THE MULTI-SCALE CHARACTER OF AIR POLLUTION: IMPACT OF LOCAL MEASURES IN RELATION TO EUROPEAN AND REGIONAL POLICIES – A CASE STUDY IN ANTWERP, BELGIUM

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Abstract: This paper describes a multi-scale modelling approach designed to assess the impact of policy plans at various decision making levels (European, regional and local). The modelling framework is applied for a case study in Antwerp, Belgium. Various tunnel options and traffic management plans for the Antwerp ring road are evaluated with respect to their impact on air quality in 2020 and 2025.

Key words: *urban air quality, EU limit values, local measures, tunnels*

INTRODUCTION

Today it is realized that many of the persistent air pollution hotspots are situated within urban agglomerations. However, due to the multi-scale character of the air pollution phenomenon, policies have to be developed at various levels to deal with this problem. At the local level city authorities can for example use urban development and traffic management plans to tackle air pollution exposure of their citizens. At the same time policy is developed at the European (e.g. EURO standards for transport) as well as the regional levels (e.g. congestion charge) to mitigate the same air pollution problem.

When the effectiveness of all these measures has to be assessed at the local scale, especially the attainment of the EU limit values at a given time horizon such as 2015 or 2020, methodologies have to be developed to deal with this multi-scale character of air pollution and its related policies. Policy impacts on the regional background as well as the impact of local actions plans have to be combined into one overall air quality projection.

METHODOLOGY

A coupled modelling framework has been setup to assess air quality at a high spatial resolution, including both regional changes as well as local variation of air pollution levels (Lefebvre et al, 2011a). The framework is making use of the traffic emission model MIMOSA, the Eulerian model AURORA and the bi-Gaussian plume model IFDM. The coupled modelling framework can be described as follows: road traffic loads are input for the MIMOSA4 emission model (Mensink et al., 2000). The resulting spatially and temporally distributed emissions are used in the bi-gaussian model IFDM (Lefebvre et al., 2011b). These results for the local traffic contribution are coupled to output of the Eulerian dispersion model AURORA (De Ridder et al., 2008) which is calibrated with the land-use regression model RIO (Janssen et al., 2008). The overall integrated framework is described in detail in Lefebvre et al (2011a).

In the couplings of the model chain, care is taken of double counting of emissions and the complexities of the ozone-NO_x chemistry. To avoid double counting of the emissions by the different models, IFDM concentrations related to the local emission sources are averaged over the grid cells of the regional AURORA model. This spatially averaged local contribution is then subtracted from the regional contribution. Afterwards the high resolution concentration pattern of the bi-gaussian plume model is added again on top of a reduced regional background. The double counting corrections described above are applied on an hourly basis. In order to deal with the fast ozone-NO_x chemistry, combination of different model results and the double counting corrections are performed at the level of NO_x, NO and NO_2 individually. In a final stage, use is made of the ozone background concentrations and local meteorology to calculate at an hourly basis an atmospheric equilibrium state for the different constituents.

This overall procedure result in hourly high resolution maps. The reliability of the model results is confirmed in a dedicated validation exercise in which NO_2 point measurements at 50 locations in the city centre are taken into account (Lefebvre et al, 2013). The validation confirms that the maps can be used to calculate annual statistics and for compliance checking in the framework of the EU Directive.

ANTWERP CASE STUDY

The modelling framework described above is applied in an urban planning case for the city of Antwerp, Belgium. At present, the very busy ring road of Antwerp is responsible for a major fraction of the air pollution in the city. Under a business as usual scenario EU limit values will not be attained everywhere within the next 10 to 15 years. To cope with this problematic situation a number of tunnel scenarios for the ring road and alternative traffic reduction plans are evaluated with the overall aim to meet EU limit values everywhere in 2020.

In this exercise, NO_2 as well as elemental carbon (EC) are considered. The NO_2 concentrations are regulated by the EU Air Quality Directive. EC or soot is a fraction of the particulate matter and for this pollutant Europe has not (yet) established air quality standards. However it appears that EC has a clear link with traffic and is possibly one of the most harmful fractions of particulate matter.

The modelling exercise shows that the implementation of current legislation as detailed in European, regional and urban policy plans will have a clear positive impact on the air quality in large parts of the city of Antwerp (see Figure 1). However, it also becomes clear that on top of this business as usual scenario, a significant traffic reduction would be required in 2020 to achieve annual NO_2 standards at any location along the Antwerp ring road. Even for 2025, current legislation policies will not be sufficient and extra traffic reduction on the ring road will be necessary to meet European standards everywhere. Building on these findings, a number of tunnel and traffic management scenarios for the Antwerp ring road are examined. These scenarios include a complete covering of the existing ring road, short tunnel elements of 250m of 500m at strategic location of the ring road, the construction of an additional new ring road at the outer bounds of the city and a back casting scenario in which traffic volumes are reduced in order to meet European NO_2 standards everywhere.

In addition to those infrastructure scenarios, a sensitivity analysis is setup with regard to the absolute traffic volumes in each scenario. It’s well known that any model simulation for 2020 and beyond come along with significant model uncertainties related to e.g. economic growth. Since traffic volumes play a crucial role in the analysis, a sensitivity analysis with +20%, -20% and -40% traffic is performed. This analysis gives further insight into the uncertainty and robustness of the model simulations.

RESULTS

A complete coverage of the ring road does not solve the problems related to the compliance of the NO_2 limit values at any location. In the vicinity of the ring road this scenario gives rise is much lower concentrations, but at the exits and open sections of the tunnel (entry and exit complexes along the tunnel), this scenario leads to a significantly increase of concentrations. Since a number of those complexes are located in densely populated areas, this has negative impact on population exposure.

Furthermore, it becomes clear that short tunnels (250m or 500m) along the ring road also do not solve the air quality problem. Indeed those tunnels can locally improve the air quality, especially above the tunnel elements. Depending on the location concentrations just below or just above the European standards can be achieved. However, at the tunnel exits significant deterioration of local air quality is expected since traffic emission are not removed in the tunnels but simply moved to the exit locations (see Figure 2 and 3). In this scenario it is therefore essential to select optimal strategic locations for the (short) tunnel elements so that the changes in air quality (both positive and negative) result in an overall reduced exposure of the citizens.

Finally, this study confirms that the most effective measures to improve the air quality are related to an overall reduction of traffic volumes. This could be achieved by the construction of a new second ring road (so called tangents) further way from the city centre. A reduction of about 40% of the traffic (and associated emissions) on the ring road provides a significant improvement in air quality, not only for the areas in the immediate vicinity of the ring road but also for large parts of the city.

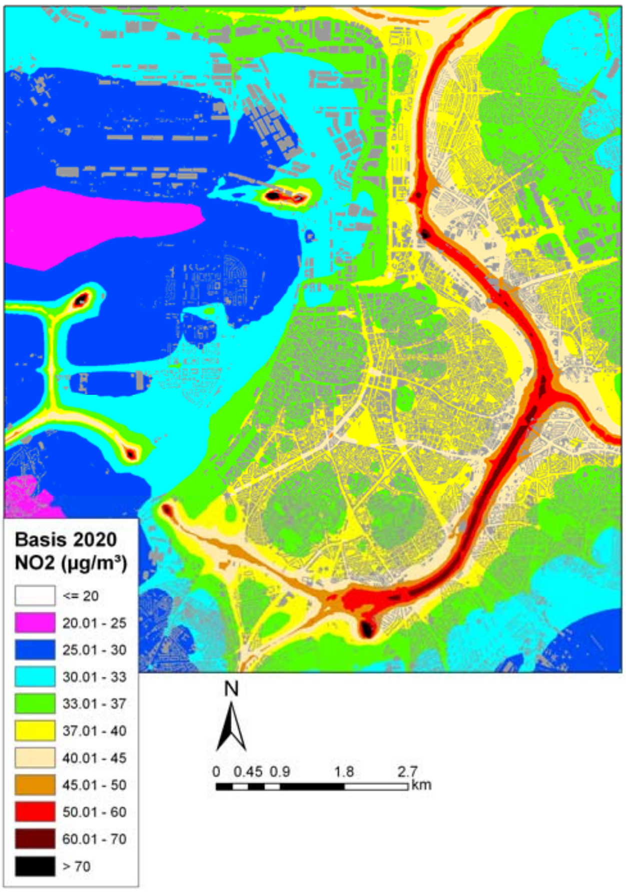

Figure 1: Model simulations of NO_2 concentrations in 2020 under a BAU scenario.

CONCLUSION

A coupled modelling framework has been setup to evaluate the impact on future air quality levels of local measures in combination with European and regional policies. Based on these model simulations it can be concluded that current legislation will not be sufficient to meet European air quality standards in 2020 or 2025 at any location in the city of Antwerp. Especially locations along the ring road remain problematic. Further (local) measures will be required to solve the problem. Therefore a number of possible scenarios for the Antwerp ring road were evaluated. All tunnel scenario can locally reduce the air pollution levels but the specific locations have to be selected carefully since tunnel exits do create additional hot spots and can increase population exposure. Further reduction of traffic volumes and related emissions are most effective in decreasing air pollution levels in the entire city.

The results of the air quality modelling exercise were part of a multidisciplinary and integrated urban planning project.

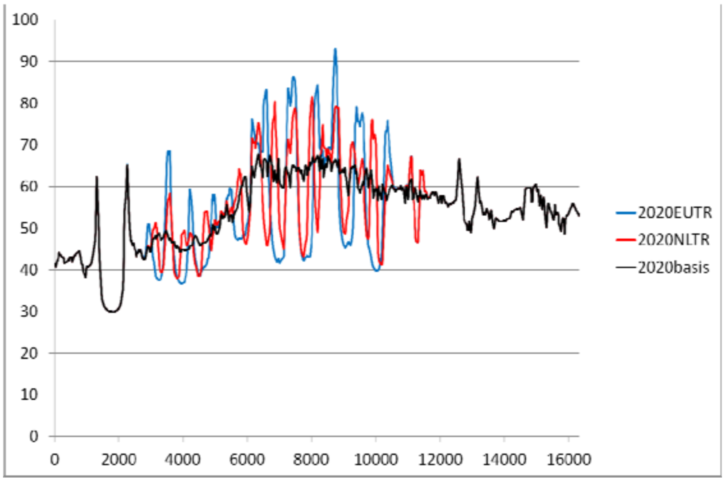

Figure 2: NO_2 concentrations on a transect along the ring road (x-axis in meter along the transect, from South-West to North-East). Concentration simualtions for 2020 under a BAU scenario (black, 2020basis), a scenario with 500m tunnel elements (blue, 2020EUTR) and with 250m tunnel elemens (red, 2020NLTR).

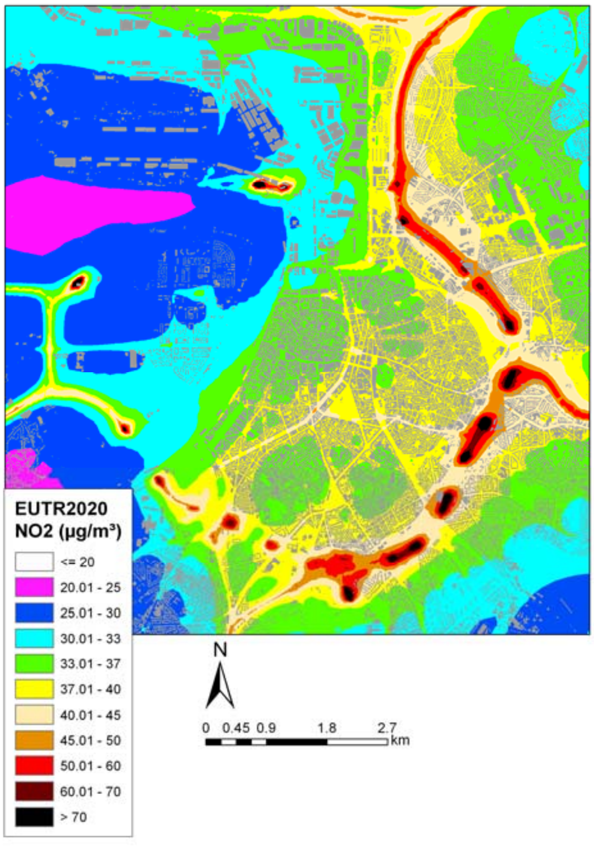

Figure 3: Model simulations of NO_2 concentrations in 2020 for the 500m tunnel scenario.

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