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Traffic-related environmental impact mapping in downtown Amsterdam

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ABSTRACT

Traffic-related environmental impact mapping includes an inventory of all downtown city streets known to have a traffic density surpassing a maximum number of cars per day.

The environmental components to be taken into account are carbon monoxide, nitrogen dioxide and benzene as air pollutants, on the one hand, and the noise nuisance level on the other. The impact mapping has been done by applying the CAR-model for the calculation of air pollutant concentrations and the Standard Calculus I-model for the calculation of the noise levels involved. Both models have been extensively validated and are mandatory under Dutch law.

The models are able to forecast an average air pollutant and noise nuisance level which is valid for a street trajectory with an average length of 200 meters. Comparison of calculated values with standard values results in a map of street trajectories where ambient air quality and noise level standards will be exceeded.

The results of the study in downtown Amsterdam demonstrate that the ambient air quality standards for both carbon monoxide and nitrogen dioxide were exceeded for a total street length of 27 and 49 kilometers, respectively in 1987. For noise, the total length of street trajectories not in compliance with the standard to be observed was 240 kilometers in that year.

Starting from the position that no environmental quality standard may be exceeded, the models are able to calculate to what extent traffic flow density must be restricted in the future in the various street trajectories concerned. The environmental impact map thus obtained for the year 2000 may be designated as the Standard Alternative Traffic Flow Pattern Map.

It is shown that the ambient air quality standard for carbon monoxide will not be exceeded in 2000 at all because of an improved automotive exhaust quality.

In order to avoid any further standard violations for benzene and nitrogen dioxide, traffic flow should be curtailed by at most 50% over a total street length of 27 kilometers. For noise, a reduction in traffic flow of at most 75% has to be achieved over a total street length of nearly 180 kilometers.

It can be concluded that noise nuisance is the critical factor in the design of traffic flow density limitations in downtown Amsterdam.

INTRODUCTION

Traffic-related environmental impact mapping is an activity which enables city planners to control the environmental impact of motor vehicle traffic in urban areas. Subsidized by the Dutch National Environmental Protection Department, local governments in the big cities are urged to produce a map of all urban streets where people run the risk of being exposed to hazardous air pollutant concentrations and annoying noise levels due to motor vehicle traffic.

The city government of Amsterdam decided to make an environmental impact map of all urban streets playing a major role in traffic flow regulation.

Previous studies conducted by Heida et al. [1,2] demonstrated that the ambient air quality standards for carbon monoxide and nitrogen dioxide are exceeded in a number of streets in downtown Amsterdam. These studies were based on dispersion model calculations. The model used is the so-called CAR model (Calculation of Air pollution from Road traffic). This model was developed by the Dutch National Institute of Environmental Health (RIVM) and the Dutch Institute for Applied Scientific Research (TNO) (Van den Hout et al. [3]).

The CAR model was extensively described and analyzed in a recent paper by Eerens et al. [4]. The model has been tested and calibrated on many occasions, not only in wind tunnel experiments (Van den Hout et al. [5]) but also under street conditions (Elskamp [6] and Heida et al. [1,2]). It has been proven over and over that the model provides sufficiently reliable results, i.e. that the calculated concentrations fall within the ± 30% accuracy range of measured values set forth by Dutch law. Because of it's obvious ability to fulfill the demands of accuracy and reliability, the CAR model has been officially adopted in Holland as an appropriate way of calculating the street air pollutant concentrations.

The mathematical representation of the CAR model is as follows:

$$C = N.E_s.\varphi.F_r.F_b+C_a \ ,$$

where C stands for the 98th percentile of 8-hour running average concentrations (P^8_{98}) for CO as well as the 98th percentile of 1-hour averages (P^1_{98}) for NO_2, both in $\mu g/m^3$; N is the average number of cars passing during 24 hours; E_s is the pollutant emission in grams per vehicle per meter per second as an average value for all types of vehicles; φ is a dilution factor which is dependent on the topographic characteristics of the street as well as on the distance between receptor site and street axis; F_r is an adjustment factor for local deviations in airport wind recordings, made at Schiphol airport; F_b is an adjustment factor for the presence of trees and C_a is the background pollutant concentration in $\mu g/m^3$.

Apart from air pollution, traffic noise is the second environmental impact component which must be taken into account to accomplish the making of an environmental impact map of urban streets due to motor vehicle traffic. The model to be used for the façade noise level calculations has been prescribed in the regulations of the Dutch Law on Noise Pollution.
The formula is as follows:

$$L_{Aeq} = E + C_{road\ surf.} + C_{intersect.} + C_{reflection} - D_{distance} - D_{extra} ,$$

where L_{Aeq} is the equivalent noise level in dB(A); E is the noise emission factor; $C_{road\ surf.}$ is an adjustment factor for the kind of road surface material; $C_{intersect.}$ is an adjustment factor for traffic flow related crossroads; $C_{reflection}$ is an adjustment factor for noise reflection from building façades and other obstacles; and $D_{distance}$ is an adjustment factor for noise level attenuation.

The L_{Aeq} value obtained represents an overall traffic lane. In case there is more than one lane which cannot be replaced by an overall one, energetic summation of all separate lanes should be performed:

$$L_{Aeq} = 10\ lg \sum_{i=1}^{n} 10^{L_{Aeq},\,i/10} ,$$

where $L_{Aeq,i}$ is the L_{Aeq} of the i^{th} traffic lane and n is the number of separate lanes.

The objective of the present paper is a presentation and discussion of the results of environmental impact mapping related to automobile traffic in the urban streets of Amsterdam.

RESULTS

The environmental impact mapping concerns the year 1987. The calculations for the air pollutants relate to carbon monoxide and nitrogen dioxide. The ambient air quality standards to be observed are the following:

Carbon monoxide	P^8_{98}	$= 6000\ \mu g/m^3$
Nitrogen dioxide	P^1_{98}	$= 135\ \mu g/m^3$
Benzene	$\overline{C}$	$= 10\ \mu g/m^3$

P^8_{98} is the 98^{th} percentile value of 8-hour average concentrations
P^1_{98} is the 98^{th} percentile value of 1-hour average concentrations
$\overline{C}$ is the yearly average concentration

The noise level standard to be observed is: $L_{Aeq} = 65$ dB(A).

Table 1 shows the results of the model calculations for the determination of the total street lengths where violations of the environmental quality standards were encountered in 1987.

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TABLE 1: Total length of street trajectories where environmental quality standards (EQS) were violated in 1987.

Environmental impact component	Total length of street trajectories in km where the EQS were violated
Carbon monoxide	36
Nitrogen dioxide	54
Noise level	240

Figure 1 shows a road map of Amsterdam with dashed lines indicating the calculated nitrogen dioxide concentrations for the urban main streets. As can readily be seen, only a restricted number of street trajectories does not meet the current ambient air quality standard of 135 µg/m^3.

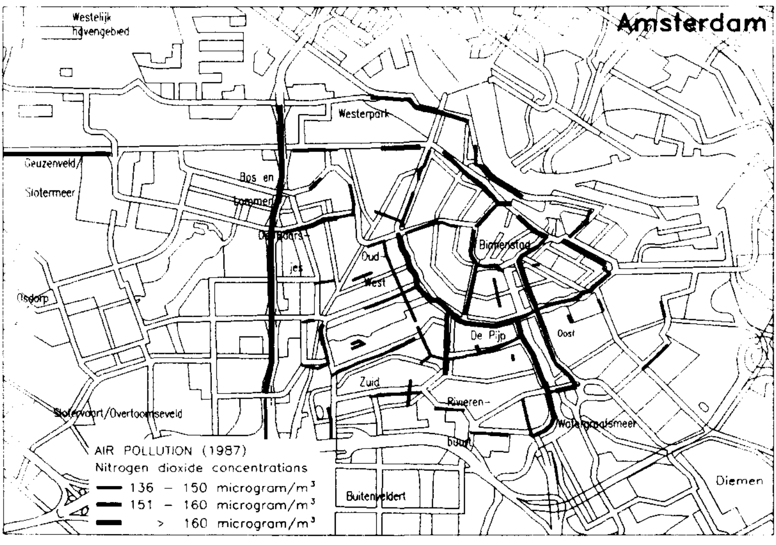

Figure 1: Violations of the ambient air quality standard for NO_2 in urban streets in Amsterdam in 1987.

Figure 2 shows a road map of Amsterdam with dashed lines indicating all street trajectories where the 24-hour-day noise level standard was exceeded in 1987. The total street length in violation was 240 km, representing 43% of the total urban road network.

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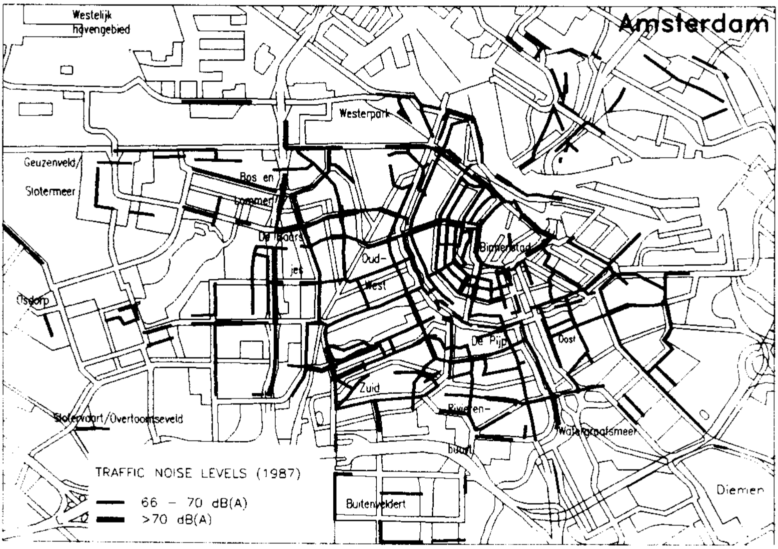

Figure 2: Violations of the 65 dB(A) noise level standard in urban streets in Amserdam in 1987.

The models used also enable one to make a forecast of the necessary traffic flow reductions to be executed in order to comply with the environmental quality standards involved. This approach gives rise to the so-called "Standard Alternative" of the traffic-related environmental impact map.

Since carbon monoxide concentrations are expected to decrease more and more as a result of continuous engine improvement and due to the introduction of the three-way muffler catalyst, this component is not taken into account. It is replaced by benzene, which is gradually becoming more important as an exhaust component.

The calculations made demonstrate that for benzene, in order to comply with the 10 $\mu g/m^3$ ambient air quality standard (as a yearly mean), a 20% traffic flow reduction as an average will be required over a total street length of 18.6 kilometers.

For a few street trajectories, a 75% decrease in traffic flow density will even be needed. The results are shown in figure 3, again showing a road map of Amsterdam.

For NO_2, an average traffic flow reduction of 18% over a total street length of 3.7 kilometers will be needed to comply with the 135 μ/m^3 standard.

For noise, the daytime and nighttime levels have been taken into account separately. The results are given in table 2 (see next page).

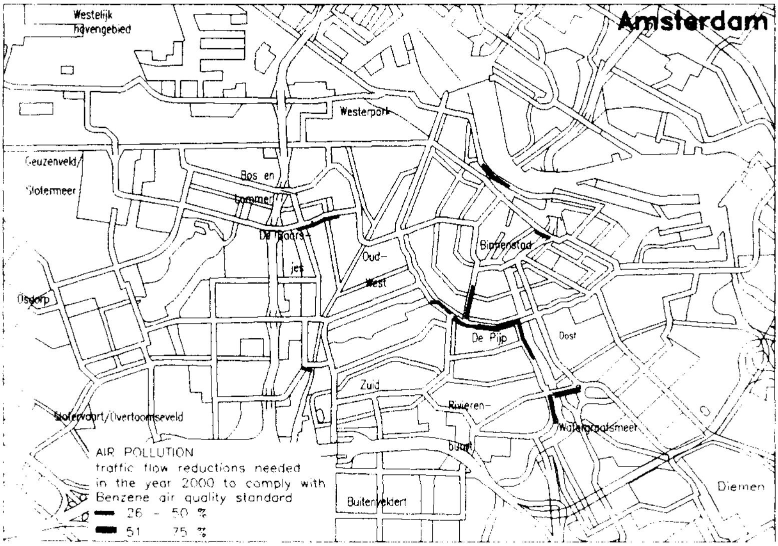

Figure 3: Traffic flow reductions in Amsterdam urban streets necessary to comply with the 10 µg/m^3 ambient air quality standard of benzene.

It is shown in table 2 that traffic flow reductions will have to be enforced over a total street length of 187.7 km, representing 33.6% of the urban road network, in order to fulfill the demand that the nighttime noise level of 65 dB(A) will no longer be exceeded in the year 2000.

TABLE 2. Summary of the required traffic flow reductions to comply with both the daytime and nighttime noise level standards.

Percentage reduction of traffic flow	Total street length in km for each category		Total street length in % of urban road network	
	daytime	nighttime	daytime	nighttime
more than 75%	3.3	8.0	0.6	1.4
51 - 75%	22.2	39.0	4.0	7.0
26 - 50%	40.7	58.6	7.0	10.5
0 - 25%	48.8	82.1	9.0	14.7
total street length > 65 dB (A)	115.0	187.7	20.6	33.6
total street length	560.3		100	

Figure 4 shows a graph presenting the required traffic flow reductions needed to comply with both daytime and nighttime noise level standards in the year 2000.

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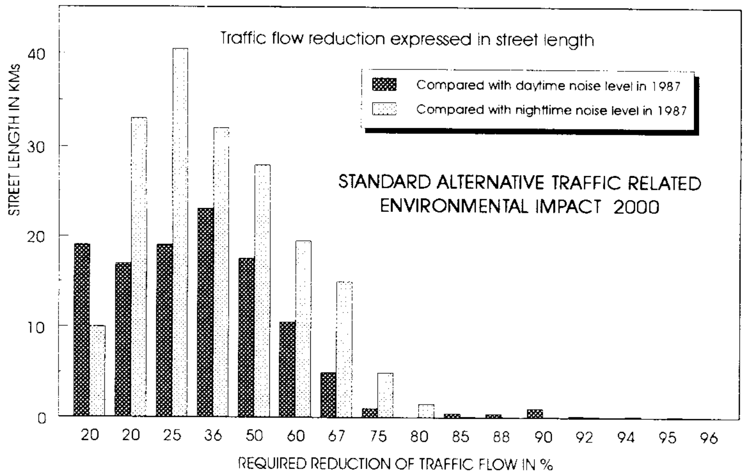

Figure 4: Traffic flow reductions in Amsterdam necessary to comply with the daytime and nighttime noise level standards in the year 2000.

DISCUSSION

Environmental impact mapping of the urban road network in Amsterdam for both ambient air quality and noise nuisance related to automobile traffic can only be a feasible policy instrument for environmental control if the mathematical models used provide sufficiently reliable results, i.e. if they comply with the accuracy and reliability demands laid down in the legal ordinances which are in force. This is the case with both models used in the study at issue.

The results of the environmental impact mapping demonstrate that environmental quality standard violations for some air pollutants, i.e. nitrogen dioxide and carbon monoxide, as well as for noise did occur in many urban streets of downtown Amsterdam in 1987.

In order to make a forecast of the traffic flow reductions necessary to comply with the environmental quality standards in effect in the year 2000, both mathematical models have been used in the reverse mode, i.e. the calculations are primarily based on the environmental quality standards to be met. The outcome is the acceptable traffic flow density which just complies with the EQS. From this, the percentages of traffic flow reduction compared to the 1987 traffic flow conditions can be calculated.

The percentages of traffic flow reduction needed to comply with the EQS concerned amount to 75% for certain street trajectories. Incontestably, noise nuisance appears to be the major environmental impact component requiring far-reaching traffic flow reductions in order to comply with the noise standard under consideration. At the same time, compliance with the ambient air quality standards for both nitrogen dioxide and benzene will be easily achieved.

CONCLUSION

Environmental impact mapping of urban streets in Amsterdam has been performed with the objective of controlling both ambient air quality and noise nuisance related to automobile traffic. It appears that the air pollutants considered, i.e. carbon monoxide and nitrogen dioxide, did not comply with the ambient air quality standards in 1987. However, most of the violations encountered were due to traffic noise.

If all environmental quality standards concerned are to be met in the year 2000, a substantial reduction in traffic flow density will have to be executed. Over a total street length of 18.6 kilometers a 20% curtailment of the 1987 traffic flow will be needed to comply with the benzene ambient air quality standard. At the same time, in order with comply to the noise level standard in the year 2000, a traffic flow reduction of at least 25% over a total street length of 187.7 kilometers, representing 33.6% of the urban road network, will be required. In some streets a reduction of even more than 75% will be needed.

The obvious inference is that noise is the major environmental impact component in urban streets demanding the most stringent reductions in traffic flow. Only then, will the environmental quality standards laid down in the Dutch environmental control legislation be fully met.

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