

# Modelling of Air Pollutants of Highway Roads in Hungary

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## Introduction

As new European Community member Hungary is obliged to harmonize its transport sector according to the European rules. The harmonization process concerns among others road network development, transport security as well as environmental issues. Due to the lack of suitable technical tools the difficult contradictory issues related to the environmental matters were not rationally managed. For the accomplishment of such concept a sophisticated environmental model is necessary considering all traffic related atmospheric pollutant emission of major roads. Implementing such an environmental model Hungary could optimize its transport sector in conformity with the EC rules.

The present work aims to provide decision makers the necessary technological support and scientific information on air quality of highway roads. To achieve this goal a road dispersion model will be used to estimate the possible effects of road traffic on ambient air.

## *Emission*

The expressway network in Hungary was in 2004 comprised of 650 km of motorway, 205 km of clearways and highways (which are comprised of highways serving as expressways, highways with expressway features later converted to expressways, and highway sections with expressway features) as well as 188 km of junction point sections, 52 km of roads leading to rest areas, and 106 rest areas (see Fig. 1).

The Hungarian CO and NO<sub>x</sub> emissions from mobile sources have been investigated by Merétei [1]. Emission of nitrogen oxides from road traffic continuously

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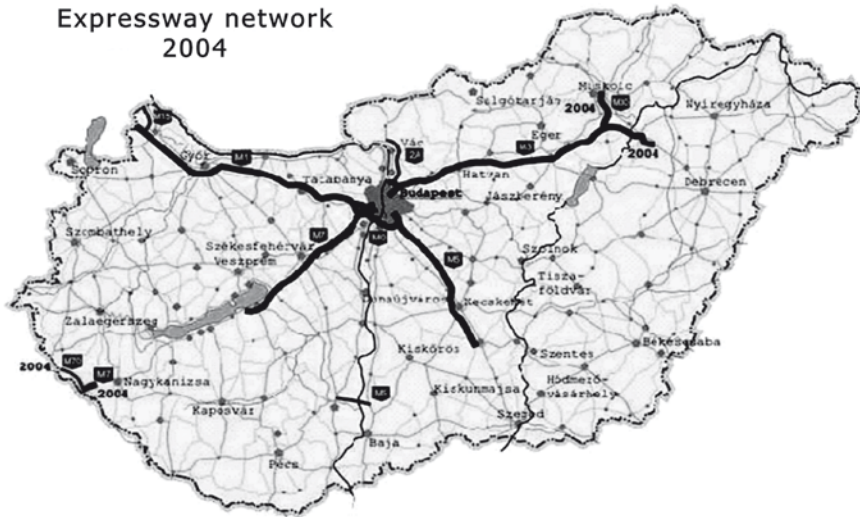


Fig. 1 Expressway network in Hungary in 2004

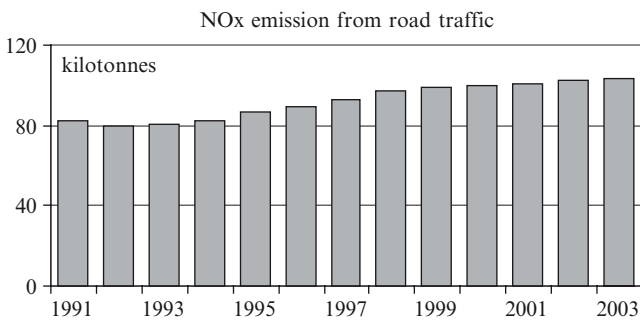


Fig. 2 NO<sub>x</sub> emission from road traffic in Hungary, determined by [1]

increased (Fig. 2), while the emission of carbon monoxide from the same sources decreased during the last 20 years (Fig. 3). The NO<sub>x</sub> emissions from road traffic is growing (growing rate is 20%) due to the increase in traveled kilometers by cars and duty vehicles. In the same time NO<sub>x</sub> emissions from the European member countries decreased by 20% due to the application of three steps catalysts in new cars and the changes of the compound of the fuel.

Source emissions are a function of both the vehicle emission factors and the vehicle activity (usually measured in vehicle kilometers traveled). The vehicle emission factors can differ greatly depending on the type of road, vehicle fleet mix, and traffic flow encountered. As a result, emission factors were determined specifically for each roadside location to ensure that the appropriate input was used for the

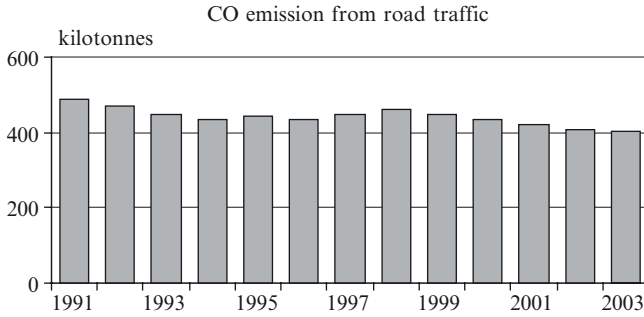


Fig. 3 CO emission from road traffic in Hungary, calculated by [1]

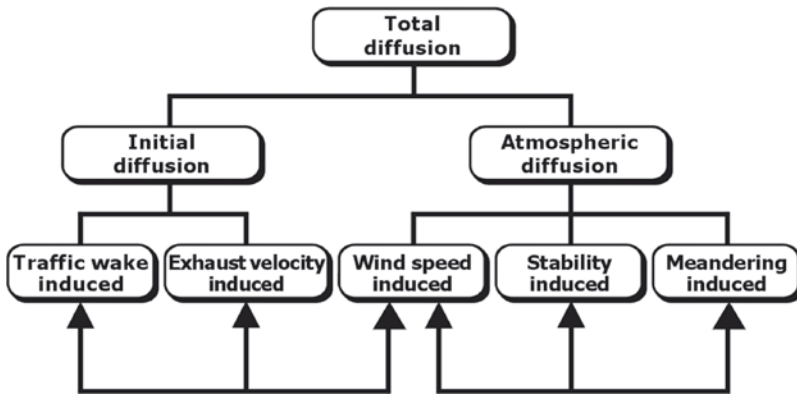


Fig. 4 Diffusion processes in road traffic modeling. Arrows represent interactions

modeling of subsequent roadway emissions. These site-specific emission factors were then combined with the vehicle kilometers traveled data to give a total emission rate for the road.

### *Diffusion Processes in Road Modeling*

The total diffusion is divided into primary diffusion affected by the traffic and diffusion caused by ambient meteorological conditions (see Fig. 4). Contaminants outcome from the tailpipe take part in the primary process, on one hand by the thermal turbulence caused by differential surface heating and by eddy movements created by the buoyant exhaust plume, on the other hand by mechanical turbulence from wind flow and the traffic wake induce turbulence. Thermal influences interact with mechanical effects. There are interactions between the ambient wind speed,

exhaust velocities of the tailpipe emissions and the traffic wake-induced turbulence. Primary turbulence is meaningful only in stagnant conditions (especially in the case of cold-running) otherwise the atmospheric turbulence dominates the process. The plume is transported with the wind speed at the emission height. A well-mixed zone can occur behind a vehicle due to the thermal and mechanical turbulence.

To sum up the effects of initial and atmospheric turbulence a coordinate system transformation has to be carried out [2]. A horizontal component of the initial diffusion parameters is directed to the road axis, and a horizontal component of atmospheric dispersion is directed to the wind flow.

### Description of CALINE4 Model

CALINE4 is a Gaussian type dispersion model for predicting air pollution concentrations near roadways [3]. Each roadway link analyzed in the model is treated as a sequence of short segments (Fig. 5). Each segment is treated as a separate emission source, which produce a plume of pollutants dispersing downwind. Pollutant concentrations at any specific location are calculated using the total contribution from overlapping pollution plumes originating from the sequence of roadway segments. CALINE4 use the mixing zone concept (Fig. 6). The model treats the region directly over the highway as a zone of uniform emissions and turbulence. This is designated as the mixing zone, and is defined as the region over the traveled way (traffic lanes; not including shoulders) plus 3 m on either side.

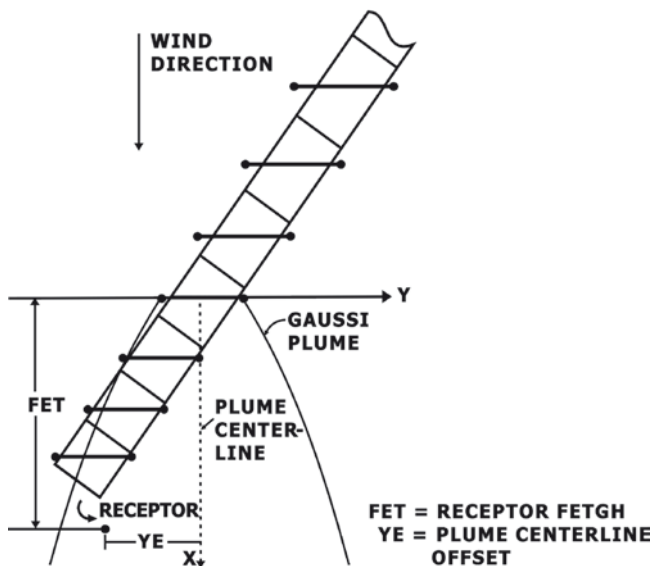


Fig. 5 Gaussian plume and roadway segments

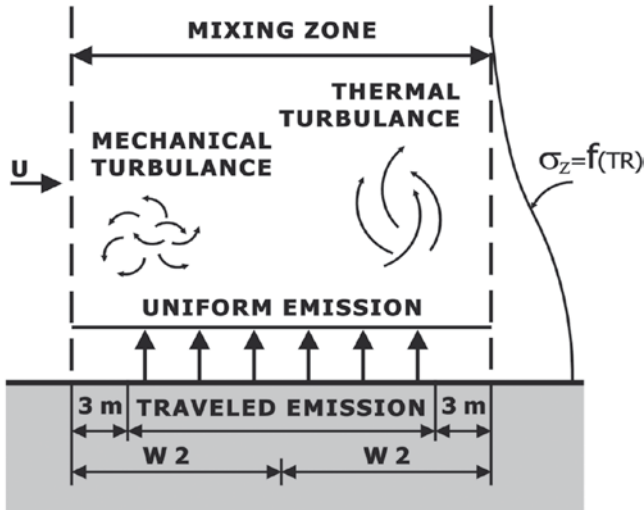


Fig. 6 Main characteristics of the mixing zone concept

The additional width accounts for the initial horizontal dispersion imparted to pollutants by the vehicle wake. Within the mixing zone, the mechanical turbulence created by moving vehicles and the thermal turbulence created by hot vehicle exhaust is assumed to be the dominant depressive mechanisms.

The chemical transformation is modeled by the so-called receptor-oriented discrete parcel method. The model includes the basic reactions of nitrogen oxides, oxygen and ozone, but the influence of other compounds is neglected. The influence of plume dilution has been accounted for according to the receptor oriented Discrete Parcel Method [4], which is a modified version of the original method.

The CALINE4 requires relatively minimal input from the user. Input data are traffic volume, emission factors, roadway geometry, wind speed and direction, ambient air temperature, mixing height, atmospheric stability class and coordinate of receptors.

## Model Experiments and Results

By using CALINE4 dispersion model, hourly and 8-h average concentrations can be obtained. The CO and NO<sub>2</sub> concentrations have been calculated at 100 m away from the road axis for the Hungarian motorway network. NO<sub>2</sub> concentration is shown in Fig. 7 for worst-case meteorology, where input is the combination of the worst wind speed, wind direction, and stability class. The highest concentrations occur around Budapest, which is explained by arterial roads structure in Hungary and by urban sprawling.

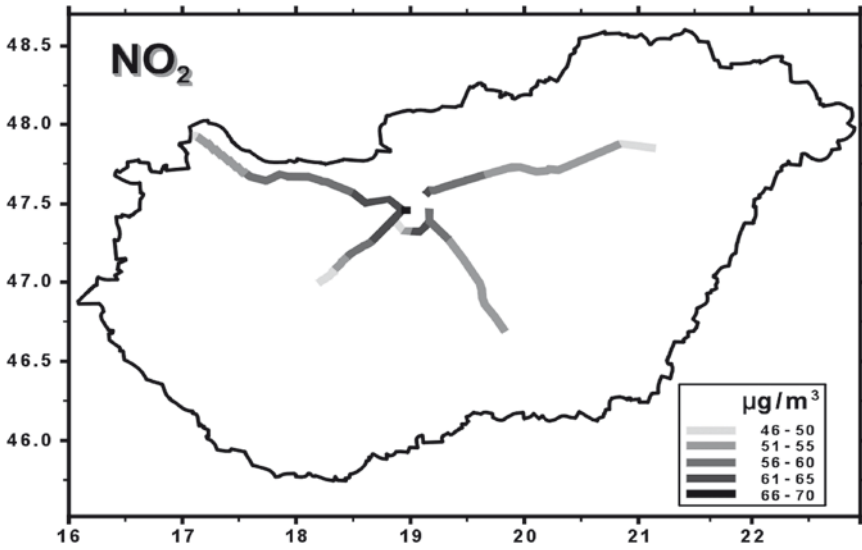


Fig. 7 Worst-case 1-h  $\text{NO}_2$  level at 100 m away from road axis

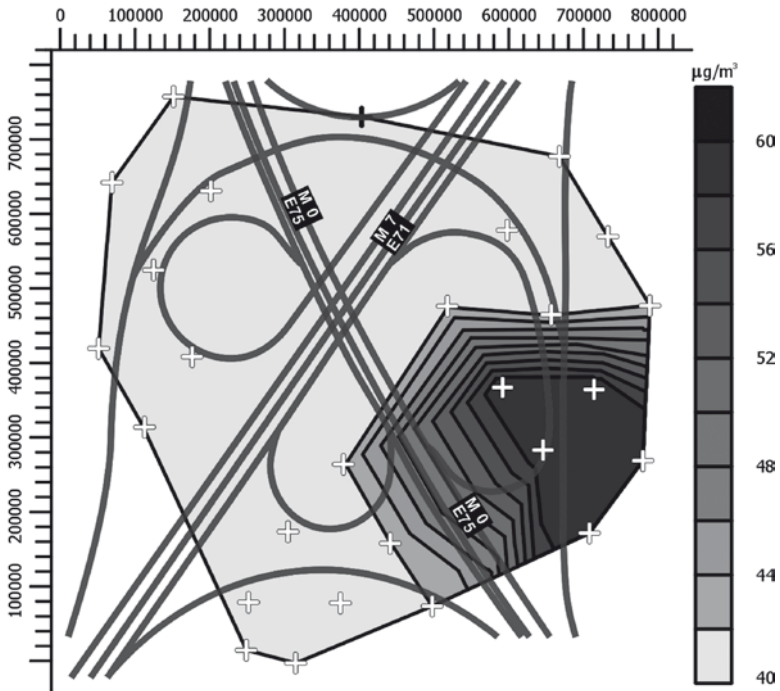
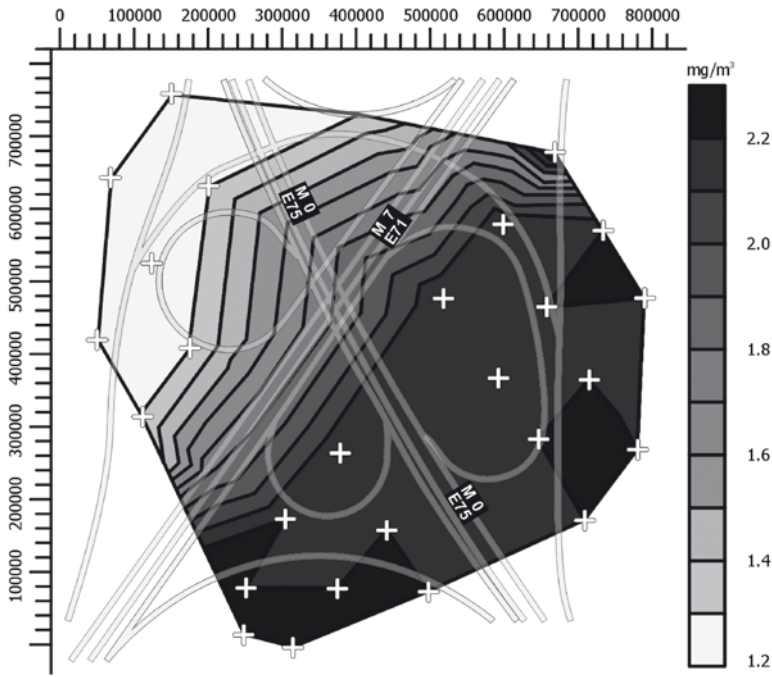


Fig. 8 Hourly average  $\text{NO}_2$  concentration around an intersection near Budapest



**Fig. 9** Hourly average CO concentration around an intersection near Budapest

A sensitivity analysis of CALINE4 model was also carried out. CO concentration was estimated to the distance from a roadway for typical daytime conditions. Wind was perpendicular to the roadway. It was established that good results could be obtained at receptors located within 500 m from the roadway.

CALINE4 model provides a possibility to predict air pollutants near intersections. Spatial distributions of hourly averaged CO and NO<sub>2</sub> concentrations are shown in Figs. 8 and 9 for an intersection near Budapest. The distance between receptors (indicated by crosses in the figures) is 100 m. Air pollutants are transported by the most frequent airflow to the SW direction. At this intersection the traffic of motorway M7 is dominant.

## Conclusion

Examples simulated by a road dispersion model showed that acceptable results could be obtained in order to consider detailed effect of traffic flow. Using a dispersion model connected to an emission model is a good tool to estimate air quality where ground based measurements are not available or not possible.

## References

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