation) and EMEP-CORINAIR. Emissions from agriculture and forestry are calculated using EMEP-CORINAIR.

### 2.6.5 State

The state is computed using the WRF/CHIMERE system. The main grid domain (RIAT+ optimisation domain) has been described by 5074 cells (3km * 3km). According to the geographical projection system latitude-longitude WGS84, the limit coordinates of the area provided in tenth degree are: 6.76°W, 9.21°E, 47.32°S, 49.66°N. As done by ASPA in the Atmo-RhenA system (MM5/CHIMERE), the Global Land Cover database has been used to describe the European land use and the MODIS data have been used to describe the vegetation fraction.

The AVN NCEP global meteorological data (extracted from http://dss.ucar.edu/datasets/ds083.2/ for the year 2005) have been used as boundary conditions to run WRF on a European grid domain with a resolution of 45 $km^2$, nested with two other domains over France and the Alsace Region with respectively a resolution of 15$km^2$ and 3$km^2$. The CTM model CHIMERE (version 2008c) was run over the two nested grids Europe and France with CLE 2020 emissions from EMEP and on the Alsace Region with local emission data (computed as described above in DRIVER and PRESSURE). The simulations over France have then been used to give boundary conditions to 22 air pollution simulations on the Alsatian domain based on the 22 emission scenarios, designed to compute Source-Receptor models (ANNs) for RIAT+ applications.

Monthly emission data (for $NO_x$, VOC, $NH_3$, $PM_{10}$, $PM_{2.5}$, $SO_2$) and monthly AQI values (mean $NO_2$, mean $PM_{10}$, mean $PM_{2.5}$, AOT40, SOMO35, $PM_{10}$ excedances, ozone maxH8) have been then used to identifiy source-receptor models describing the relationship between emissions of the precursors and the Air Quality Index for each temporal period (year, winter and summer). Such models are used in the optimization module (see Responses). For this plan Artificial Neural Networks (ANNs) have been identidied as source-receptor models.. The ANNs validation confirmed that the neural network system is capable of reproducing the relationship between emissions and precursors.

### 2.6.6 Impact

A description of population exposure was provided by modelling of average mean annual exposure.

### 2.6.7 Response

An optimization procedure has been performed through the application of the RIAT+ model (http://www.operatool.eu). RIAT+ is a regional integrated assessment modelling tool that helps policy makers and technicians to select optimal emission reduction measures to improve air quality at minimum cost. RIAT+ is built as an integrated modelling environment, using tabular/geographic data and simulation/optimization models.

Specific components of the RIAT+ core system are:

1. A multi-objective optimization problem solver which is used to improve one or more air quality indicators (e.g. yearly $PM_{10}$ average) in the policy application domain, minimizing the costs of emission reduction measures. The solver is able to select the set of efficient abatement measures (needed to reach a particular optimal solution), in terms of application rates (level of application of the considered measures) and to calculate the corresponding emission reductions, AQI, costs and external costs. Since a Chemical Transport Model (CTM) cannot be run in real time within the RIAT+ optimization procedure due to its CPU time requirements, a simpler relationship between emission sources and air quality indicators at given receptor sites (S/R models) is used.

2. In RIAT+ it is possible to choose both linear and Artificial Neural Networks (ANN) relations for the Source/Receptor relation. If using ANNs, it is possible to capture the non-linearity in the relationships between emissions and concentrations, maintaining a low CPU time. In RIAT+ different air quality indexes are included (see list above). Also, it is possible to aggregate these indexes considering different time horizons, as yearly or seasonal (summer and winter).

3. The budget available for air quality can be constrained to a specific value (cost-effectiveness approach) or can be split in different macro sectors.

4. Other features are related to the fact that: different policy application subdomains (e.g. critical air quality zones) can be defined; state-of-the-art technologies may be fixed for some years while older technologies could be substituted; optimization can be limited to a subset of macro sector technologies; scenarios can be simulated fixing aggregated emissions or specific technologies.

Several simulations have been performed to test the capability of the model. A few of the results may be found in Carnevale et al., 2014.

### 2.6.8 Possible improvements to the DPSIR blocks used in the AQP

Even if the complexity of the AQP is ‘high’ for drivers and pressures, a few improvements are needed in the future as discussed in the guidance D4.1 for traffic and residential combustion of wood sectors.

Concerning the traffic sector, improvements are possible for the following points that are currently not considered in the D4.1:

- the description of the vehicle fleet that is issued in this AQP study are based on national data. However the Alsace Region is close to Germany and probably less representative of national standards than other French regions;
- the computation of cold start emissions is based on a very simple analysis of a survey on the daily mobility of the individuals to identify the number of vehicles that could be in a cold regime during the day (counted as the number of departures from a specific site).

Concerning the sector of residential combustion of wood, improvements are mainly related to the evaluation of the energy consumption per type of building. The buildings are described using the building register as prescribed by the guidance. However, the energy consumptions in private household are issued from a survey that is not updated regularly, that doesn’t provide detailed information on wood burning heating devices, and that doesn’t take into account the behavior of each habitant in their energy use.

Concerning the agriculture sector (not discussed in the D4.1), improvements concern mainly, the estimation of the emission factors. These emission factors are strongly linked to the agricultural practices and soil biological characteristics that are not well described yet.

Even if the AQP according to the current guidance levels of complexity, considers a high level for the state, a few improvements are needed:

- increase the spatial resolution of the state in order to well represent the air pollution in sensitive zones where high pollutant concentrations are observed; reduce study domain on these sensitive zones (adapt or change the CTM);
- improve the CTM, and especially the simulations of PM: improve the representation of the PM production over land surfaces, in general the link between meteorological conditions and PM emissions (including emissions by residential combustion as discussed above), include the processes involved in the production of secondary organic aerosols;
- improve the identification of source-receptor matrices; these don't take into account a possible future modification of the land use (i.e. development of new emission sources in the study domain);
- objective evaluation of state and uncertainties using FAIRMODE tools (following advice of the guidance).

Concerning the impacts, the following improvements are possible:

- use of local data on health impact of air pollution (local dose-responses functions; several health program have been performed in the Alsace Region);
- take into the account the daily mobility in estimating the exposure to air pollution;

For responses, the improvements we would consider are:

- verify that the European GAINS database of technology costs is applicable to the local scale and coherent with the national database;
- distinguish between local, regional and national costs, as well as costs for individuals and authorities;
- complete the local non-technical database;
- improve the optimization procedure to manage multiple objectives. The first test of RIAT+ shows that a reduction of an exposure to $NO_x$ concentrations may increase the exposure to ozone, and the contrary (Carnevale et al., 2014). In order to define optimized strategies to reduce $NO_x$ and/or ozone, the user needs to define a priority, i.e. a weight to precise if the priority should be the reduction of $NO_x$ or $O_3$ or both. This optimization should be done in an objective way.

### 2.6.9 Missing guidance

An explanation on how simple source-receptor relationships could be built for use in an IAM would be welcome. The guidance is currently not detailed enough to be useful for improving a local IAM. The guidance should also more specifically be extended with the topics that are mentioned in 2.6.8 above concerning the emissions from traffic and the agricultural sector.

## 2.7 AQP for the Warsaw Agglomeration (WUT)

### 2.7.1 Description of the AQP

Title: Air Quality Plan

Region: Warsaw Agglomeration, Poland (PL.14.01.a.01)

Reason/purpose: To improve the air quality in the agglomeration; to meet air quality limit/target values for the protection of human health.

Specific characteristics of the case: Warsaw has about 1.7 million inhabitants and is the largest and one of the most congested cities in Poland. This is mainly due to the lack of a real bypass road, so most of the traffic is routed through city streets, which are quite narrow in many areas. The Warsaw metro is one of the newest subway system in Europe, however it has only one line so far. Building of the second line - which is being realized currently - constitutes an additional disruption in city traffic. In general, bicycle routes are scarce, being well organized only in a few districts. As a result, according to the latest assessment (Deloitte, 2014) each Warsaw's dweller loses on average a month of salary a year, due to time spent in traffic congestion.

The first Air Quality Plan for Warsaw was issued due to the exceedances of $PM_{10}$ and $NO_2$ limit values in 2004. The road transport sector (SNAP07) has the biggest share in all pollutants concentrations, but there are a few districts with a significant share of residential heating. In general, the contribution of transport emissions in PM concentrations constantly grows. Beyond the exceedance zones, the pollutants inflow from outside of the agglomeration has an important share, at times being the prevailing one.

This study was performed as the Air Quality Plan for the years 2004-2007. Furthermore, Plans concerning B(a)P (2007) and PM2,5 (2010) were also established. Warsaw agglomeration zone is considered as a hot spot with problems in terms of exceedances of the $NO_2$ and PM guidelines of the EC Directive. An AQP is currently being implemented (up to the end of 2016).

### 2.7.2 Elaboration of the DPSIR blocks

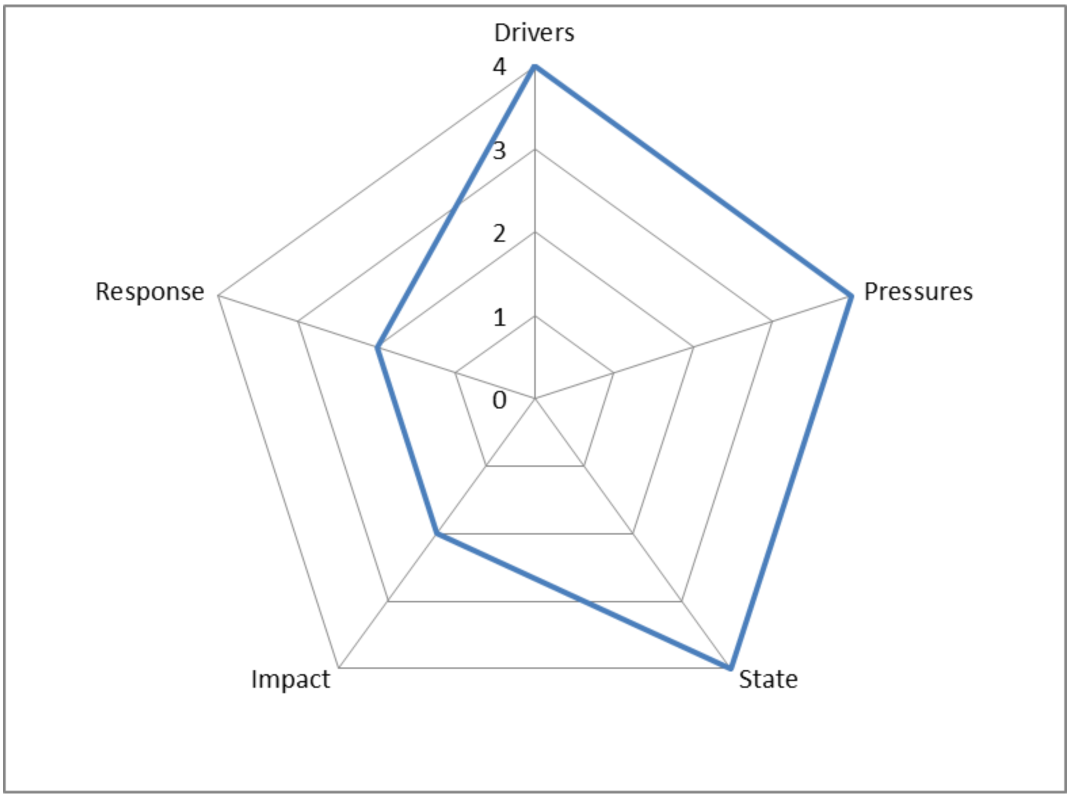


**Figure 7: Radar chart for the AQP for Warsaw Agglomeration (levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

### 2.7.3 Drivers/Pressures

The Air Quality Plan (AQP) for Warsaw takes into account national, regional and local strategies and applies bottom-up approach, therefore the complexity of the DRIVERS block is high (level 4). The main local activities are: road transport, residential heating, energy production and industry.

The complexity of the PRESSURE block is also high (level 4) as emission were calculated by the emission model with the fine resolution in space and time, using a bottom-up method.

The emission database was generated by EKOMETRIA Agency. For traffic, hourly emissions for a road network were calculated as a function of traffic volume, road characteristics and fleet composition, based on the data from the Warsaw's Boards of Urban Roads and of Public Transport (250 m x 250 m resolution). Residential emissions were calculated based on the local information on residential units not connected to the city central heating system, their furnace type and fuel used (coal, coke, gas, oil, wood) (250 m x 250 m resolution as well). For the industrial emissions a detailed emission inventory with stack level data was used that was compiled by the Voivodeship Inspectorate of Environmental Protection in Warsaw.

### 2.7.4 State

In the case of STATE the level of complexity is also high (level 4). To determine the $NO_2$ and $PM_{10}$ concentrations a chain of models was used. The concentrations for the study area (covering the agglomeration and its 30 km diameter surroundings) were calculated with a CALPUFF Gaussian puff model setup (discrete receptors were used) with decreasing resolution from 1km (for city surroundings) to a very high 250 m resolution (for the agglomeration itself). Regional (voivodeship) background concentrations were calculated at a resolution of 7 km using the CAMx Eulerian chemical transport model (Environ, 2006) and included as monthly boundary conditions (also for aerosols). The CAMx model setup used results of the EMEP Unified model (50 km resolution, monthly averages) as initial and boundary conditions.

Operational model evaluation was carried out with the set of statistical metrics proposed by Juda-Rezler et al., 2012.

The contribution of different source categories to the air pollution in study area (source-apportionment) was calculated with the dispersion model, based on the features of CALPUFF Lagrangian model.

### 2.7.5 Impact

In the AQP for Warsaw the human health effects were not directly considered, thus the IMPACT assessment block level is 1. However, the impact was indirectly considered, on the basis of exceedances of limit values for the protection of human health, according to the EU Directive. The analysis was based on yearly average concentrations for $NO_2$ and both yearly and daily averages for $PM_{10}$ concentrations.

### 2.7.6 Response

The RESPONSE block is based on expert judgement and scenario analyses, so it complexity is low (level 2). In this study a preliminary list of economically and/or socially and politically feasible measures was drafted that was then extended and screened based on expert opinion and previous experience with respect to the effectiveness of the individual measures. Besides the measures also a map of hot spots was provided for which the measures should be applied. The finally proposed measures were split into two groups:

1. Measures to be implemented to the residential emission
   Connection of individually heated houses to the municipal heating network. This measure is proposed for 4 districts, covering approximately 1% of the agglomeration area, with approximately 13 000 inhabitants.
2. Measures to be implemented to the road transport emission
   Improvement of public transport network by building of 2 ring roads: City Centre Ring Road & City Ring Road (up to 2020) and establishment of a low emission zone in the City Centre.

Implementation of the first measure alone will reduce total $PM_{10}$ emission in the zone by as much as 21%, while implementation of the second one will reduce total $PM_{10}$ and $NO_2$ emissions in the zone by 30% and 53%, respectively.

For each of proposed measures differences in concentration were calculated (scenario analyses).

The study did not use neither source apportionbment nor an optimisation procedure to derive the set of abatement measures.

### 2.7.7 Possible improvements to the DPSIR blocks used in the AQP

In this study uncertainty in the quantification of the activities and the emissions was not considered, however the applied model chain was positively validated against measurements. Moreover, uncertainty analysis have been made in a research project for Warsaw Agglomeration (see 2.8), which uses the same activity/emission data.

The level 1 for IMPACT in the radar chart (Figure 7) is due to the fact that the study does not explicitly consider health impact. A possible improvement would be to calculate health impact from the the high resolution concentration maps and combine this with a detailed population density map for Warsaw. With respect to the choice of the RESPONSE this study did not use an optimisation approach to determine the optimal set of abatement measures. The AQP was intentionally limited to the set of measures that can possibly be realized by the Warsaw authorities.

The results of the new study of Tainio et al. (2014, in press) performed for the Warsaw agglomeration could be applied as an improvement in both the IMPACT and the RESPONSE blocks of the AQP. The authors modelled annual average pollutant concentrations on a 1 km grid (CALPUFF model) and combined these with population data to predict the contribution of each individual source to population exposure. They quantified the intra-urban intake fractions (iF) that describes the fraction of the pollutant that is inhaled by people in the study area for a number of pollutants and pollutant-source category combinations. It was shown that exposure due to intra-urban air pollution emissions could be decreased more effectively by specifically targeting sources with high exposure potency rather than all sources.

### 2.7.8 Missing guidance

In general, for the air pollution modelling community, more guidance seems to be needed mostly for improving the IMPACT block. Assuming that a HIA study needs to be done not by epidemiologist, but by the air pollution modeller, the guidance in this part may possibly be more illustrative, give more examples of specific studies, especially for exposure modelling and be also extended with references to data sources with concentration-response functions. In addition some formulations in the text are not commonly known and should be explained (e.g. “so-called effect modification” or “cocktail effect”).

In the PRESSURES part (chapter 4.5 in D4.1), the section on how emission inventories for different scales should be used and combined should be extended with examples and references.

There is a lack of guidance to the source apportionment methodology in the document. Even if this is covered in another deliverable, some explanation and references should be given.

In the STATE block a short explanation of assimilation method is needed in the beginning of the chapter as well as references. For evaluation, a reference to the DELTA-tool will be helpful. Moreover, especially this section should be rather a real guide than a presentation of model performance evaluation methods. If possible, criteria for “good” model performance should also be suggested.

## 2.8 Research project for the Warsaw Agglomeration (SRI/WUT)

### 2.8.1 Description

Title: Air Quality Analysis and Uncertainty Assessment

Region: Warsaw Agglomeration, Poland (PL.14.01.a.01)

Reason/purpose: To assess air quality and uncertainty of air pollution forecasts related to emission data uncertainty.

Specific characteristics of the case: The analysis covers a rectangular domain, approximately 30km x 40km covering the Warsaw area (about 520 $km^2$ within the administrative borders). Emission and meteorological data for the year 2005 are used. Spatial resolution applied in the computational analysis is 1km x 1km. The following pollutants, primary and secondary, are considered: $SO_2$, $SO_4^{2-}$, $NO_x$, $NO_3^-$, $PM_{10}$, $PM_{2.5}$, $PM_{10R}$, $PM_{2.5R}$, Pb, Ni, Cd and BaP (index "R" means emission from road traffic). Air quality computations and uncertainty analysis refer to the annual mean concentrations generated by the model at 563 fictitious receptor points located in computational domain (receptors locations coincide with the spatial resolution of the grid).

Besides the practical value of the final results concerning concentrations and health effects (see Holnicki & Nahorski, 2013), general objectives of the presented uncertainty analysis are to bring scientific predictions of air quality models closer to reality, increase decision maker's confidence in the scientific results, improve the stakeholder's and public's confidence in science and improve the quality of the final regulatory decisions.

### 2.8.2 Elaboration of the DPSIR blocks

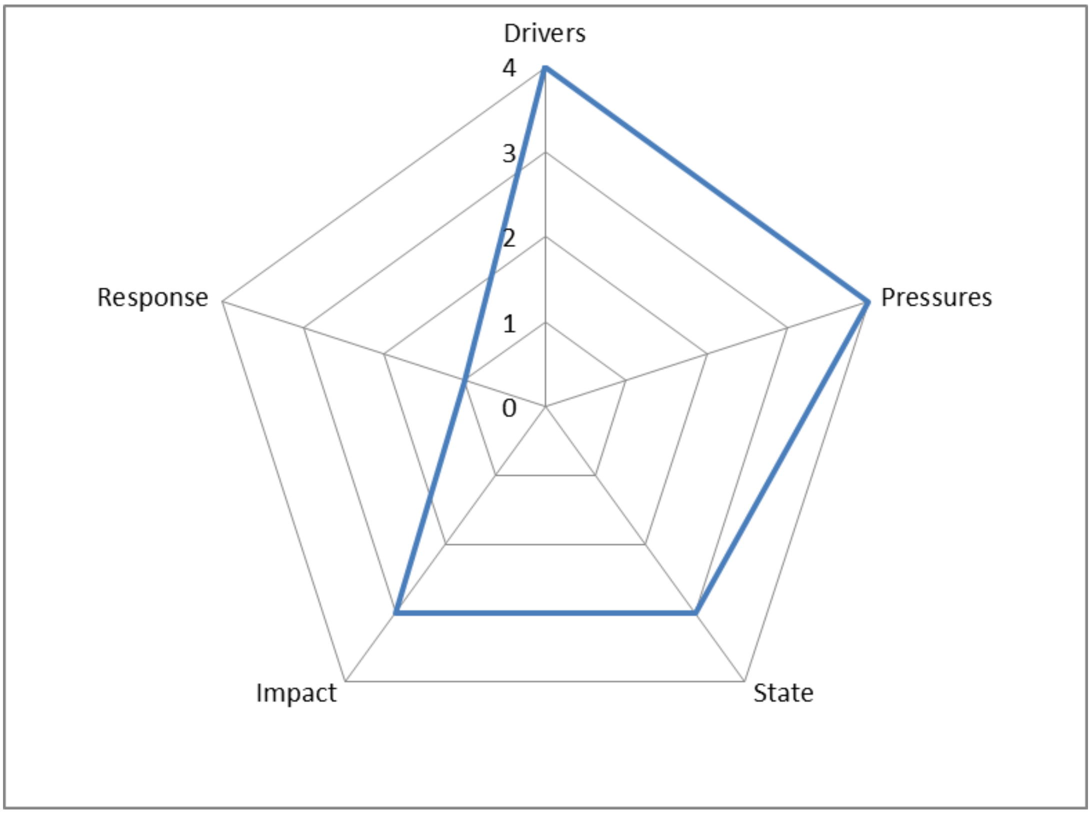


**Figure 8: Radar chart for the research project for Warsaw Agglomeration. (levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

### 2.8.3 Drivers/Pressures

Activities and emission relevant technologies are considered as DRIVERS. The main activities relevant for Warsaw are: road transport, residential heating, energy production and industry. In addition to the activity rates for the above sectors, emission relevant technology parameters were collected. The emission dataset for the Warsaw study is prepared by the Voivodeship Inspectorate of Environmental Protection in Warsaw and EKOMETRIA Agency. The total emission field consists of 3 categories: point (high/low), area and line (mobile) sources.

Due to the purpose of this study, the emission field was decomposed into separate categories, mainly according to source parameters, composition of the polluting compounds, emission intensity and intrinsic uncertainty. The total emission field was categorized into the following four classes (number of the individual sources in each category is indicated):

- 16 high point sources (power/heating plants – low uncertainty),
- 1002 low point sources (industrial sector – medium uncertainty),
- 872 area sources (residential sector – high uncertainty),
- 1157 linear (mobile) sources (road transport – high uncertainty).

In order to assess uncertainty of the concentration forecasts due to the emission uncertainty, a Monte Carlo analysis was applied. For each source and source category 2000 randomly generated sets of emission values were pre-processed, according to the accepted normal distribution and uncertainty range. The assumed range of emission uncertainty for the basic polluting compounds refer to emission category, composition of the polluting compounds and technological characteristics of the source.

It is shown that accuracy and uncertainty of air pollution forecast measured at any receptor point is directly related to the following three factors: (a) the kind of polluting compound considered, (b) the contributing and dominant emission source categories along with the assigned input uncertainties, (c) the number of the individual emission sources having a substantial share in the total pollution. The resulting uncertainty assigned to a receptor point decreases for growing number of contributing emission sources (the averaging effect). An example of the contribution of emission category and the resulting uncertainty is shown in for a receptor in the vicinity of intensive traffic (Łazienkowska str.)

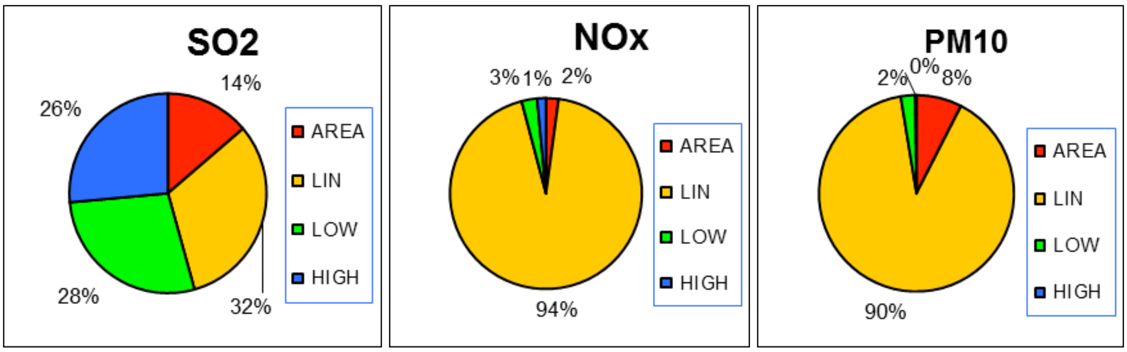


**Figure 9: Contribution of emission categories (receptor 275) and related uncertainty: ($SO_2$ ± 6%; $PM_{10}$ - ± 18%; NOx - ± 21%)**

### 2.8.4 State

The concentrations of the main species related to the local sources were calculated with the CALPUFF Gaussian puff model at 563 receptor points. The outside inflow of the key pollutants was based on the EMEP model predictions (for 50 km x 50 km resolution) and included as the boundary conditions for the CALPUFF model.

The annual mean concentrations and full uncertainty characteristics of each pollutant at the 563 receptors have been obtained. Moreover, the contribution of each individual emission source to the total air pollution recorded at each receptor point was calculated, based on the CALPUFF model results. The information was utilized in further uncertainty analysis.

Also the accuracy of the modelling results for $PM_{10}$, $NO_x$ and $SO_2$ was evaluated based on the available data for 16 stationary monitoring stations using the following measures of modelling quality: Normalized Mean Bias, Fractional Bias, Normalized Mean Square Error, Normalized Standard Deviation, the fraction of modelled values within a factor of two of observations (FAC2). Generally, the above indices demonstrated the satisfactory accuracy of the model predictions.

For the air pollutants considered, relatively homogeneous distribution and low uncertainty applies to the concentrations of $SO_2$, which mainly depends on the relatively precise input for the emissions from point sources. On the other hand, significant uncertainties were observed in the $NO_x$, $PM_{10}$, $PM_{2.5}$ and Pb forecasts, which strongly depend on the structure of the contributing sources, with dominating impact of the urban transport. Moreover, the high spatial variability of concentrations, emission sources' contribution and uncertainty relate to traffic-dependent pollutants (see Figure 10 for $PM_{10}$).

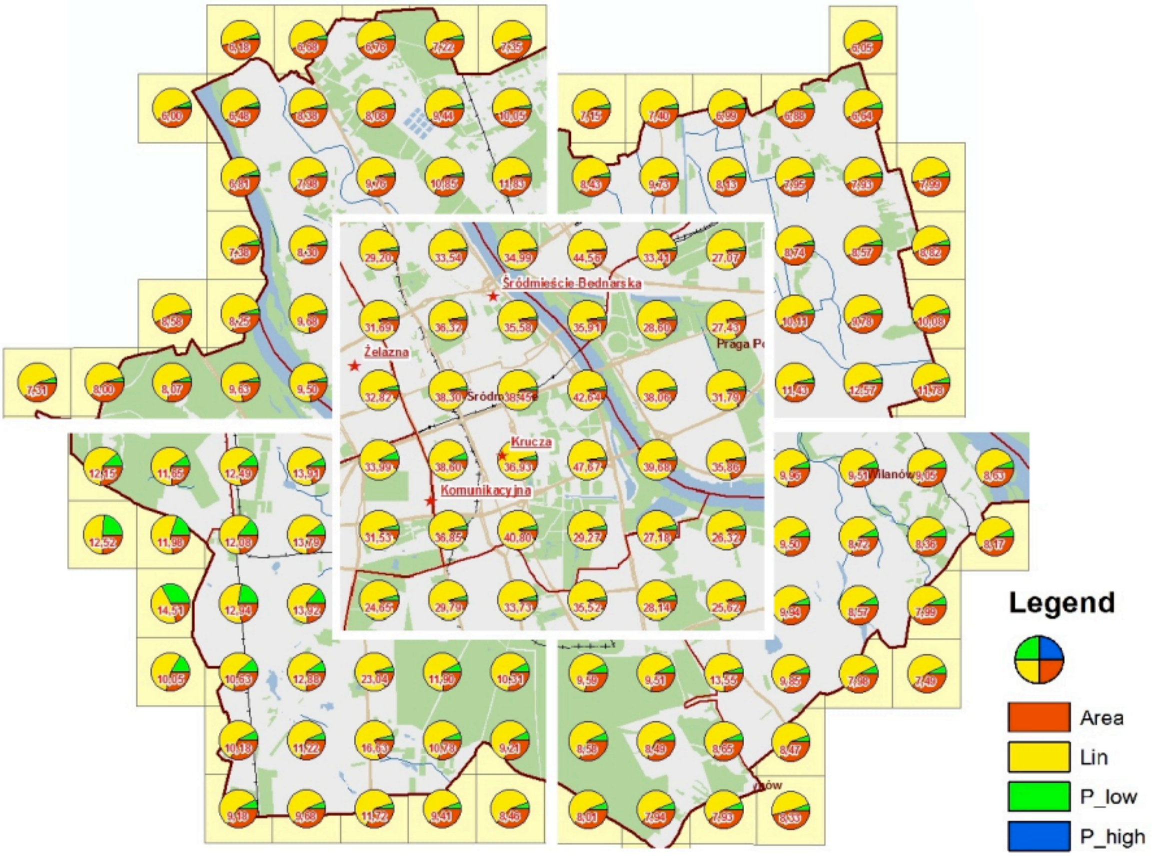


**Figure 10: Relative share of emission categories in $PM_{10}$ concentration.**

### 2.8.5 Impact

Model predictions were used to assess the health impact of $PM_{2.5}$ concentration in the study area. The concentration map was combined with a high resolution population density map (100 x 100 m). These data were used to assess population exposure to $PM_{2.5}$ pollution as well as the intake fraction (iF) index.. The spatial distribution of iF values showed a substantial contribution of the mobile sources of the road transport sector.

### 2.8.6 Response

In this research project the response was not considered. , although this block has been intensively addresses in further studies mentioned in 2.8.7.

### 2.8.7 Possible improvements to the DPSIR blocks used in the AQP

One of the main purposes of this research study was to perform an uncertainty analysis based on the Monte Carlo technique (Holnicki & Nahorski, 2013), thus the results of this work could be used for the improvements to the PRESSURES and the STATE blocks of the AQP.

In the present study population exposure to $PM_{2.5}$ pollution was assessed based on a combination of the concentration map and a high resolution population density map (level 2 of the radar chart).In the meantime, further studies have already been performed (Tainio et al., in press) and its results could be used for the improvement of the IMPACT block of the AQP for the Warsaw agglomeration (see 2.7). The intra-urban intake fraction (iF, see 2.7.7) related to source-specific pollution was quantified for Warsaw, including its spatial resolution and uncertainty resulting from emission data. As it was mentioned above (see 2.8.6) the RESPONSE was not considered in this research study. However, the RESPONSE block of the AQP (2.7) could be improved as Tainio et al. (in press) showed that exposure due to intra-urban air pollution emissions could be decreased more effectively by specifically targeting sources with high exposure potency rather than all sources.

Quite recent, unpublished yet, studies were also connected with assessing the impact of the transport sector on health. The transport sector impacts the population health through four stressors: (i) air pollution, (ii) noise, (iii) traffic accidents and (iv) physical activity. The purpose was to assess the transport related exposure to these stressors and then predict the positive and negative health effects caused by each stressor. For air pollutants the emission-to-exposure relationship was quantified by the Intake Fraction (iF, see 2.7.7), providing convenient summary measure to describe the impact of exposure to air pollution. By means of iFs it is possible to quantify the changes in population health due to changes in the transport related air pollution. The exposure-response functions (ERF) are used to calculate the health effects of different stressors. Health effects were finally summarized using the Disability-Adjusted Life-Years (DALY) method.

The most substantial negative health effects in Warsaw are due to air pollution – mainly $PM_{2.5}$ – (loss of 27,000 DALYs), noise (loss of 27,000 DALYs), traffic accidents (loss of 2,400 DALYs), and health benefit due to physical activity (gain of 27,000 DALYs). Total impact of transport has been estimated as a loss of 29,000 DALYs a year.

### 2.8.8 Missing guidance

See comments 2.7.8

## 2.9 AQP for Helsinki (SYKE)

### 2.9.1 Description of the AQP

This study (Kousa et al., 2012) for the most heavily trafficked street canyons of Helsinki was intended to assess the exceedances of $NO_2$ concentration with different future scenarios on road traffic. Dispersion modelling was used to evaluate the development of $NO_x$ emissions and $NO_2$ concentrations in Helsinki in those areas where there is the highest risk of the limit value to be exceeded. Based on this study the City of Helsinki wants to assess different opportunities to reduce the area of exceedances of $NO_2$ limit values.

There is more than one million inhabitants in Helsinki Metropolitan Area and approximately 600,000 in Helsinki. Helsinki is the capital and largest city in Finland.

### 2.9.2 Elaboration of the DPSIR blocks

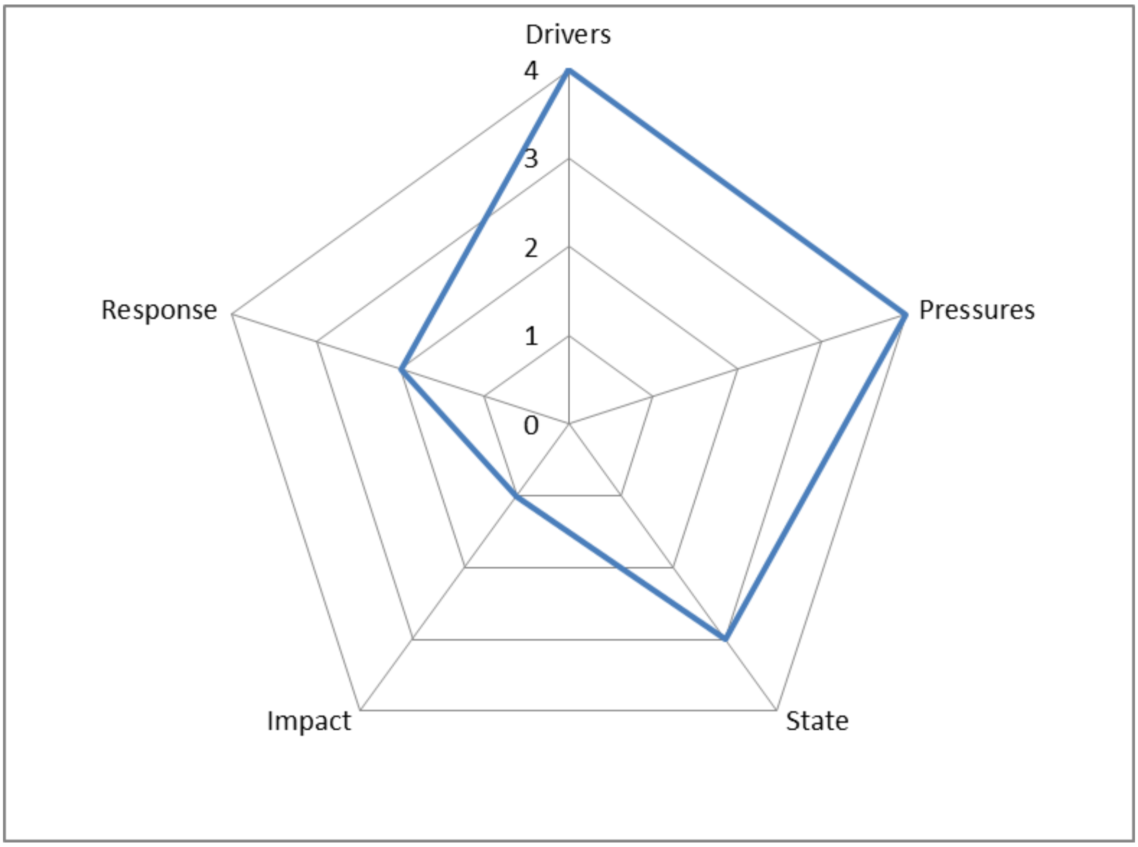


**Figure 11 Radar chart for the AQP**
**(levels: 4=high; 3=medium; 2=low; 1= not considered; 0= no level)**

### 2.9.3 Drivers/Pressures

The study considered several scenarios for the year 2015:

1. Base year 2005
2. No measures projection 2010
3. Business-as-usual 2015
4. Traffic volume change 2015
5. Environmental zone 2015
6. Smoother traffic 2015

The total number of vehicles and their share in different vehicle categories for various scenarios has been provided by the Helsinki City Planning Department. The share of diesel passenger cars was estimated taking into account national average values, local factors in Helsinki and changes in Finnish tax legislation in 2008 that changed the pattern considerably. Average speed in the street canyons was based on the study conducted by the Helsinki City Planning Department (Hellman, 2009). The vehicle fleet composition in different emission standard categories for vehicles was based on a national database developed by VTT Technical Research Centre of Finland (LIPASTO, 2011). The more detailed estimations were made for, e.g., the estimated percentage of urban buses falling into different emission standard categories based on information from the Helsinki Regional Transport Authority HSL. Emission factors from the HBEFA (version 3.1) database for congested traffic were used for most of the vehicles. However, because of lack of sufficient EEV data in the HBEFA database the emission factors for EEV buses were based on national data (RASTU project, 2009).

Complexity level Drivers/Pressures = 3

### 2.9.4 State

For modelling $NO_2$ concentrations a street canyon model OSPM (Operational Street Pollution Model) was used. The model has been developed by the National Environmental Research Institute, Department of Atmospheric Environment, Denmark (Berkowicz, 2000).

Background concentration data measured at the urban background station (Kallio) was used from year 2010 in all projections assuming that the concentration decreases 1 % per year as a result of emission reductions. Also meteorological data was used from year 2010 in all projections.

Complexity level State = 2

### 2.9.5 Impact

The study considered only $NO_2$ exceedances, i.e. no health or environmental impact assessment was involved.

Complexity level Impact = 0

### 2.9.6 Response

The studied scenarios were selected based on the collaboration and expert judgement of local actors: Helsinki City Planning Department, HSL (Helsinki Regional Transport Authority) and HSY (Helsinki Region Environmental Services Authority). Impact of different vehicle categories on concentration in different scenarios were assessed based on the modelling results.

Complexity level Response = 1

### 2.9.7 Possible improvements to the DPSIR blocks used in the AQP

We estimated in this study only $NO_2$ concentration in different scenarios. Combining exposure estimation (e.g. Expand model, Kousa et al 2002 and Soares et al., 2014) and health outcomes we could estimate the health impacts of population for different scenarios.

### 2.9.8 Missing guidance

The emission factors needs more guidance. For example there are not so much data of direct $NO_2$ emissions (emission factors are only for $NO_x$) and its contribution for ambient level air quality is nowadays significant. Also real life emissions are important. The amount of emissions is much higher in city traffic than in official driving cycles. The emission of busses are significant in the street canyons and especially their emission estimations need improving. The number of busses in different EURO classes is essential when the emissions are estimated. There are very limited data of the amount of different after treatment techniques (SCR, EGR) in busses in operation and how well these techniques actually are working in real life traffic. There is an urgent need for EURO 6 emission factors. There are also very limited data about EURO classes of the busses outside the HSY area.

For AQP studies extending to other pollutants (e.g. fine particulate matter, black carbon) and a more complete set of emission sources, there is a lack of guidance on the assessment of residential combustion emissions.

# 3 Conclusions

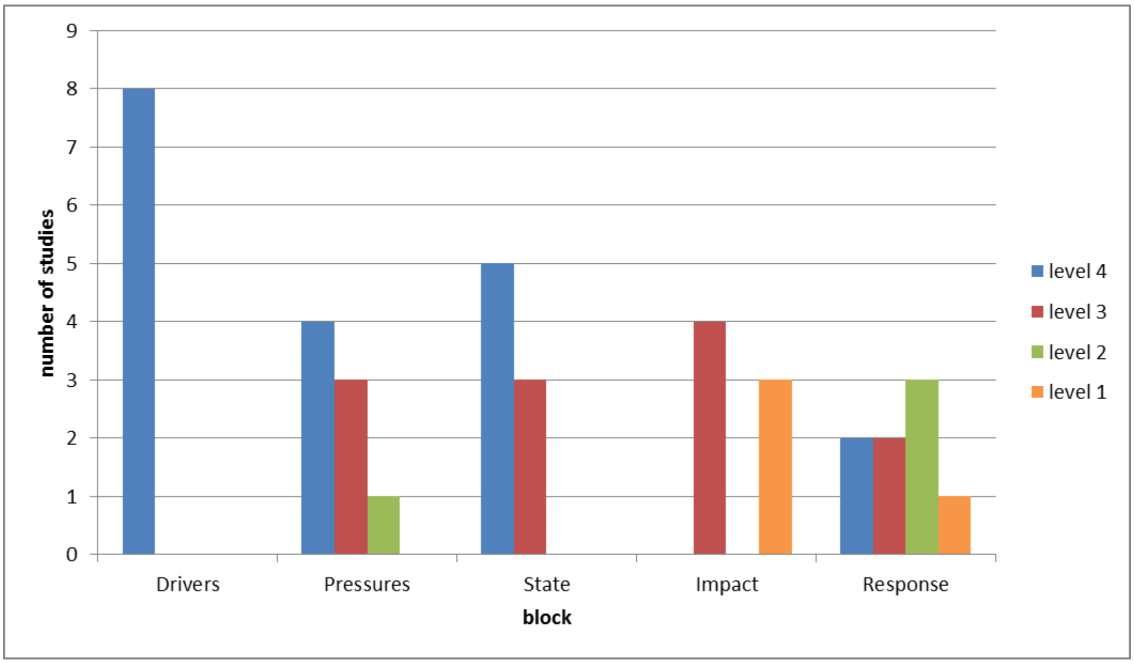


**Figure 12 Summary of complexity levels for all studies considered (level 4 = high, level 3 = medium, level 2 = low, level 1 = not considered)**

From the summary in Figure 12 you can observe that in all the cases considered the drivers and to a somewhat lesser degree the pressures and state were well elaborated while in none of the studies the health impact was considered with the highest level of detail and also the choice of abatement measures is mostly based on expert judgment.

Based on the analysis for the eight practical AQP studies in the previous chapters we can make the following observations:

- In general the guidance document would benefit from including more (references to) practical examples and we should try to provide more solutions instead of just pointing out the problems.
- Much effort was put into quantifying the drivers and pressures (emissions) in all the studies that were considered. In all examples the drivers are treated at the highest level of complexity and only in one of the examples the emissions are based on a top-down and thus 'low level' methodology. Regardless of this already high level of detail, the drivers and the emissions are still seen by some as the topic where most of the additional guidance would be welcome and more in particular the guidance document should be extended with practical references to additional data sources with an emphasis on 1) 'real life' emission factors for traffic, domestic heating (wood/coal burning appliances) and agriculture 2) projections and future estimates and 3)practical examples on combining emission inventories at different scales.
- The state (concentrations) is in all the examples handled with one or more models. For some of the AQP that lack detailed local scale concentration assessments, it is also acknowledged that this is a point for improvement. The guidance document needs to be extended with guidance on using data assimilation and a better reference should be made to FAIRMODE for the evaluation of model results.

- Uncertainty both in the emissions and concentrations is not addressed except in a single research study which was included in this analysis. Based on the feedback given for the eight cases there is however no need for additional guidance on doing such an analysis in the guidance document.
- If health impact is considered in the examples in general exposure is evaluated without mentioning health indicators and this is never done based on a detailed temporal and spatial resolution for the exposure and population data and in three of the plans health impact is not addressed at all. Also for this topic more practical guidance would be welcome with references to example applications and to where input data (dose-response, ..) can be found. As this a subject unfamiliar to most of those involved in developing air quality plans some of the topics addressed in the guidance document should be better explained.
- Only the two studies using the RIAT modelling system rely on an objective, optimisation method to identify the optimal mix of abatement measures. It can however be noted that for both applications, even if these represent the highest level of complexity for the response block, some of the improvements that were identified relate to improving the database with costs and emission reduction efficiencies for the abatement measures or other inputs such as the weights attributed to single objectives when doing a multi objective optimisation . It should be clear that – as in any modelling activity – the results of the optimisation process off course heavily rely on the quality of the input data that are used in this process. In the other AQP abatement measures are selected through a process involving an interaction with policy makers, expert opinion and scenario modelling to assess the effectiveness of proposed abatement measures. The guidance document should be extended on guidance on how a simple source receptor model can be identified. Guidance on source apportionment is currently also lacking.

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