METHODOLOGY FOR SELECTION OF DISPERSION MODEL

assoc. prof. Beti Angelevska[1], full prof. Aleksandar Markoski[2]
[1]Faculty of Technical Sciences, [2]Faculty of Information and Communication Technology, University "St. Kliment Ohridski"
Bitola, Macedonia
beti.angelevska@tfb.uklo.edu.mk; aleksandar.markoski@fikt.edu.mk

Abstract

Dispersion modeling of air quality is a primary regulatory tool for prediction of levels of pollutants in the air. The process of dispersion modeling is routinely used for assessment of the effectiveness of traffic management measures, considering their impact at air quality. In this paper, a methodology for selection of appropriate dispersion model for air pollution research is developed and elaborated. Once selected, the dispersion model has been used for "what-if" analysis, assessing the impact that traffic flow reduction has at air quality. Obtained results clearly underline the irreplaceable significance of properly selected dispersion model for assessment of current and future air quality referring traffic management measures. The intention of this developed methodology is not to make an unnecessary burdening to those who perform and conduct traffic management and air quality assessment. The methodology, above all, should be understood as a tool for upgrading the modeling process and for facilitating the communication between everyone included in the processes of managing and modeling.

Keywords – dispersion modelling; methodology; air pollution

INTRODUCTION

Air quality modeling is an area with a significant progress and interest in the past two decades, mostly because of the increased public awareness for the potential health and environmental damages from air pollution.

The basic technique for determination and prediction of air pollution and its impacts are dispersion models [1]. Dispersion models are developed for spatial and temporal prediction of pollutant concentrations, being the only way for simulation of the impacts from current and future changes in air pollution.

The combination of really large choice of dispersion models and wide community of users has led to the need of ensuring directions necessary for the selection of models. These directions comprise the structure of the methodology for selection of dispersion models.

Hence, the purpose of this paper is to develop and present a methodology for selection of dispersion models, as a tool that supports air pollution assessment. This methodology underlines the role of dispersion models in the simulation of air pollution and the significance of the selection of appropriate model according to the specific conditions for application.

Applying this methodology, the AEOLIUS dispersion model has been selected as suitable for the current conditions in the analysis. Then, this model has been practically used for the assessment of the effectiveness that reduction of traffic flow has at air quality. This structure of this "what-if" analysis clearly shows the irreplaceable significance of correctly selected dispersion model and understanding of obtained results for the management and control of traffic air pollution.

ROLE, SIGNIFICANCE AND PURPOSE OF DISPERSION MODELING

Dispersion modeling is a mathematical simulation of the way that pollutants disperse in the atmosphere. Dispersion modeling in traffic is used for prediction of past, current and future atmospheric concentrations of pollutants at particular locations.

Dispersion models are widely used for prediction and/or problem resolving and are frequently used for identification of the best solution for specific problems with air quality in the environment [2].

It is particularly important to understand the role and the place of dispersion models, according to the fig. 1, in which a system for air pollution and maintenance of air quality is presented. In this system, a scientific components for analysis and components for development and implementation of environmental policy/legislation are presented. It should be noted that the modeling part is just one component in the whole procedure for air quality analysis. The specific purpose of air quality modeling is to determine the best control strategy for air quality improvement in specific areas [3].

Dispersion models, as an important tool for assessment of the current and future air quality, have particular significance for the design of more effective strategies for air quality maintenance [4]. Further on, dispersion models for air quality assessment could help for evaluation of the plans and strategies for emission reduction, in order to achieve a compliance with the national standards [5].

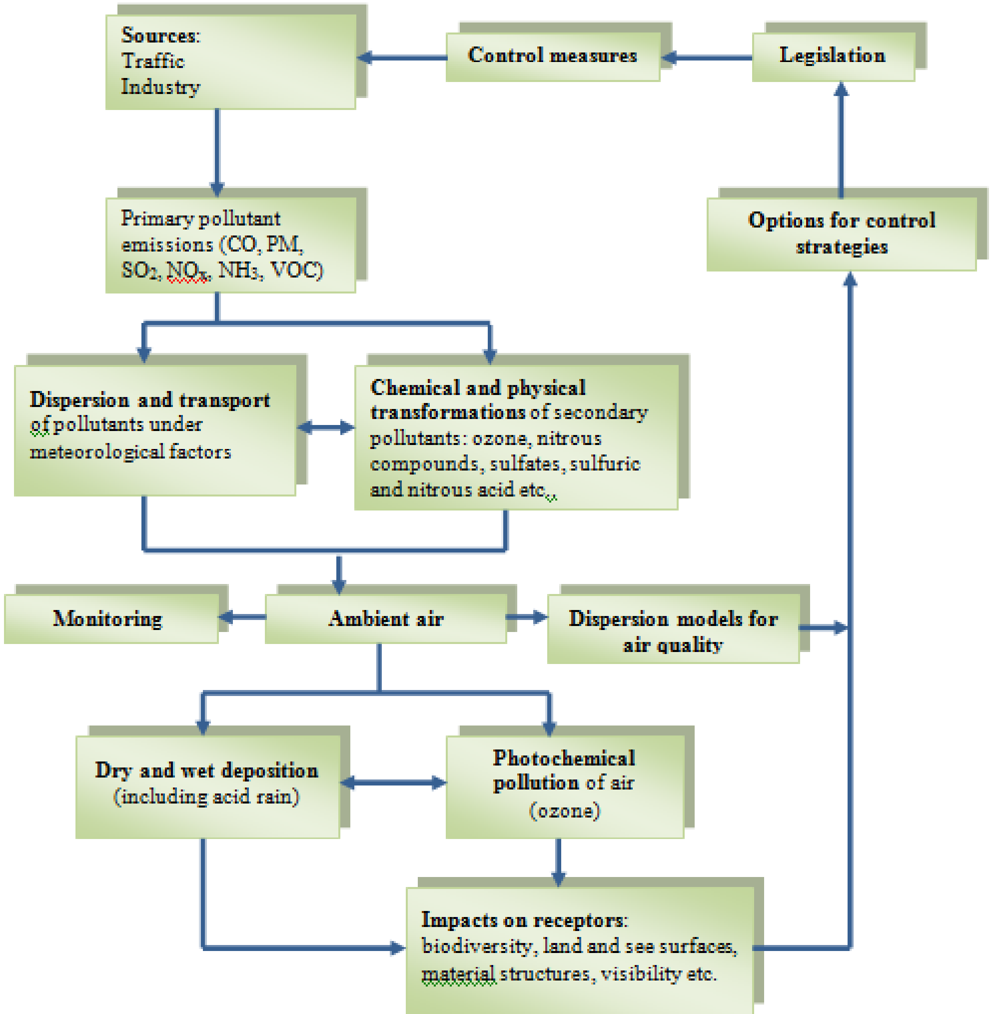

Fig. 1. System for air pollution and air quality maintenance [3]

Dispersion modeling is widely used for assessment of air quality. In the world, governmental sectors, agencies and local authorities continuously (but not exclusively) are relying on the dispersion models for air pollution. These models are used for decision making referring both air quality management and traffic management, as well as for urban planning and public health protection. As a result, the community of users is getting bigger and more various [6].

These potentials of air pollution modeling were a motivation for development of the methodology for selection of dispersion model.

METHODOLOGY FOR SELECTION OF DISPERSION MODEL

One of the key factors for effective modeling of pollutant dispersion is a choice of dispersion model, which should be appropriate with the range of the impacts and the complexity of air pollution source [2].

A large number of dispersion models is available, with a well developed range of research of dispersion modeling for traffic air pollution [7]. Hence, there are many types of dispersion models with a wide range of complexity and capacity, which create opportunities for diverse choice. Apart of that, there is a wide community of users, with different interests and experience in the modelling process: authorities, academics and researchers, consultants, regulatory services, as well as the whole public [8].

Dispersion models, without exception, are developed to provide precise assessments of the concentrations of pollutants under specific conditions. But, to perform these assessments, it is important to select a model which will simulate changes in the current or future air pollution with the highest precision. Therefore, it is important to develop and use a methodology for selection of dispersion model (fig. 2).

Although the level of detail at every step in the structure of the methodology is different for different assessment levels and goals, the methodology provides useful guidance in every modeling application.

PRACTICAL APPLICATION OF THE METHODOLOGY FOR SELECTION OF THE MODEL

Based on the methodology for dispersion model selection and considering this analysis' intention for assesment of the effectivenes of specific traffic management measure, the AEOLIUS dispersion model has been selected. The full name of the models is **A**ssessing the **E**nvironment **O**f **L**ocations **I**n **U**rban **S**treets (AEOLIUS).

Next, all the steps in the methodology during the selection process of AEOLIUS are briefly explained.

Step 1: Definition of the research

Definition of the role, intention and purpose of undertaking dispersion modeling at the same beginning of the research has been of the critical importance. The intention of this analysis is to show the potential of dispersion model for assessment of traffic management measure, i.e., "what-if" analysis. Being a dispersion model for estimation of urban "street canyon" pollution, AEOLIUS model can be applied for this type of analysis.

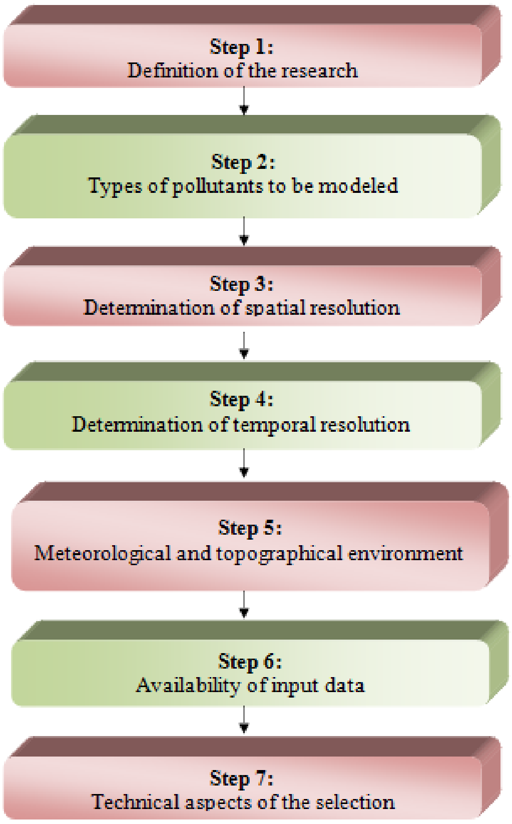

Fig. 2: Methodology for selection of dispersion model
Source: Made by the authors, according to [8]

Step 2: Types of pollutants to be modeled

Based on the research aims, defined in the previous step, the modeler must determine which types of pollutants from the traffic are the interests for modeling.

In AEOLIUS, hourly concentrations in ppb are calculated for these pollutants: NO_x, CO, SO_2, C_6H_6 (benzene) and C_4H_6 (1,3 butadiene) and in μgm^{-3} for PM_{10}. For NO_x further calculations are made for an hourly concentration of NO_2 and a 98 percentile value of NO_2. The concentrations calculated are leeward concentrations where leeward is defined as the side of the street from where the wind is blowing.

These pollutants are enough for the purpose of our analysis. In contrary, if the model estimates bigger number of pollutants (above 100), than it certainly needs a higher variety and precision of the input data [2].

Step 3: Determination of spatial resolution

Dispersion modeling has large domain for estimation of air pollution, ranging from local to global. A scale of the modeling is determined based on the type of research. Considering the local range of this analysis, the AEOLIUS model calculating the concentrations in “urban canyon” is applicable for estimation of concentrations at local level.

Step 4: Determination of temporal resolution

Temporal resolution can vary from minutes (peak concentrations), years till decades (trends). Ideal is the hourly resolution. The temporal resolution used in dispersion models in general is one hour. Most of the meteorological data have this resolution as well. AEOLIUS fits in this frame, estimating the hourly concentrations of pollutants in “street canyons”.

Step 5: Meteorological and topographical environment

Meteorological and topographical complexity of the environmental configuration around the source of pollution determines the dispersion of pollutants. This has direct influence on the selection of the model [9].

This step comprises description of the atmospheric conditions (temperature, wind speed and direction, moisture, thermal flows etc.), and geo-physical configuration (flat or hilly terrain, land use, presence of buildings etc.). These characteristics have influence at the level of complexity of the pollutants dispersion [10]. All these conditions were taken into account for Bitola town. Mild meteorological environment and typical urban topography allowed the application of AEOLIUS model to be suitable.

Step 6: Availability of input data

Every dispersion model has its own requests for different amount of input data referring meteorology, traffic, topography and other pollution sources (background pollution). Also, the availability of statistical and monitoring data for air quality should be determined.

AEOLIUS model has the need of following input data: street width, height of the street buildings, traffic speed, traffic flow per hour, wind speed and background concentrations. All these data for this analysis are available.

The precision and availability of input data is particularly important for the selection of models. In case when input data are insufficient or have low quality, there is no need to apply sophisticated dispersion models. The usage of more simple models is more appropriate for the situations with limited input parameters. Hence, the AEOLIUS being a simple model is very suitable for our present circumstances with scarce input data.

Step 7: Technical aspects of the selection

The users of dispersion model, besides of the basic knowledge for meteorological and chemical processes in the atmosphere, should be aware for some other technical aspects during the modeling process:

- their own level of experience and technical competitiveness
- available computational and financial resources
- time frame in which modeling should be completed.

AEOLIUS model isn't a demanding model, meaning that it doesn't have high computational and financial requests. The results can be obtained almost immediately. Still, during the model selection, in this step additional consideration for AEOLIUS were taken into account. Although it doesn't have on-line technical support and isn't integrated with GIS, being developed by the Meteorological Office in London and being in longer period of operative usage were decisive facts that contributed for its final selection.

ASSESSMENT OF TRAFFIC MANAGEMENT MEASURES USING THE SELECTED DISPERSION MODEL

Considering their potential, dispersion models can be used for assessment of effectiveness of traffic management measures, simulating the current and future scenarios with air quality. This evaluation could be based on "what-if" analysis [11], in which changes could be done to the structure and size of traffic flows, traffic demand, traffic speed etc.

Reduction of traffic flows could be used as a traffic management measure for improvement of urban air pollution. This measure is very simple and rationale for implementation [12], with a potential to reduce pollutants levels. Reduction of traffic flows could be achieved through different restrictions: introduction of the program for even-odd license plate numbers, payment for entering in the city centre, banning the high duty vehicles etc. Regardless of the restriction type chosen, the AEOLIUS is applyed first for the current levels of traffic flows, and then for the assumed reductions. This type of analysis is „what-if" analysis.

Assessment of pollutants had been performed for a street in a wider central area of Bitola town, Macedonia, with high traffic volume. The hour with the highest flow (peak hour) was selected. This is the current situation (table 1). Then, reductions of traffic flows are simulated in the AEOLIUS (table 1). The results of "what-if" analysis are given in table 2. Following polluters were included in the calculation: NO_x, NO_2, CO, PM_{10}, SO_2 and C_6H_6. Input data needed for AEOLIUS were available from different sources: Traffic study for the town of Bitola 2011, urban plans as well as meteorological reports and wind rose for the town of Bitola. Characteristics of all these input data are precisely described in [10].

Table 1: Results for the dispersion of pollutants using AEOLIUS

Pollutant	Unit	Current situation Q=884 vehicle/h	20% reduction of traffic flow Q=726 vehicle/h	30% reduction of traffic flow Q=647 vehicle/h	40% reduction of traffic flow Q=567 vehicle/h
NO_x	ppb	73.49	65.07	60.52	55.61
NO_2	ppb	31.47	29.68	28.59	27.32
CO	ppm	0.83	0.73	0.68	0.63
PM_{10}	$\mu g / m^3$	7.50	6.64	6.18	5.67
SO_2	ppb	2.56	2.27	2.11	1.94
C_6H_6	ppb	1.67	1.48	1.37	1.26

Source: [10]

As it was expected, the biggest reductions ranging from 13.18÷24.55 % for all pollutants are noticed for the highest reduction of traffic flows. These "what-if" results, or in other words, range of all changes of emission amounts are presented next.

Table 2: "What-if" results: emission reductions [%]

Pollutant	20% reduction	30% reduction	40% reduction
	Q=884 v/h Q=726 v/h	Q=884 v/h Q=647 v/h	Q=884 v/h Q=567 v/h
NO_x	11.45	17.64	24.32
NO_2	5.68	9.15	13.18
CO	12.04	18.07	24.09
PM_{10}	11.46	17.6	24.4
SO_2	11.32	17.57	24.21
C_6H_6	11.37	17.96	24.55

Source: [10]

Through this presented application of the selected model for specific traffic management measure, a significant opportunity is given to the policy creators, urban and traffic planners and others directly included in the process of traffic management and air quality modeling. “What-if” analysis using dispersion modeling provides a proper decision to be made referring whether or not to implement the analyzed measure, considering the air quality impacts [10].

CONCLUSION

The potential of dispersion models to provide assessment of the current and future air quality underlines their essential significance for control and reduction of the impacts from traffic. Apart of their possible calculative or structural imprecision, dispersion models are the only tool that provides prediction of air pollution levels.

When selecting dispersion model, a large number of models is available. Also, the community of users is becoming wider and more various. Therefore, for assessment of air quality using the dispersion modeling a methodology for selection of dispersion model is developed and presented.

Although is difficult to provide general recommendations for every situation of selection of dispersion model, the use of this developed methodology provides balance between the availability of appropriate models and flexibility needed for research in real situations [8].

After all these steps in the methodology, the modeler has the opportunity to select a model. The structure of this methodology is dynamic and can evolve with the advance in the pollution research and air quality maintenance [8].

This paper has significant contribution for selection of dispersion model in correct and suitable manner for every specific situation. Additionally, with the performed “what-if” analysis, the paper contributes for the practical application of the selected model considering traffic management measure for air quality improvement.

In this way, the process of dispersion modeling will become closer to the common user and will contribute for the development of the capacities for understanding and usage of the results from dispersion models. This contribution is necessary for the support during the decision making and for responsible traffic management referring air quality protection.

REFERENCES

[1]. El-Harbawi et al., „Air pollution modelling, simulation and computational methods: a review”, International Conference on

Environmental Research and Technology ICERT 2008, Penang, Malaysia, 2008.
[2]. NIVAR, „Good practice guide for atmospheric dispersion modelling”, National Institute of Water and Atmospheric Research NIVAR, ISBN: 0-478-18941-9, ME number 522, Wellington, New Zealand, 2004.
[3]. San José R. et al., „W17 - Air quality modelling: state of the art”.
[4]. Mahmod M.M. and Van Arem B., „A simulation framework for modelling the impacts of an integrated road-vehicle system on local air quality”, TRAIL Research School, Centre for Transport Studies, University of Twente, Netherlands, 2008.
[5]. Mensink C. and Cosemans G., „From traffic flow simulations to pollutant concentrations in street canyons and backyards”, Environmental Modelling & Software, 23, Elsevier Ltd, pp. 288-295, 2008.
[6]. Vardoulakis S. et al., „Model sensitivity and uncertainty analysis using roadside air quality measurements”, Atmospheric Environment, 36, Elsevier Science Ltd, pp. 2121–2134, 2002.
[7]. McAdams M.A. et al., „Predicting short term vehicular related air pollution for corridors: a case study in Istanbul, Turkey”, Third international symposium on air quality management at urban, regional and global scales, Istanbul, Turkey, pp. 20-28, September 26-30, 2005.
[8]. EQB, „Guidelines for air quality dispersion modelling in British Columbia”, British Columbia Ministry of Environment, Environmental Protection Division, Environmental Quality Branch EQB and Air Protection Section Victoria, British Columbia, 2008.
[9]. Lorentz H. et al., „GIS based urban scale air pollution modelling within a german-bulgarian twinning project”, Contribution to 17^{th} International Conference: Informatics for environmental protection, Cottbus, September 24-26, 2003.
[10]. Angelevska, B., „Integrated system for decision making support (DSS) for assessment of traffic impact on air quality”, Doctoral dissertation, Faculty of Technical Sciences, University „St. Climent Ohridski”, Bitola, Macedonia, pp. 147, 2012.
[11]. Lim L.L. et al., „Integrated decision support system for urban air quality assessment”, Environmental Modelling & Software, 20, Elsevier Ltd, pp. 947-954, 2005.
[12]. Lin C.C.Y. et al., „The effects of driving restrictions on air quality - São Paulo, Bogotá, Beijing and Tianjin”, University of California, USA.