A TRAFFIC NOISE AND AIR POLLUTION ATLAS AS A RESEARCH INSTRUMENT FOR ENVIRONMENTAL POLICY IN AMSTERDAM

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1. INTRODUCTION

In 1990 the traffic-related environmental impact atlas of Amsterdam was completed. Compared to previous published traffic-noise maps in 1976 and 1984, the 1990 noise map had been supplemented with statistical data on the number of noise-loaded houses and with air pollution maps of NO_2 and benzene encountered at the edge on the pavement. Together they form an environmental atlas of the city. The additions made the atlas much more suitable as a policy tool for the evaluation of the environmental pollution inherent in different traffic scenarios. The present paper concerns the noise section of the environmental impact atlas.

1.1 Environmental policy in the Netherlands

A noise abatement law pertaining to industrial noise, railway noise and traffic noise was adopted in the Netherlands in 1981. According to this law the maximum allowable day-night (DNL) noise level, which is either the daytime noise level from 7.00 a.m. to 19.00 p.m. or the nighttime level from 23.00 p.m. to 7.00 a.m + 10 dB(A), whichever is higher, is 50 dB(A) at the facade of new houses. Exemption to this rule up to a maximum of 75 dB(A) are allowed in urban areas. For existing houses with a noise level higher than 65 dB(A) there is a national insulation plan which aims at upgrading all the houses in this category to achieve a maximum inside noise level of 40 dB(A) in a period of 25 years. The costs are subsidized mainly by the government.

An evaluation performed in 1989 showed that there had been some improvement in traffic-noise annoyance in the country as a whole, but that the noise levels in the cities had become worse due to the increased traffic. In that year a national environment plan was adopted with the stated goal that the number of people annoyed by the traffic noise in the year 2000 should not exceed that in 1985. A major goal of the policy with regard to traffic-noise in Amsterdam is to reduce the number of houses with a noise level exceeding 65 dB(A). At this moment about 13,000 houses have already been insulated, but at the present rate of about 1300 houses per year, 38 more years will be required.

In order to make possible the development of an effective environmental policy for the cities, there was a need for research. Therefore a national program was started to make noise and air pollution maps of all cities with more than 40,000 inhabitants. Because of its experience with previous noise maps, Amsterdam, with 800,000 inhabitants, was the first big city in the country to complete such a map. After the initial project had been completed the local authorities wanted to continue the research, so that a number of additional studies followed.

2. THE NOISE MAP

The traffic-related environmental impact atlas for the city of Amsterdam consists of the following maps and statistical information.

2.1 Traffic network

The basic system of the noise map is a traffic network of the main routes in the city with road sections having a traffic density of more than 2450 motor vehicles per 24-hour day, this being the lower limit set in the noise abatement law. The traffic network must be adjusted geographically so that the lengths of the different road sections can be used for statistical purposes and can be plotted on a city map scale 1 : 25,000. In Amsterdam, the network consists of 1800 main road sections with a total length of 560 km. The all over traffic data per road section are subdivided into vehicles per average daytime and nighttime hour, separately for the vehicle categories shown in table 1.

Table 1 Vehicle categories

cat. nr	vehicle category definition
1	motor cycles
2	light vehicles on 4 wheels, mainly passenger cars and vans
3	middle weight class trucks with double rear wheels
4	heavy weight class trucks with more than 2 axles
5	public buses
6	trams

The traffic densities are validated regularly by counting the traffic during the peak hours and occasionally during an entire 24-hour day at a limited number of counting points. In addition to the traffic density the car speed per road section is required. For this purpose the maximum allowable speed is used. Normally, within the city limits, this is 50 km/h, but road sections with maximum speeds of 70, 80 and 100 km/h are also present.

2.2 Geometrical data

A second series of parameters consists of the geometrical data per road section, such as the distance from the middle of the road to the fronts of the houses and the percentage of the opposite side of the road which can reflect the traffic noise. These data are obtained from city maps with a scale of 1 : 2000

2.3 Other input and statistical data

For statistical analyses the number of houses along the street is required. Because there is a great variety of house types and sizes, a house equivalent (HEQ) has been defined, which refers to the number of floors with living-rooms or bedrooms at the (noisy) front side. This HEQ probably correlates better with the number of occupants and the total façade area which must be insulated. Acquiring these data is rather time-consuming. They can be obtained in part from the files of municipal services, but most of the files are not complete, so that the rest of the information has to be acquired by observation on site. During these local observations the percentage of sound-absorbing surface between the middle of the road and the façade is also noted, as well as the existence and height of sound barriers, the presence of trees along the road and the height of the buildings. (required for the air pollution calculations)

2.4 Calculation model

The calculations were carried out with a computer program which calculates according to the Dutch regulations "model 1". The accuracy of this model is normally within 1 dB(A) in an average city situation. In this way the noise level per road section per road side per vehicle category per daytime and nighttime hour is calculated and stored in an output file.

2.5 Output

The following output is produced by the computer program

- A map with noise level classes in 8 different colors from 50 to 80 dB(A).
- Statistics on the number of HEQ per noise class of 5 dB(A) and the number of HEQ exceeding 65 dB(A).
- Statistics on the road length per noise class of 5 dB(A) and the total road length exceeding 65 dB(A).
- A "top 50" list of the noisiest roads

The calculations have been done for both day and night, but to avoid confusion we will show only the daytime situation, in spite of the fact that the nighttime level+10 is normally 1 to 4 dB(A) higher than the daytime level.

3. THE REFERENCE SITUATION IN 1987

The statistics for the situation in Amsterdam in 1987 are used as reference and are shown below.

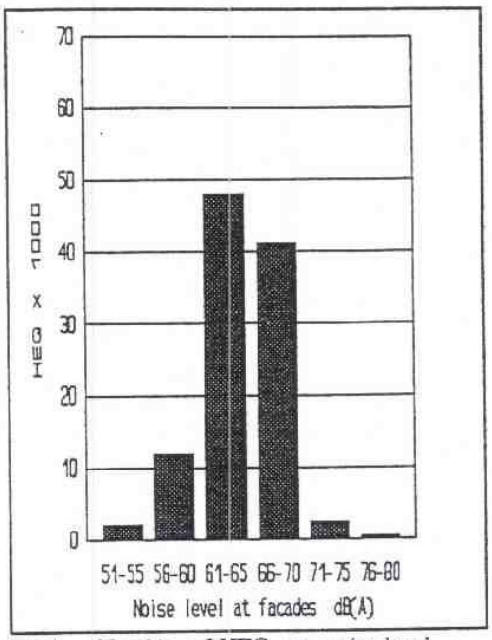

Fig.1 - Number of HEQ per noise level. There are 110,000 HEQ in the network of which 44,000 exceed a 65 dB(A) daytime noise level

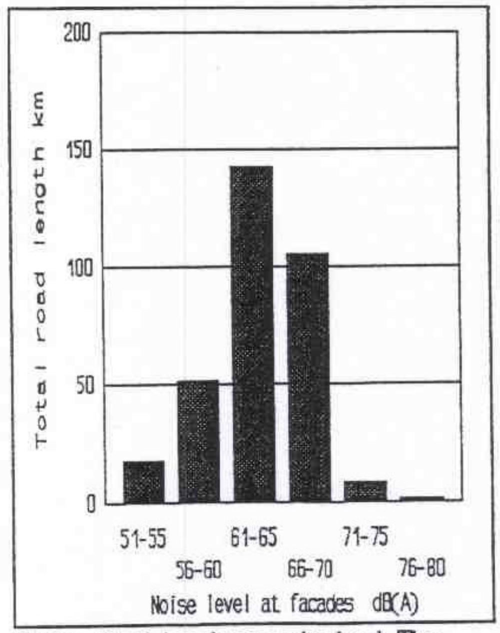

Fig.2 - Road length per noise level. The total road length of the network is 560 km of which 115 km or 21% exceeds a 65 dB(A) daytime noise level

It is remarkable that the largest single group in both diagrams has a noise level of 61-65 dB(A). This is probably caused by the average width of the main roads in the city and the maximum traffic flow through such a road section. In Amsterdam, the streets are rather narrow. In other cities this distribution may be different.

4. ANALYSES

After an analysis of the actual situation has been made, the system is available as an instrument for parameter and scenario studies.

4.1 Parameter analyses

Because each of the different vehicle categories requires a different unique treatment, it is important to know what the influence is of the various vehicle categories on the total traffic noise. Fig. 3 shows that trucks are the worst noisemakers. The high contribution (26 %) the public transport to the total traffic noise production is remarkable.

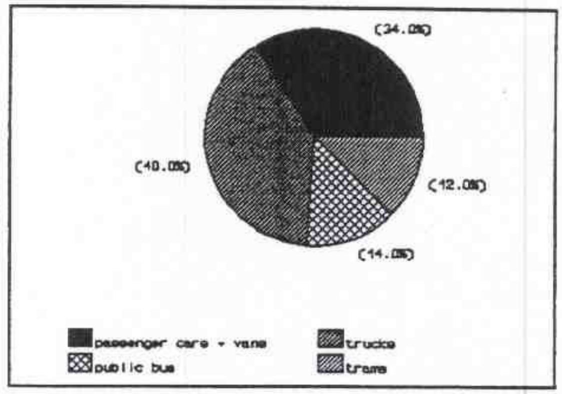

Fig. 3 - Noise portion of vehicle categories in total traffic noise

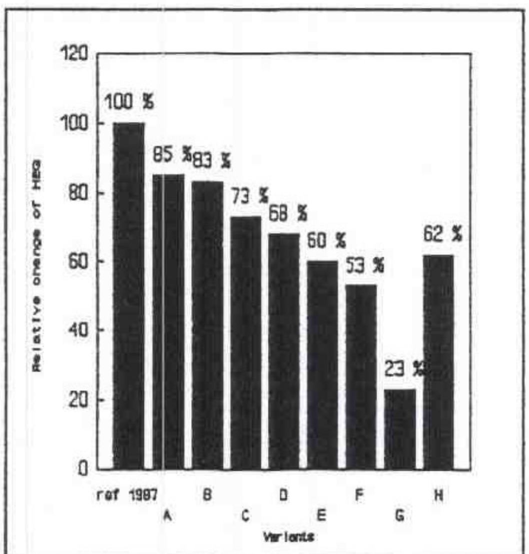

Fig. 4 - HEQ > 65 dB(A) in a number of different scenarios.

In order to determine the influence of various scenarios such as:

A: no public buses
B: no trams
C: public transport 10 dB(A) quieter
D: no public traffic
E: no light cars
F: no trucks
G: just public transport
H: 2 dB(A) absorbing whisper asphalt

It is possible to calculate the number of HEQ > 65 dB(A) when the noise emission of some vehicle categories is neglected or has been reduced (see Fig.4)

4.2 Noise sensitive routes

With the output data, a map can be made showing which routes are either more or less sensitive to traffic noise. In this case, the sensitivity is determined by the noise level multiplied by the HEQ per m road length per car. It can be calculated according to the formula:

$$NS = Leq_{(V1)} + 10 \log(N) - 10 \log(L) \qquad [1]$$

where:

- NS = noise sensitivity in dB(A)
- $Leq_{(V1)}$ = noise level caused by 1 light car per hour in dB(A)
- N = number of HEQ along the road section
- L = length of the road section in m

Such a map can be useful for city planners in order to direct the traffic over less sensitive routes as much as possible, or to make the main routes as insensitive as possible.

4.3 Equivalent annoyance rate

On the basis of a noise-dose effect it is possible to calculate the average annoyance rate in the whole network. In table 2 and formula [2] a simplified noise-dose effect is given, based on various national and international investigations. For every noise class the number of annoyed HEQ can be calculated. The equivalent annoyance rate ANQ can be determined according to formula [3].

$$PA_{(u)} = 3\,Leq_{(u)} - 140 \qquad [2]$$

$$ANQ_{(n)} = \sum_{u=1}^{u=7} \{ PA_{(u)} \cdot HEQ_{(u)} \} / HEQ_{(n)} \qquad [3]$$

where:

- $Leq_{(u)}$ = Average noise level in class (u) (dB(A))
- $PA_{(u)}$ = Percentage of annoyance in noise level class (u) (%)
- $HEQ_{(u)}$ = Number of HEQ in noise class (u) (-)
- $HEQ_{(n)}$ = Total number of HEQ in the network (-)
- $ANQ_{(n)}$ = Total average annoyance rate of the traffic network (%)

Table 2 - Noise-dose effect of traffic noise at the façade and annoyance rate

noise level dB(A)	annoyance rate %
50	10
55	25
60	40
65	55
70	70
75	85
80	99

The equivalent annoyance rate can be used to make a comparison with other cities having the same network definitions or with the same network under different circumstances. In Amsterdam, in the reference situation, the ANQ is 51.2%. A city with wider streets, silent public transport, noise barriers, etc. should have a lower ANQ. The ANQ should also decrease as a result of environmental policy.

5. TRAFFIC SCENARIOS

5.1 Future with unchanged policy

The next step in the study was to calculate the projected situation in 1997 (table 3). In spite of an projected average growth of 32% in the total number of vehicle kilometres in 10 years from 1987 to 1997, the number of HEQ exceeding 65 dB(A) in the daytime situation is rather constant. The explanation for this is that during the day, the roads in the city are at their maximum traffic capacity already. The traffic growth is therefore concentrated mainly on roads along which the noise sensitivity is less, such as motorways. On the other hand the nighttime traffic is not yet maximal, so that for this period higher noise levels can also be expected.

- Relative increase of HEQ's exceeding 65 dB(A) day level 1987-1997

noise level	reference HEQ	increase HEQ
dB(A)	number	%
51-55	2248	- 9
56-60	7450	- 5
61-65	33391	+ 2
66-70	55671	+ 2
71-75	6429	- 18
76-80	67	+ 7

ıffic reduction

ɜr to illustrate the degree to which the allowable noise limits in Amsterdam are ed by the current noise levels, a new map was drawn showing the amount of on required, per road section, to meet the noise limit of 65 dB(A). The results mmarized in Table 4.

- Required traffic reduction to meet 65 dB(A) day noise-limit

tion rate	total road length
%	km
to 25	48,8
5 to 0	40,7
l to 75	22,2
than 76	3,3
	114,7 km > 65 dB(A) 560 km network

ferendum on traffic policy in the city

rch 1992 a consultative referendum was held in Amsterdam. The following ›n was posed(free translation of the choice between two policies on the ballot): " u agree with a drastic reduction in parking facilities in the city centre in order to more room for pedestrians and bicycles and reduce the traffic-noise annoyance r pollution?"

The consequences of the proposed drastic measures for the parking facilities and traffic densities in the city were estimated to be the following :

- elimination of 18,000 of the 33,000 parking places in the city centre
- creation of 4000 new parking places in the area around the city centre.
- a 66% reduction in commuter traffic
- a 25% reduction in business traffic
- a 50% reduction in shopping traffic
- no change in public transportation

A study of the projected noise levels and air pollution was then carried out to determine the environmental consequences. The results showed that the number of houses with noise levels exceeding 65 dB(A) noise level would be reduced by only 37%; this was less than originally expected. Further analyses demonstrated that in 50% of the city streets the public transport would then produce more noise than the other traffic. This supports the conclusion that bus and tram noise must be reduced.

The result of the referendum was that 52% of the total voting population of Amsterdam voted "yes". In the centre this percentage was 55%. The plans are expected to be effectuated in the next few years.

5.4 Electric cars

An alternative way of reducing noise pollution is by the introduction of electric cars. As part of a European study, the environmental consequences of the introduction of electric cars in Amsterdam were calculated. The noise emission of electric vehicles compared to that of internal combustion motor-cars is assumed to be as follows:

Light cars: No noise reduction because at speeds of 50 km/h and higher the tire-noise is greater than the motor noise

Light trucks: 10 dB(A) reduction

Public buses: 10 dB(A) reduction

Heavy trucks: No reduction because Electric Vehicles in this category are not available yet

Several scenarios with different assumed penetration percentages (see Table 5) were calculated.

Table 5 - Penetration percentages of electric vehicles

scenario	passenger cars	vans	light trucks	buses
	%	%	%	%
A-2005	18	26	6	14
B-2005	30	28	15	44
B-2010	60	56	45	78
C	0	0	0	100

The results are shown in Table 6.

Table 6 - Number of HEQ and road length > 65 dB(A) after introduction of electric vehicles, daytime situation

scenario	relative reduction of number of HEQ > 65 dB(A)	relative reduction of total road length > 65 dB(A)
Reference	44240	118 km
	%	%
A- 2005	-1,8	-1,4
B- 2005	-9,5	-4,1
B- 2010	-20,3	-11,0
C	-12,7	-9,9

The effects of scenario A-2005 are small because of the limited number of hybrid trucks and electric vehicles. The effects of scenarios B-2005 and B-2010 are significant. Particularly striking is the effect of 100% electric buses. This is due to the fact that buses sometimes travel along routes with little other traffic so that there is a large effect on the total noise level. Generally, the noise reduction effects of electric vehicles in the city are an underestimate because the noise reduction on acceleration was neglected. Experience in the city of Arnhem in the Netherlands with electrification of a bus line showed a stronger positive effect on the annoyance level of the population.

6. FUTURE DEVELOPMENTS

Some new scenarios which should be investigated are:

6.1 Technological developments

With regard to motor noise, buses with natural gas motors are quieter than those driven by a diesel motor. In Amsterdam and other cities in the Netherlands, some of these buses are now in use to obtain experience with their operation. In the area of quiet road surfaces some progress is also being made. New twinlay sound-absorbing asphalt with a fine-grade porous top layer and a coarse porous underlayer has better sound-reducing properties than the single layered type. A third development is the use of traffic information systems to guide the traffic in different directions so as to cause less pollution.

6.2 Freight distribution centres

Another development is the establishment of freight distribution centres outside the city centre. Analysis has shown that the greater part of the total freight carried by heavy trucks in the city is transit freight, i.e. freight with an ultimate destination elsewhere. Sometimes, that part of the freight of 10 heavy trucks with a real destination in the city could be delivered by a single van. Since a heavy truck produces noise equal to that of 30 or 40 vans, the implementation of one or more freight distribution centres using vans, possibly driven by electric motors, could mean a massive reduction of noise and air pollution in the city.

7. CONCLUSIONS

A traffic-related environmental impact atlas consisting of a collection of noise and air pollution maps and statistical information is a useful instrument to develop environmental policy in a city like Amsterdam. A number of previous studies supports the conclusion that a wide variety of rather drastic measures is needed to decrease the noise pollution at the façades. The following measures may be considered: reducing parking space in the centre, stimulating public transport, introducing electric cars, making public transport quieter, and reducing the number of heavy trucks that drive through the city. Each of these measures provides some reduction. Together, they can mean a successful abatement of noise pollution in cities.

8. REFERENCES

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