

AIR QUALITY MANAGEMENT - FROM TRAFFIC MANAGEMENT TO ENVIRONMENTAL TRAFFIC MANAGEMENT

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ABSTRACT

Traffic management systems are commonly used to optimize traffic flow in urban areas, e.g. to prevent traffic congestion. However, the regulation of traffic flows can also be used to control traffic induced emissions and therefore affects air quality. To use a traffic management system as an instrument for the benefit of air quality, the application requires reliable information about the current air pollution along all major traffic routes. This can be provided by the online modelling system IMMIS^{mt}. The system consists of a combination of linked air quality models using online traffic, weather and station data to monitor the citywide distribution of pollutants within the streets. In addition it can be operated in offline mode with archived data to assess various regulation scenarios. Thus IMMIS^{mt} enables traffic management systems to be used as Environmental Traffic Management System.

In recent years, the application of Environmental Traffic Management Systems has been subject to extended research e.g. within the framework of the project "iQ mobility". Here IMMIS^{mt} is used to develop situation-related operational control measures and to monitor the current air pollution for the City of Berlin. The quality of the monitoring system, the efficiency of measures in reducing NO₂ and PM₁₀ and the practicability of the system were tested in a field study in autumn 2007.

1 INTRODUCTION

The benefits of Traffic Management Systems (TMS) in urban areas are widely known. In general, a TMS is an instrument for larger cities that helps managing road works, big events or unforeseeable situations like accidents. Further, it allows for a situation-related control of traffic signals and can be used to optimise road capacities in order to improve traffic flow and quality.

Stricter limit values for air pollutants, demanded e.g. by the EC directive (EC, 2008), require to reduce environmental effects of traffic within urban areas. Because measures of a TMS influence traffic load and flow, they have a certain impact on air quality, especially for traffic related pollutants such as PM₁₀ or NO₂. Thus, traffic management systems can be used to improve air quality (Diegmann, 2008 and Tullius, 2003). The extension of traffic management by air quality strategies such as decreasing traffic related emissions within critical segments will lead to an Environmental Traffic Management System (ETMS).

Focusing on a single street section, the reduction of traffic related emissions can be achieved by a number of measures like speed limits, reducing traffic control stops, preventing disturbances due to lane blocking (e.g. while delivering goods) and finally by partial or full road closure (Diegmann, 2008).

Before implementing measures to manage air quality, the range of their effects in space and time need to be understood. The following aspects should be considered before taking action:

- What is the efficiency of the measure?
- What are the side effects?
- Is it possible to shift high emissions and/or concentrations to non-sensitive areas?
- When is the best time to apply the measure?

Answers to these questions can be obtained from an air quality monitoring system providing online citywide information of the pollutant concentrations.

Conventional monitoring systems based on regular station measurements can only assess air quality at the point of measurement but do not provide information on the spatial distribution of pollutants. However, air quality problems are generally widely distributed in a city. The highest values of pollution are mostly found along major roads within street canyons where concentrations will vary from segment to segment according to the local traffic (e.g. volumes, driving pattern...) or dispersion conditions (e.g. orientation, height, width, porosity of buildings). Measurements at all potential hot spots are not feasible. Thus, air quality monitoring covering all relevant streets can only be achieved with air quality models.

For this purpose, the monitoring system IMMIS^{mt} was developed (Diegmann, 2002 and Diegmann et. al., 2004). This validated system is capable of quickly calculating concentration values at a given point within a street canyon on a micro scale basis using a canyon box model with online traffic data and can therefore be used to monitor air quality in all relevant streets in a city.

2 System Description

2.1 Design

IMMIS^{mt} consists of numerous components, whose cooperation is described referring to Figure 1. The core of IMMIS^{mt} consists of three models, forming a modelling chain to calculate traffic-induced emissions, urban and local dispersion. The control of the data flow between the models is coordinated by software components controlling the temporal sequence of the overall system, which includes data supply, start of the models, data transmission to the archive and data export of the results to further clients (e.g. map clients).

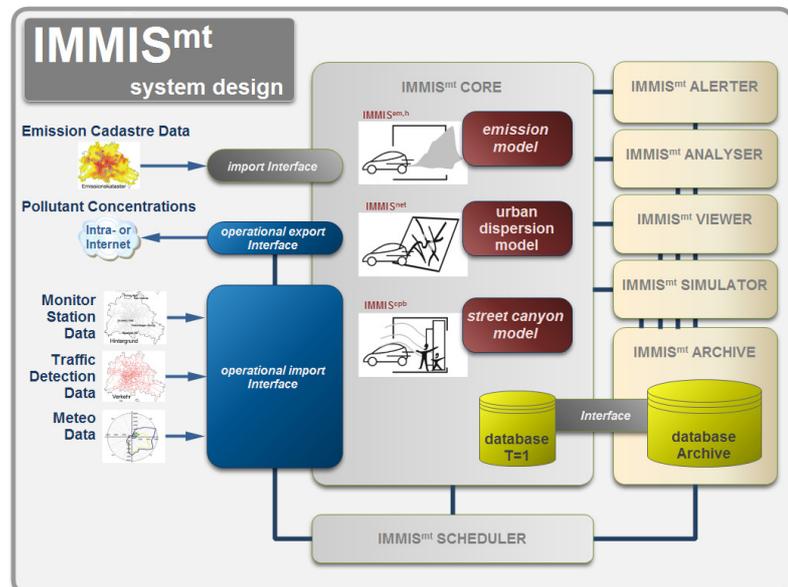


Figure 1: System design

All the input and output data is passed through an adjustable interface, capable of controlling various data transmission techniques like SOAP, ASCII, or HTTP. The internal data storage structure is realized by a local or a client-server database (e.g. Oracle). The database stores all static data (e.g. road and canyon geometries, emission cadastre data) as well as all dynamic data for the current modelling interval. The system-archive is based on a client/server database and holds the total input and output data of all computations. Together with the simulator module the stored computations can be repeated - if desired with changed conditions. This allows the analysis of scenarios e.g. for planning traffic control measures and is a good basis to develop further improvements of the models.

2.2 Data Requirement

2.2.1 Online Data

The system is mainly driven by traffic data. Each street segment is characterized by a default traffic situation. This information can be updated for each time step where the current situation can be derived from velocity profiles of the detected traffic data. The dispersion models use meteorological data such as temperature, wind data and stability class. Available data from air quality monitoring stations are used to derive background concentrations. The interval at which the online data should be provided depends on the temporal resolution of the results. In most cases an hourly interval will be adequate.

2.2.2 Static Data

To account for urban background concentration, emissions of the main sources like industry, shipping, rail traffic, off-road traffic and domestic combustion, usually available from an emission cadastre, are required for the regional dispersion model. The modelling approach on the micro scale requires a parameterisation of the major roads. All street segments with adjacent buildings, called sections, are described by their width, height and porosity (gaps between the buildings). Within a section, one or more points can be defined where concentrations are calculated.

2.3 Modelling Control

The modelling process calculating the total concentration at a hot spot in a street canyon needs to account for regional background caused by long distance transport, urban background caused by the urban emission sources and the “additional concentration” caused by the road traffic in the street canyon itself. The data flow of the modelling process for each time step is described as follows: Based on incoming traffic data, the

emissions of the major roads are determined by the emission model IMMIS^{em} (IVU Umwelt 2008a). Together with emissions of other urban sources the citywide spatial distribution of air pollution is calculated using the urban dispersion model IMMIS^{net} (IVU Umwelt 2008b). This provides the urban background concentration for each section and for the location of the air quality monitor stations. The regional background can then be determined as difference between the observed concentration at the background station and the urban concentration modelled for the station. Finally the micro scale model IMMIS^{cpb} (Yamartino, R. J., Wiegand, G. 1986) is applied to assess the additional concentration within each street canyon by the Canyon Plume Box approach using meteorological and local emission data. To determine NO₂ values out of the NO_x results, IMMIS^{mt} is able to provide different methods ranging from simple rational techniques based on measurements to complex photochemical models.

3 RESULTS AND DISCUSSION

3.1 Validation

Within the project iQ mobility (2007) the monitoring system IMMIS^{mt} was set up to monitor the city centre of Berlin. The “Leipziger Strasse”, a typical street canyon with around 42000 vehicles a day, was chosen as test field to validate the system for a period of several weeks. Figure 2 shows the modeled NO_x concentration compared to the measured values together with the modeled stop&go-fraction for a time span of 3 weeks in autumn 2007. The figure shows that there is a good match of the model results with the diurnal patterns of the measured concentrations. The rise in the NO_x concentrations correlates highly with the increase of the traffic stop&go fraction indicating congested situations.

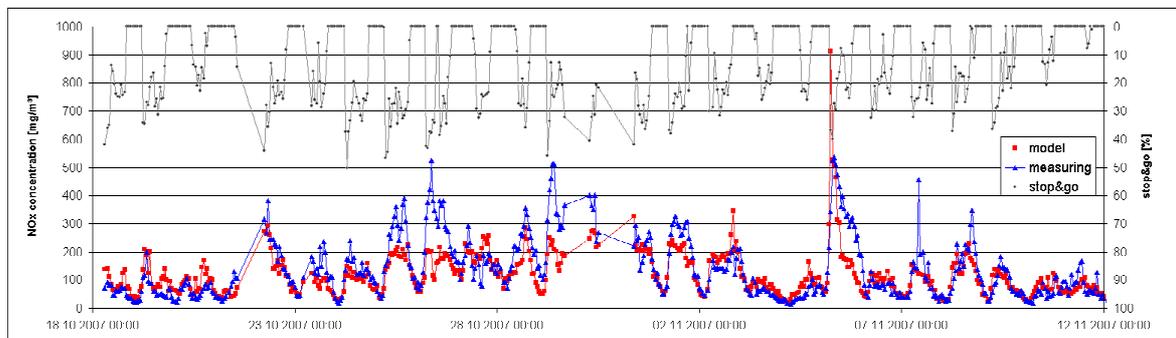


Figure 2: Total NO_x concentrations in the Leipziger Strasse (modeled and measured) and fraction of stop&go

A regression analysis of modeled versus measured concentrations gives a coefficient of determination (R²) of 0.56 for the hourly NO_x values of the evaluated period. For PM₁₀ the coefficient rises up to 0.7. The measurements are underestimated both for NO_x and PM₁₀ leading to a regression gradient of 0.54 and 0.77, respectively. For PM₁₀, the methodology used to model non-exhaust emissions heavily influences the correlation.

3.2 Potential of Measures

The evaluation of the field test demonstrates that, in accordance with expectations, meteorological conditions have a high influence on the additional concentrations in the canyon. The concentrations at the south side of the street section, which is oriented east-west, were found lowest with wind from the west, whereas wind from the south resulted in higher concentrations.

As shown in Figure 3, the quality of traffic flow has a great influence on the concentration level. It can be shown that the *Level of Service (LOS)*, which describes the quality of traffic flow (HBS 2001), is highly

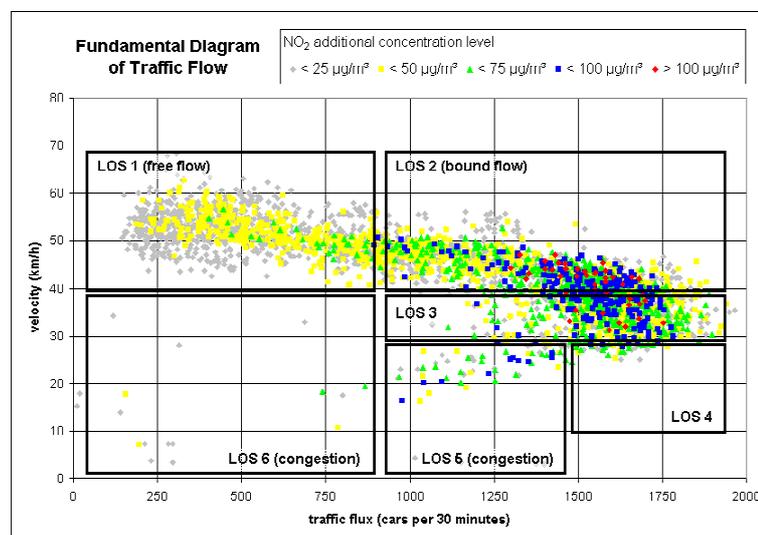


Figure 3: Fundamental diagram of traffic flow for Leipziger Strasse, Berlin

correlated with the observed additional concentration. First assessments suggest that an improvement of the LOS by one stage during critical meteorological situations could lower the annual mean value for the additional concentration of NO₂ by approx. 10%.

3.3 Monitoring

Measures controlling traffic flow will often have a more or less intense impact to the surrounding road network. Therefore, it is necessary to observe the effects on air quality in a larger area. Thus, the monitoring system IMMIS^{mt} currently covers an area of approx. 24 km² containing 116 km of major roads in length in the city centre of Berlin.

4 CONCLUSIONS AND OUTLOOK

Traffic management systems (TMS) are being used in a growing number of cities. The motivation is primarily to reduce travel times and optimise road capacities. However, there is a potential for a TMS to reduce air pollution. To use a TMS for environmental traffic management, it needs to be extended by an online air quality monitoring system to assess the situation in hotspots and surrounding areas. For this purpose, IMMIS^{mt}, a validated, technically mature system, is currently used in the city centre of Berlin and planned to be installed in other German cities. Also, it is intended to enlarge the monitored area for Berlin to cover the entire city area including the adjacent City of Potsdam. Within the scope of a research project funded by the German Ministry of Transport, Building and Urban Affairs, the monitoring system will be setup as a part of an ETMS in Braunschweig (pop.: ~250.000) to assess operational traffic control measures for hotspots and affected areas (UVM-Braunschweig, 2008). In preparation for an implementation of an ETMS in the City of Cologne (pop.: ~1.000.000), the efficiency of operational traffic control measures is currently being analysed.

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