ENVIRONMENTAL TRAFFIC MANAGEMENT – IMPROVE AIR QUALITY WITHOUT SACRIFICING MOBILITY

12th World Conference on Transport Research - Lisbon 2010

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INTRODUCTION

The demand for mobility has risen dramatically during the past 50 years, and is expected to continue. Exploding numbers of commercial and private vehicles travel a vast number of kilometres, a significant part of it within urban areas. Especially in the fast-growing megacities of today, where road traffic infrastructure size is limited and the building topology often prevents proper ventilation, the population density is high and severely affected by permanent air pollution. On the other hand, the availability of mobility is an economical and socio-economical factor, and heavily restricting traffic is neither desired nor feasible. This situation calls for innovative approaches to dynamically preserve an efficient balance between mobility and the environment.

Motorized road traffic represents a major source of urban air pollution, among others for NO_2 and PM_{10}. With general regulations in place that constitute hard limits to the maximum daily and yearly averages, traffic remains one of the few air pollution sources that can actively be influenced in short- and mid-term time scales. The European Union introduced important regulations and directives with respect to the maintenance of ambient air-quality in 2005, including limits for concentrations of particular matter. Since many cities could not comply with the regulations in first place, the limits are not lowered in 2010, but closer attention to compliance with the regulation is being paid. Further, the limitation of $PM_{2.5}$ and NO_2 has been introduced, intensifying the challenge for the cities to find viable solutions for the right balance of Mobility and the Environment.

ENVIRONMENTAL TRAFFIC MANAGEMENT

The first challenge to integrate air pollution as an input factor into traffic management is to assess the urban air quality both temporally and spatially.

Temporally means that real-time or close to real-time data about pollutant concentrations is required. The usually available yearly environmental surveys may help to understand typical areas and typical times of increased air pollutions, but due to the highly dynamic nature of the topic this information is of limited use for traffic management.

Spatial coverage is important as particles (opposed to road traffic) tend to traverse across the network according to wind- and weather conditions as well as influenced by local building topologies. Changes to traffic therefore may very well lower the concentrations in one corridor, but severely exacerbate conditions in adjacent areas.

Environmental situation assessment has to specifically consider the highly dynamic causes for locations of increased concentrations (“hot-spots”). Meteorological conditions as wind direction and speed, temperature gradients, inversion layers and sunlight determine the development of hot-spots. As traffic is by far not the only source of air pollution in an urban environment, existing industry, domestic fuel and particles transported from additional sources out of the target area also play a role in urban air pollution. Depending on the local building situation, the same circumstances may be non-critical in i.e. a well-vented open area or lead to a critical hot-spot, i.e. in a dense urban canyon. All of these factors are out of control from a traffic management center's point of view and are – with the exception of the building topology – highly dynamic, and thus need to be accounted for when selecting appropriate traffic strategies.

Sensors are widely installed in European cities, many of them also capable of online data delivery. However, the values measured represent spot-values and contain limited information about the surrounding areas. Especially in strong wind conditions, the placement of the sensor device may have more influence on the measured value than any of the actual pollution sources. The measured values are highly sensitive to changes in the local area, i.e. trucks parked in front of the sensor or nearby construction sites. Still, as sensors directly measure the air quality, they can be utilized as "ground-truth" verification *in certain spots*.

For area coverage, Siemens Traffic Solutions selected a real-time modeling approach. Detailed traffic information about volume, speeds and vehicle classes is used to quantify the emitted amounts of relevant gases and particles on a link. Additional information about traffic-external sources of air pollution (i.e. industry and power plants) in and around the city completes the emission information. Meteorological data – also in real-time – is being considered to calculate the complex concentrations of the pollutants within the cities topology of buildings, walls and other obstacles. Sensors are used to constantly verify and validate the model values in specific (high interest locations. The result is a solid assessment of the urban pollution situation and existence of hot-spots as summarized in Figure 1.

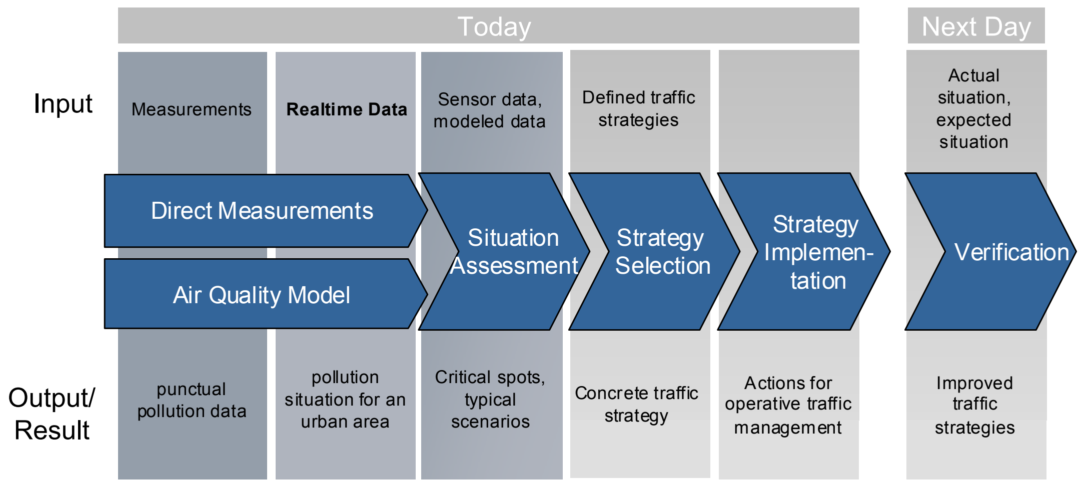

Figure 1: The Environmental Traffic Management Process

INTERACTION OF TRAFFIC STRATEGIES AND ENVIRONMENTAL MANAGEMENT

The real-time situation assessment of the air pollution in a city serves as the basis for traffic strategy decisions, as we now know *where* and *when* we are facing a critical situation. Using advanced traffic management technology, the traffic can be influenced in various ways. For example, if we manage to smooth the traffic flow and prevent vehicles from permanent breaking/acceleration cycles, we can reduce emission significantly without actually restricting mobility. This measure can be considered a win-win-situation for travelers and inhabitants, and an evaluation of the potential of these measures is described later in this paper.

More restrictive measures like dynamically lowering the speed limits or preventing access of some areas for certain vehicles would undoubtedly cause more reluctance of the road users, especially when imposed 24 hours/7 days a week. Still, they might be necessary at some times, and knowing that they are only active when the situation clearly calls for it could increase the drivers' acceptance. On the other hand it is not even clear whether e.g. road closures or speed limits will not worsen the environmental conditions along roads or will cause greater congestion than before. It is therefore necessary to fully understand the impacts and select the most appropriate strategy in terms of keeping mobility and protect the urban environment.

Figure 2: Three major clusters of traffic management strategies

Comprehensive traffic management today is usually based on strategy tools that serve for (1) the identification of the situation of concern and furthermore provides (2) mechanisms to apply predefined measures. By means of those measures (e.g. traffic control, information services) the development of unwished situations shall be defused. In order to realize an environmental traffic management is particularly relevant to couple the network-wide traffic state with the environmental model. Both models provide their data then to the strategy management that can process these input values.

THE NEW CHALLENGE FOR 2010

The EU Directive 2008/50/EC substantially revised the existing EU directives and especially added nitrogene oxide limits to the challenging – but not lowered – limits for particulate matter.

Pollutant	Average	Limit	Validity
Particulate Matter (PM_{10})	24h	50µg/m³, (max. 35 exceedings/year)	since 1.1.2005
Particulate Matter (PM_{10})	1 year	40µg/m³	since 1.1.2005
Particulate Matter ($PM_{2,5}$)	1 year	25µg/m³	starting 1.1.2015 (Target value starting 1.1. 2010)
Particulate Matter ($PM_{2,5}$)	1 year	20µg/m³	starting 1.1.2020
Nitrogen Dioxide (NO_2)	1h	200µg/m³, (max. exceedings/year)	starting 1.1.2010
Nitrogen Dioxide (NO_2)	1 year	40µg/m³	starting 1.1.2010

Figure 3: The revised EU directive sets new limits for nitrogene oxides

While the number of days with PM_{10} 24h-average exceedings have not been lowered to 18 days as anticipated, this value will continue to be a major problem for most larger European cities. Further, the previously introduced but now active yearly NO_2 average of 40µg/m^3 is expected to be the second critical challenge many cities will have to face. This combination implies that both a quick-response, short-term strategy portfolio has to be developed to cope with the dynamically appearing critical days for PM_{10} levels, as well as a long-term control strategy for the NO_2 yearly average. Besides the difference in the reaction time for the individual traffic strategies for PM_{10} and NO_2, the effects of fleet.oriented measures must be kept in mind. For example, some filters for Diesel engines to *reduce* PM_{10} emissions are known to *increase* NO_2 emissions at the same time.
The pressure on cities is expected to rise with the fact that the existing PM10 restrictions have not been lowered, but stronger focus on compliance has been indiciated. One example is that effective, short-term actions (in contrast to action *plans*) are mandatory if levels are continually exceeded.

THE POTENTIAL OF TRAFFIC MANAGEMENT

The most popular question in relation to Environmental Traffic Management is how (or even if) it can actually support cities to comply with the limits, especially considering the limited share of traffic-related emissions compared to total air pollution. However, a closer look at the limits reveils a chance.

A well-known hot-spot in Berlin (Silbersteinstraße) showed 95 days of 24h-PM10 average exceedings - levels of 24h-PM_{10} averages greater than 50µg/m^3 - in a modeled scenario. Sorted by the intensity of the exceedings and cutting off the (still) tolerated 35 days, the remaining exceedings range from 1 to 13µg/m^3 above the 50µ/m^3 limit. If these “low-hanging-fruits” can be achieved (literally avoided) using intelligent traffic control, this former hot-spot would achieve compliance status without requiring any further actions. Returning to the former mentioned traffic induced share of emissions, Figure 4 illustrates exactly this share in relation to the overall exceeding, and thus clearly demonstrating the unique chance of traffic management in combination with the unchanged number of exceeding days.

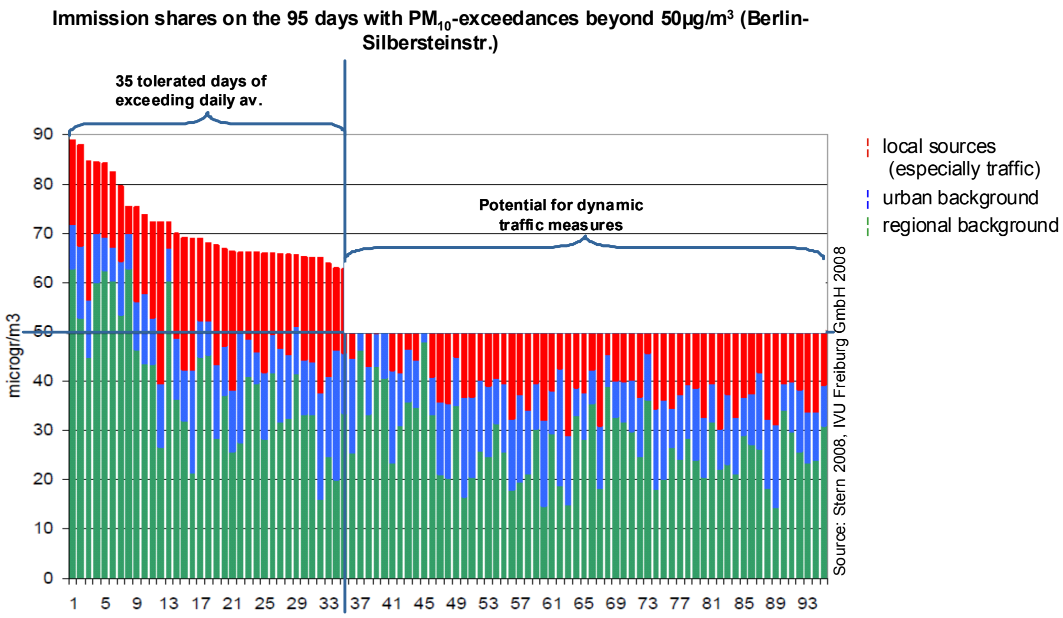

Figure 4: The potential for dynamic traffic measures are the days in excess of the 35 most critical days.

To underline the relation of traffic flow paramters and emissions, Figure 5 shows traffic volume, velocity and NO_X emissions for normal traffic flow and in disturbed state. It is clearly visible that during the congested period with decreased volume and velocity, the emissions increase significantly.

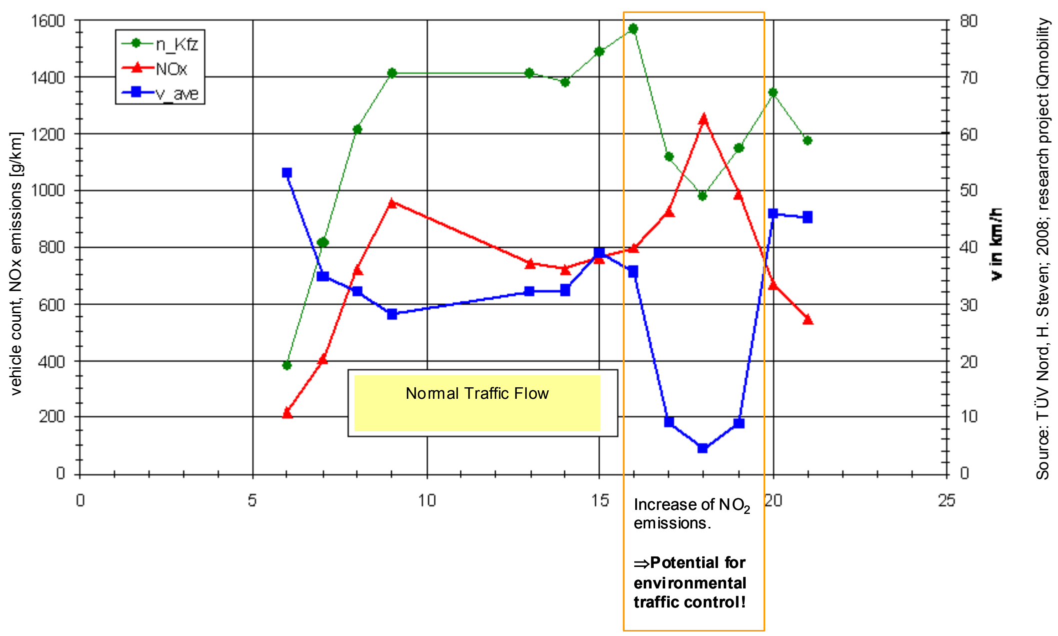

Figure 5: Relation of traffic flow parameters and NOx emissions

SOFT-MEASURE EVALUATION

As described earlier, restrictive measures with their negative impact on economy and personal mobility are usually the last resort. More favorable are soft measures, which in many cases impose positive effects on mobility as well as on the environment. Still, both efftiveness as well as efficiency of these measures are often unclear.
From the pool of soft measures, two have been selected for qualitative and quantitative analysis at a local hot-spot in the City of Cologne, Germany:

1. Optimized signal plans (i.e. via manual planning or an adaptive signal control scheme) promise reduced emissions by decreasing the number of accelleration/decelleration cycles (*Case 1*)
2. Additional gating aims at shifting inevitable emissions to better ventilated areas, in the case of this analysis a bridge over the river Rhine (*Case 2*)
3. The combination of coordinated signal plans and gating as stated above, but with the public transport priorization disabled (*Case 3*)

All cases have been compared to the base scenario without measures (*Case 0*)

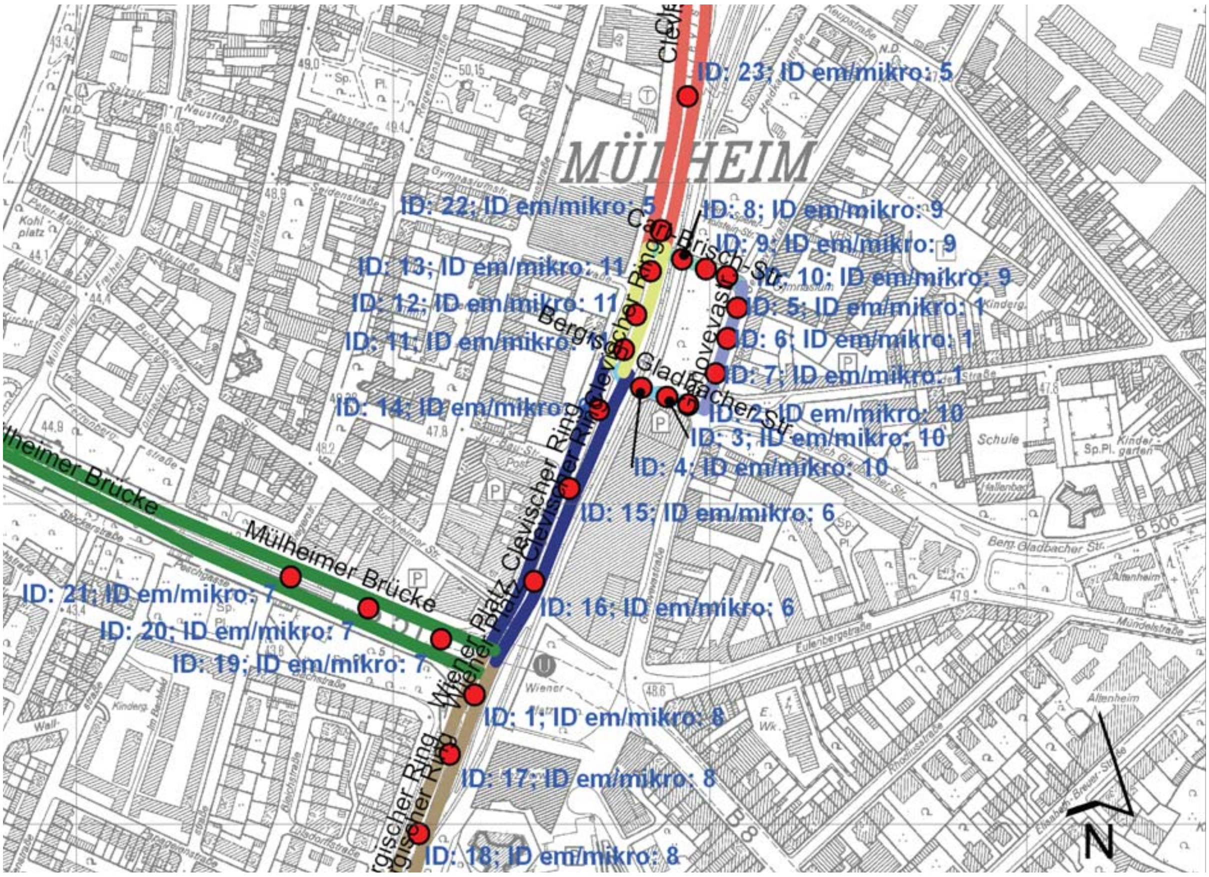

Figure 6: The main area for soft measure evaluation (Source: Umwelt- und Verbraucherschutzamt Stadt Köln, 2009)

The analysis consistsof a complete traffic flow analysis using the simulation tool VISSIM, emission calculation according to HBEFA 2.1 using IMMIS$^{em/mikro}$, and local small.scale immission modeling using MISKAM 5.02. Meteorological conditions were assumed to be rather unfavorable to analyze the worst-case scenario.

Looking at the impact in the different cases, Figure 7 illustrates the relative differences in NO_X emissions to the base scenario for each link and for each case. The area of the hot-spot is marked and shows a significant decrease of emissions. Also clearly visible is the shifting induced by the gating of Cases 2 and 3, with slightly increased emissions on links adjacent to the hot-spot, but further decrease in the hot-spot itself.

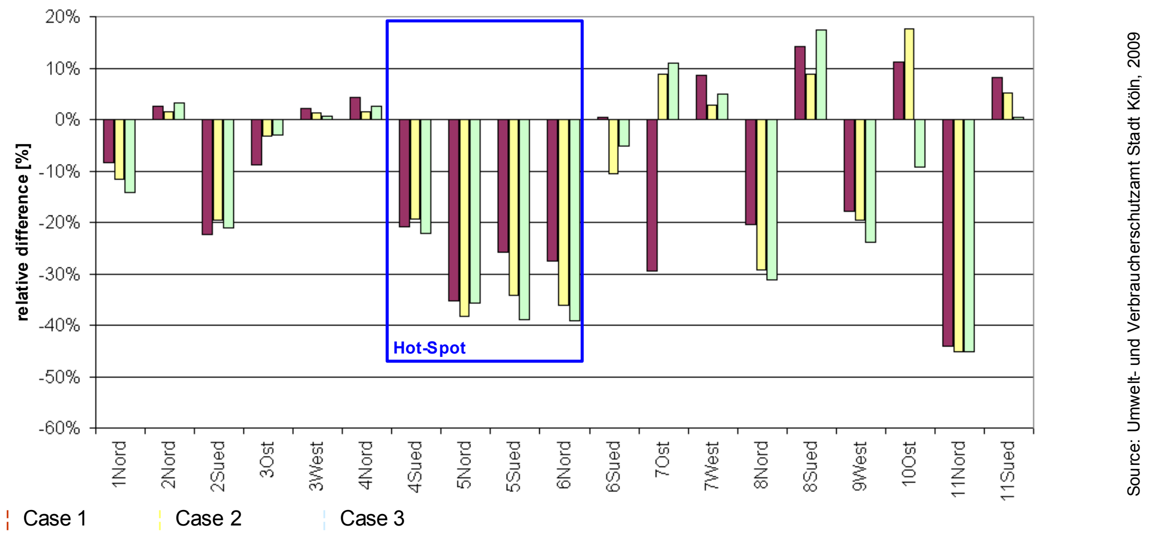

Figure 7: Relative Difference of NOx-Emissions for each main road link

Put into numbers, Figure 8 reflects the benefits in term of emission reduction of each of the cases. In general, reductions of up to nearly 20% of NO_X and almost 26% of PM_{10} have shown to be feasible.

Emissions	NO_X		PM_{10}	
	Total [g/(km*h)]	Difference to Base	Total [g/(km*h)]	Difference to Base
Base	30.28	-	4.34	-
Case 1	24,70	-18,4%	3.32	-23.6%
Case 2	24,50	-19,1%	3.25	-25.1%
Case 3	24.25	-19,9%	3.23	-25.8%

Source: Umwelt- und Verbraucherschutzamt Stadt Köln, 2009

Figure 8: Impact on emissions in the analysis area

The emission reduction certainly is the most direct impact of these measures, and consequently the critical NO_X immissions show similar reductions (see Figure 9). However, (unexpected) slightly lower reductions have been experienced with deactivated public transport priorization, but this effect remains very small compared to the reductions of case 1 and 2.

Immissions	NO_X	
	Immissions [µg/m³]	Difference to Base
Base	362.4	-
Case 1	322.3	-11.1%
Case 2	276.5	-23.7%
Case 3	283.7	-21.7%

Source: Umwelt- und Verbraucherschutzamt Stadt Köln, 2009

Figure 9: Impact of measures on NOx immissions

In summary, case 1 significantly reduced the emissions (hot-spot & total) of PM_{10} and NOx – despite of a slightly higher traffic volume. The additional gating of Case 2 further improved the situation (-24% and -14% in the hot-spot), the impact of the expected shift to the bridge in the west accounts for: +5% respectively +7%.

CONCLUSION

The analysis clearly indicates that an environmentally oriented traffic flow optimization is an effective soft measure to lower the traffic-induced local pollution even in very challenging urban conditions.

An additional gating enables the shift of emissions into meteorological more favorable areas. Implementing these benficial soft measures reduces the need of restrictive measures to less (or even none) occasions.

Environmental Traffic Management using soft measures can help to attain the air quality goals even in unfavorable conditions.