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Background Noise: An Increasing Environmental Problem?

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Summary
This paper presents the results of a joint noise study of the Dutch National Institute for Public Health and Environment (RIVM) and the Dutch National Aerospace Laboratory (NLR). The study aims to predict background noise levels caused by road-, railway and aircraft traffic. Background noise may be of increasing importance for future outdoor noise quality and health effects, as traffic activities are expected to grow further in the next decades.
A statistical model was used for mapping background noise levels (L90) using traffic numbers. The model was validated for road traffic noise by long term measurements at motorways in the Netherlands. For airport noise, predictions were validated by simulation of time data based on real flight traffic numbers provided by the NLR. Subsequently the model was applied to the main roads, railways and Amsterdam Airport Schiphol in the Netherlands. The study shows that both for road traffic noise and airport noise, background noise levels will increase stronger than equivalent noise levels when traffic numbers increase. It is therefore important that policymakers give high priority to further reduction of noise emissions in the next decades.

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1. Introduction

In the Netherlands over the past decennia, there has been a substantial increase of transport activities from road-, railway and aircraft traffic. Figure 1 gives the trend from 1955 onwards for various modalities.

As a consequence, like in most European countries, mobility growth has led to areas of high noise exposure and annoyance of the population. The resulting increase of environmental noise became significant in the eighties and in order to limit noise exposure and annoyance, an intensified noise policy has now been implemented into the Dutch noise legislation. On a large scale this has led to extensive noise measures, such as barriers along road- and railway lines, and the use of silent asphalt pavements. For aircraft noise both national and international regulation has led to a strong reduction of the noise emission, e.g. [1]. These measures have not succeeded in fully compensating traffic growth, but they have been of crucial importance for maintaining an endurable environment.

Up to now, the Dutch noise policies were mainly focussed at keeping noise levels below limit values as specified in the Dutch noise legislation. In line with the European Directive 2002/49/EC for the rating of environmental noise levels, in 2003 the former Dutch noise indicator the 'etmaal'-value (L_{etm} in dB(A)), has been replaced by the harmonized European noise indicator L_{den}. The Dutch limit values have been adjusted accordingly. The L_{den} rates a broadband noise level and averages time varying noise values over one year. For evening and night time underlying noise levels are weighted by respectively 5 and 10 dB before averaging. Although the L_{den} is now widely used as the European standard noise indicator, it does not account for time en frequency characteristics or soundscape aspects in general and does not fully explain annoyance and health effects [2]. In order to provide policymakers with the best information regarding noise exposure, a thorough knowledge of the various types of noise exposure is important, along with better understanding of the relation between noise exposure and its effects. In particular, the present knowledge of the influence of time and spectral characteristics of the noise on human perception should be improved. One important aspect of noise is the time behaviour of environmental noise. Few events with high SEL or L_{max} values and many events with low SEL or L_{max} values may result in equal L_{den} levels, but the effects on perception may be quite different. For this reason, the National Institute of Public Health and Environment and the National Aerospace Laboratory have carried out a joint research project that aimed at extending knowledge on noise exposure from the usual A-weighted noise exposure indicator (L_{den}) to the background noise level.

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The background noise level here is defined as the level that is exceeded 90% of the observed time period. As long as the background level remains reasonably low, its impact on environmental noise quality is presumably negligible, as this will be dominated by the effect of the noise events. However, if the background noise level increases, its effect on environmental noise quality may become important, because noise events are no longer separated by silent periods. As traffic growth still tends to increase and a further reduction of the noise emission of cars and airplanes is not to be expected shortly, in many urban areas the outdoor background noise level may surpass threshold levels for speech communication. Also, along with L_{night} and $L_{\max}$, continuous high background levels may affect human sleep quality [3] and even influence breeding behaviour in nature areas, e.g. [4].

This paper deals with the modelling and assessment of background noise levels (L_{90}) from road- and railway traffic and airport traffic. The paper describes the application of a statistical model for the mapping of background noise and an evaluation of its potential development and consequences. The statistical model was validated, using an extensive set of road traffic measurements and airplane flight tracks. As an application, a complete map of the background noise for the Netherlands was determined, in which the contributions to the background noise from all Dutch roads, railways and airports were accumulated. The paper concludes with an evaluation of future traffic development, its possible impact on future background levels and a discussion on the potential risks for environmental noise quality.

2. Theoretical background

Before deriving a statistical model that can be used for estimating the background noise, first the well known formula for the average level from a line source will be given. Next we will explain a first approximation for the determination of percentile values according to Kuttruff [5].

2.1. Average noise level

Figure 2 shows a line source with a randomly distributed number of noise sources.

In Figure 2, $\langle s \rangle$ is the average length between the sources, and a the shortest distance between the propagation line and the receiver. This situation may represent a road or railway line with cars or trains passing by or an airport flight path. The sources in Figure 2 are each characterized by the sound power level L_w, and a corresponding sound power of $W = 10^{L_w/10}$. Within a certain observation time T a number of N sources pass by. In this case the average sound intensity I at the receiver follows from straightforward integration of the contribution from each segment with angular opening $\mathrm{d}\theta$ and is given by

$$I = \int_{-\infty}^{\infty} \frac{NW\,\mathrm{d}x}{2\pi vT(x^2+a^2)} = \int_{-\pi/2}^{+\pi/2} \frac{NW\,\mathrm{d}\theta}{2\pi avT} = \frac{NW}{2avT}, \quad (1)$$

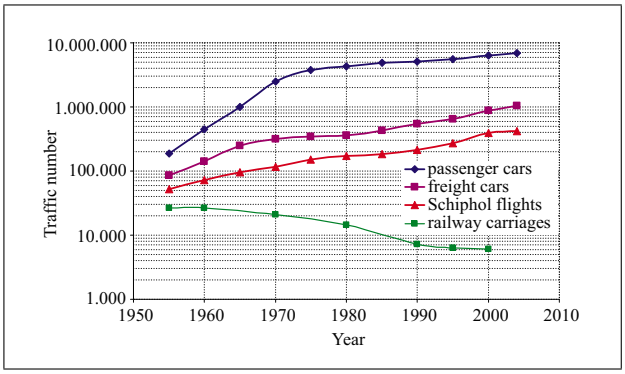

Figure 1. Trend developments of transportation in the Netherlands 1955–2004.

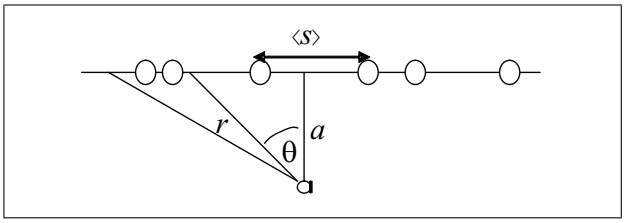

Figure 2. Representation of a line source containing omnidirectional point sources.

where v is the average speed of the vehicles; the average distance $\langle s \rangle$ between the sources is given by vT/N, so equation (1) can be rewritten as

$$I = \frac{W}{2a\langle s \rangle}. \quad (2)$$

So far air attenuation and soil impedance have been neglected. From equation (2) the equivalent noise level L_{Aeq} in dB follows from

$$L_{\text{Aeq}} = 10\log\left(I/I_{\text{ref}}\right) = L_w - 10\log\left(2a\langle s \rangle\right). \quad (3)$$

In many standards, equation (3) is used as basic equation for determining equivalent noise levels from roads or railways, in combination with additional attenuation terms that account for air absorption, soil impedance and meteoro-logical conditions. For the determination of equivalent noise levels from road and railway traffic we used the RMW [6] and RMR [7]. For airport traffic, the NLR uses [8].

2.2. Statistics of road traffic

Equation (3) only gives the average noise level over the time of observation. It does not contain any information as to the statistical distribution of noise levels in time at the receiver point. These depend on the traffic volume and the spatial distribution of the sources over the line source. In order to estimate the time distribution of noise levels at the receiver point, one has to know the spatial distribution of the sources. In this study, the basic assumption in the estimation of percentile values is that the distances between the sources are governed by a Poisson distribution. In this case the time values of the number of cars present at each

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subsection of the line, denoted by n, are independent statistical variables and are also Poisson distributed according to:

$$f_n = \frac{1}{n} e^{-n/\langle n \rangle}. \tag{4}$$

The average value $\langle n \rangle$ is given by $l/\langle s \rangle$, with l the length of each subsection and is equal for all subsections.

The resulting time distribution of noise levels has been investigated extensively by various researchers, e.g. [9, 10]. In this study we follow an approach proposed by Kuttruff [5] in which a Pearson III distribution for the sound intensity is assumed. The parameters and the shape of the distribution are determined by the mean $\langle I \rangle$, given by Equation (2) and by the relative variance of the sound intensity,

$$\xi = \frac{\mathrm{var}(I)}{\langle I \rangle^2}. \tag{5}$$

Assuming neglible variation in the traffic speed v and the sound power levels L_w of the sources, the variance $\mathrm{var}(I)$ can be obtained by integration along the source line, using the property that for a Poisson distribution the variance of n equals n, i.e. $\mathrm{var}(n) = n$.

The infinitesimal contribution $\mathrm{d}\nu$ of each segment with angular opening $\mathrm{d}\theta$ and containing $\mathrm{d}n$ sources to the variance of the sound intensity is given by $\mathrm{d}\nu = G^2(x, a)\,\mathrm{var}(\mathrm{d}n) = G^2(x, a)\,\mathrm{d}n$. Here, $G(\theta)$ is the sound intensity of one source at an angle of θ,

$$G(\theta) = \frac{W}{2\pi r^2} = \frac{W \cos^2\theta}{2\pi a^2}. \tag{6}$$

Furthermore $\mathrm{d}n = N/vT\,\mathrm{d}x$, so that

$$\mathrm{d}\nu = G(\theta)^2 \frac{N}{vT}\,\mathrm{d}x = \frac{W^2}{4\pi^2}\frac{N\cos^2\theta}{vTa^3}\,\mathrm{d}\theta. \tag{7}$$

Integration over the entire line source gives the total variance

$$\mathrm{var}(I) = \frac{W^2}{4\pi^2}\frac{N}{vTa^3}\int_{-\pi/2}^{+\pi/2}\cos^2\theta\,\mathrm{d}\theta = \frac{W^2 N}{8\pi vTa^3}. \tag{8}$$

Combining equations (2), (5) and (8) results in the following expression for the relative variance:

$$\xi = \frac{vT}{2\pi aN} = \frac{\langle s \rangle}{2\pi a}, \tag{9}$$

where $\langle I \rangle$ is average sound intensity over the time interval considered, given by $I = 10^{L_{\mathrm{Aeq}}/10}$ with L_{Aeq} the equivalent noise level in dB (ref 10^{-12} Watt/m^2) and $\langle s \rangle = vT/N$. One can see that the relative variance is inversely proportional to the distance between the line source and the receiver. This explains why the roads at large distances are perceived as rather constant, continuous noise sources.

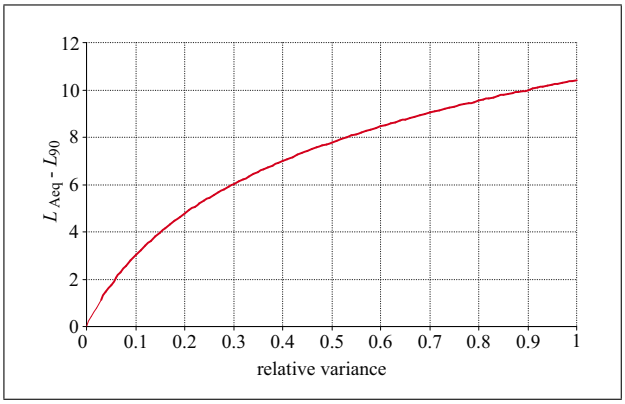

Figure 3. Representation of equation (10), where the δ depends on the relative variance ξ.

2.3. Difference between equivalent noise level and background noise level

After matching the Pearson III distribution with the mean given by equation (2), and the relative variance of the sound intensity ξ given by equation (9), the Pearson III distribution can be converted to a probability density function for the time values of the sound level at the receiver [5]. Using this density function an approximation for the difference between the equivalent noise level and the background noise level can be derived, depending only on the relative variance ξ,

$$\delta(\xi) = L_{\mathrm{Aeq}} - L_{90} \approx 10\log\left(1 + 10\xi\right). \tag{10}$$

The difference according to Equation (10) is shown in Figure 3.

It can be seen that the difference between L_{Aeq} and L_{90} increases with the relative variance ξ. To illustrate: if the traffic density decreases, the average distance $\langle s \rangle$ between the sources increases, and using Equations (9) and (10) this leads to a larger difference between L_{Aeq} and L_{90}.

Equation (9) only accounts for contributions to the variance due to varying traffic density and neglects the additional variance in sound power levels of the sources W. This could lead to an underestimation of the difference between the L_{Aeq} and the background level. This point will be further discussed in the section on validation.

As an alternative for the expression for an entire line source in equation (9) it is also possible to determine the contribution to the variance from each line segment separately. It can be shown that the contribution to the total variance of the sound intensity by $\Delta\mathrm{var}(I) = 1/\langle n \rangle$, when $\langle n \rangle$ is the average number of sources of the segment during the time of observation. The total variance can be obtained by adding all individual contributions $\sum \Delta\mathrm{var}(I)$ of the segments. By dividing the resulting total variance by the squared value of the total sound intensity, $\sum \Delta I$ the relative variance can be obtained. This procedure is needed in situations where the sources do not follow a straight line, but for example are part of a complex road network and was used in this study for the determination of a complete

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map for the background noise. In addition to the determination of the equivalent noise level, at each grid point of the map, also the relative variance was determined using the procedure outlined above. Finally, the background noise levels at the grid points were determined using Equation (10).

2.4. Aircraft noise

Equations (3), (9) and (10) can also be used for approximation of aircraft background noise from flight paths having a Poisson distributed traffic flow [11]. For the aircraft attribution to the L_{90}, for practical purposes in this study an additional simplification was made. For every runway all takeoffs and landings were projected on an average centre track, disregarding the spatial deviations from this track. As for road- and railway traffic, the sound power levels and speed of the planes were considered constant.

2.5. Accumulation of background noise from different source types

Background noise levels caused by the different types of environmental noise (e.g. aircraft, roads and railways) can be accumulated by adding their variances and determining the resulting total relative variance, according to:

$$\xi_{\text{total}} = \frac{\sum_k \text{var}_k(I)}{\left(\sum_k I_k\right)^2} = \frac{\sum_k \xi_k I_k^2}{\left(\sum_k I_k\right)^2}. \qquad (11)$$

In this procedure the contributions from roads, railways and airplanes to the total background noise are considered independent statistical variables.

3. Validation

The theory as outlined in the previous chapter only gives a first order approximation statistical distribution of noise levels and the resulting background level. It is based on a number of assumptions and simplifications. Validation of the model was therefore necessary in order to test its applicability in practice and assess deviations from measured data.

3.1. Road traffic

To validate the predicted L_{90} levels for road traffic noise, measurement data from a RIVM noise monitoring station at the A2 motorway between Amsterdam and Utrecht [12] was analyzed. The site is located at 25 m east of the road. For each hour the L_{Aeq} and the L_{90} are both measured and stored. Also from a counting device, for each of the six lanes, the number of vehicles and average speed were registered. This data allows to determine the relative variance of the sound intensity and the resulting difference between the L_{Aeq} and the L_{90} for each hour, according to the theory outlined previously. The hourly values were averaged in order to obtain an average 24 hour distribution of the equivalent and background levels. The result is shown in Figure 4

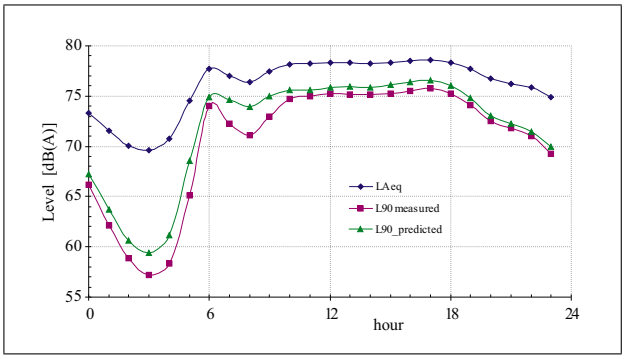

Figure 4. Comparison of measured and predicted average 24 hour distribution. Measured data were acquired from the A2-Motorway Amsterdam-Utrecht at Breukelen in 2004.

As can be seen in Figure 4 the predicted background noise, that is based on a Poisson distribution of distances between the vehicles according to equation (4), gives a fair approximation of the measured background noise. The largest deviations can be seen between 3 and 4 am and between 8 and 9 am. The former stems from the relatively low traffic volume at that time, and the second probably has to do with congestion. In case of traffic jams, the assumption of constant speed and sound power level of the vehicles is less justified. In general, the difference between the L_{Aeq} and the L_{90} is somewhat underestimated, indicating that the relative variance is underestimated. This could be improved by refining the model and differentiating between passenger cars and trucks. The effect seems limited though. During day time and the evening, the agreement is excellent.

3.2. Airport noise

For validation of the predicted L_{90} levels from airport noise, no real long time measurement data of background levels was available. This is because in a practical situation the background level from airplanes is often exceeded by the levels from road traffic. Therefore, use was made of modelled data, calculated at the National Aerospace Laboratory. The data comprises a set of calculated arrival times and SEL-values at a known distance between the source and receiver. Although the reference data was calculated instead of measured, the real passages times are taken into account, which allows one to validate the statistical behaviour of the noise levels. These passage times are provided by Schiphol airport, using the FANOMOS flight data.

The calculated arrival times were validated in a previous RIVM study [13] using a 'Luistervink' airport monitoring system [14]. The 'Luistervink' uses a device that distinguishes aircraft noise from other noise sources and registers airplane arrival times and SEL values. In Figure 5 modelled NLR data is compared with 'Luistervink' measurements.

Figure 5 shows that modelled arrival times using the NLR flight data base are in excellent agreement with measured arrival times (indicated by the vertical lines). There

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are a couple of measured SEL values before 2:00 that do not have a corresponding arrival time. These discrepancies have been discussed in [13] and are due to incorrect recognition of airplane noise at lower SEL values by the measurement system. These measured SEL values were caused by other local environmental noise sources. In general the modelled arrival times proved suitable for validating the statistical assumptions in the modelling of background levels. Using a set of calculated arrival times based on real flight data, a time series was constructed according to:

$$Lp(t) = 10\log\sum_k \frac{10^{0.1L_{w_k}}}{4\pi\sqrt{a^2+v^2(t-t_k)^2}}. \qquad (12)$$

Here, k is an index taken over all planes passing in the observed time period and t_k indicates the time of shortest distance from the plan to the receiver. The sound power levels L_w for each plane k were obtained from the calculated SEL values for each plane passage, according to

$$L_w = \mathrm{SEL} + 10\log\left(4av\right) - D_{\mathrm{air}}, \qquad (13)$$

in which a is the shortest distance between the source path and the receiver, v is the source speed and D_{air} the air attenuation factor.

To save computation time, the summation is limited to the 20 nearest planes at the time t of interest only. Figure 5 gives an example of the behaviour of the instantaneous level $Lp(t)$ at a receiver located 5 km west of the 'Buitenveldert' runway from Amsterdam airport Schiphol from 4 pm to 5 pm at January first of 2007.

Figure 6 shows 28 planes flying over the receiver, causing an equivalent noise level L_{Aeq} of 59 dB. The L_{90} percentile level in the observed hour is approximately 34 dB(A). This simulated L_{90} can be compared with the predicted background noise level as defined by Equation (10). The relative variance as defined by Equation (9) comes at 7 dB(A) and subsequently Equation (10) predicts a background level L_{90} of 40 dB(A). In this case the 90% percentile value is overestimated by 6 dB. The estimated value of 40 dB(A) corresponds to the level that is exceeded approximately 77% of the observed hour. In a similar way the calculation was extended for all hours of 2007 at the receiver point. For each hour, both the observed L_{90} and the predicted L_{90} were determined and averaged. The results are given in Figure 7.

Figure 7 shows that the predicted background noise level in general overestimates the simulated L_{90} levels. This particularly is the case for the hours in which there are hardly any planes passing by i.e. the night hours and evening hours after 9 pm. For the day hours the predicted backgrounds levels exceed the simulated levels by approximately 4 dB. The differences for airport noise between the prediction and the observations are higher than for traffic noise. This is probably due to the number of sources involved. Also the assumption of constant sound power levels in the prediction of the background level is probably less justified than for road- and railway traffic. As the relative variance becomes larger, the first order approximation

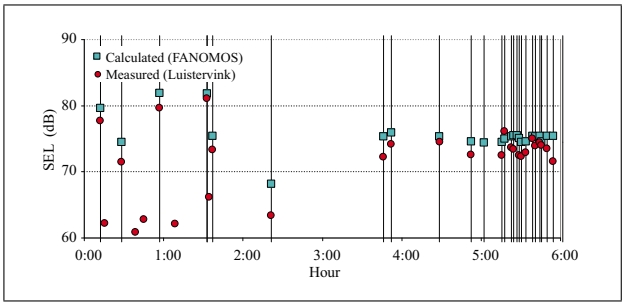

Figure 5. Comparison of measured and calculated SEL values, from known arrival times. Measured with a 'Luistervink' system near Krommenie, on August 1st 2007 [13].

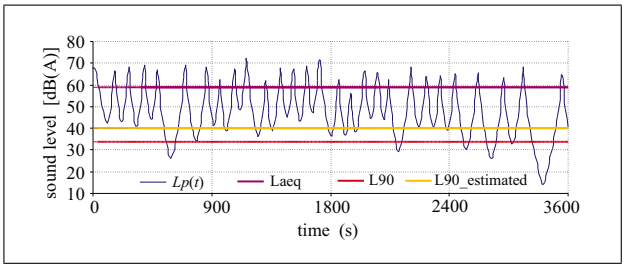

Figure 6. Time behaviour of the sound level due to aircraft flying by at 5 km west of the Buitenveldert runway of Amsterdam Airport Schiphol, 4 pm–5 pm 1-1-2007.

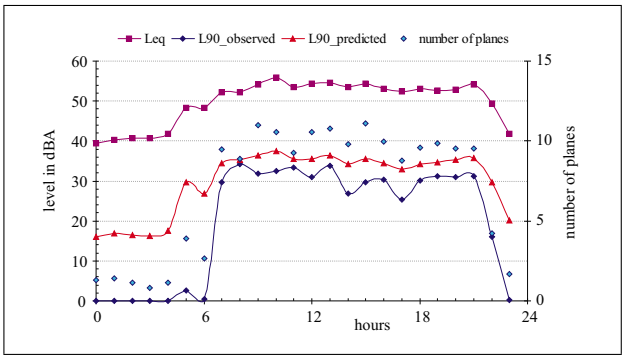

Figure 7. Comparison of the simulated and predicted background noise levels.

as given by equation (10) is less accurate and eventually a more sophisticated statistical model is needed. However with regard to periods in which relatively many planes are passing by, the model gives a useful first approximation of the behaviour of background levels from airplane tracks.

4. Noise maps

4.1. Overview

Using traffic numbers for the major roadways in the Netherlands and combined with the Schiphol data, a noise map of the background noise can be constructed using Equations (10) and (11). Using equivalent noise levels for specific periods of the day, it is possible the produce noise maps for the background noise present specifically in the daytime (7 am–7 pm), evening (7 pm–11 pm) and night-

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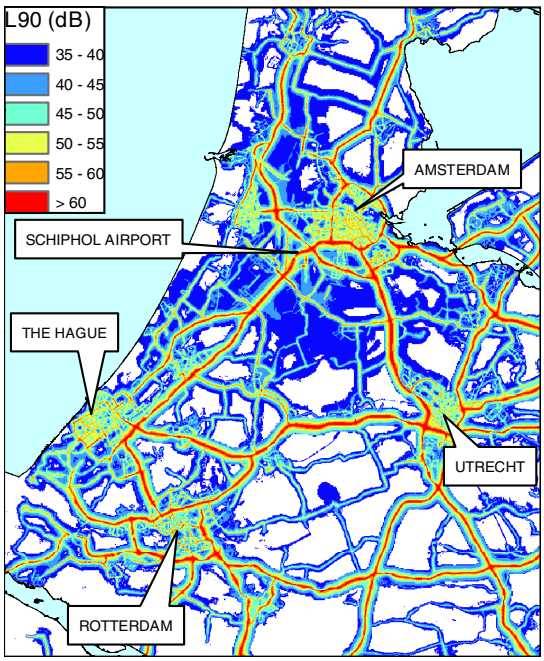

Figure 8. Noise Map of the background noise produced by roadways, railways and Schiphol Airport in the daytime period.

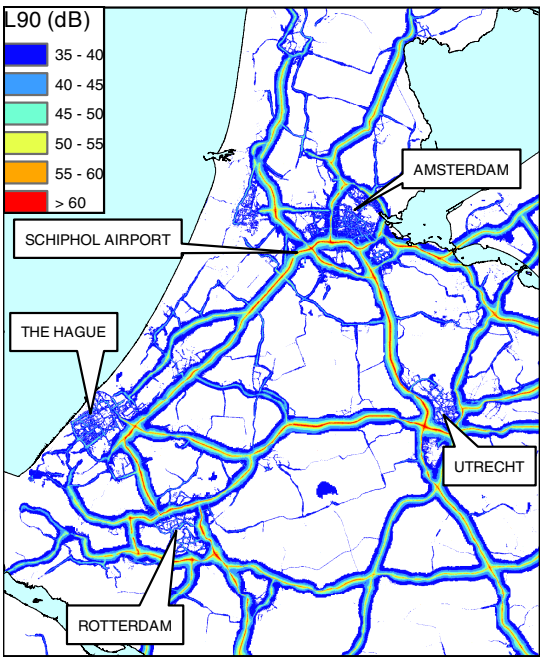

Figure 9. Noise Map of the background noise produced by roadways and Schiphol Airport in the nighttime period.

time periods (11 pm–7 am). Figure 8 shows such a noise map of the background noise produced in the daytime period, for the Randstad region in the Netherlands.

It can be seen that the background noise from the main motorways has a large impact on the surroundings due to their high traffic density. For most of the local roadways, a background noise is present but not as dominant as for the motorways. Also the impact from Schiphol Airport can be seen, runways and routes are just visible. The railway traffic however is nearly absent from this noise map: the average distance between each train s is much larger than for roadway traffic, resulting in a high relative variance in the sound intensity and subsequently a low background noise level.

Figure 9 shows the noise map of the background noise present in the nighttime period.

For the nighttime, the only significant sources of background noise are the major motorways, due to the high traffic numbers still present in the night. The local roadways still produce some background noise between 30 and 40 dB, but this will cause little disturbance to the surroundings. The background noise from Schiphol airport has disappeared; the number of flights in the nighttime period is not high enough to produce a significant background noise levels.

4.2. Impact in urban areas

Figure 10 shows the impact of background noise in the daytime period in an urban setting, in this case the city of Rotterdam near the north part of its beltway, the A20 motorway.

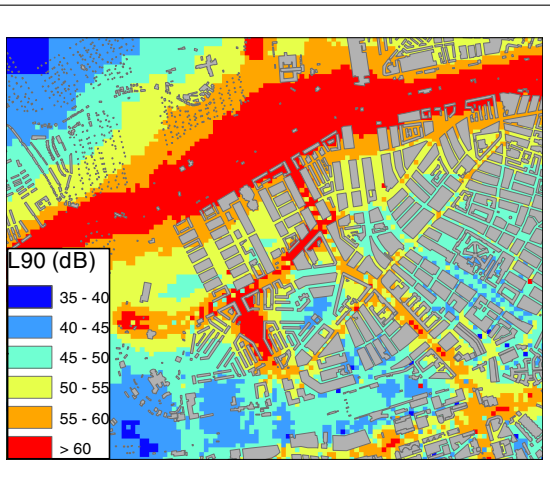

Figure 10. Noise Map of the background noise in an urban area.

Here, the dwellings are indicated by the grey areas. Although they are largely located in areas with relatively low background noise levels (below 50 dB), there are large regions near the motorway that are exposed to background noise levels of over 50 dB, and even 60 dB. This corresponds with indoor noise levels of over 30 dB, which can have a serious impact on the quality of life for the people living there. Combining the entire map with a GIS database containing the Dutch dwellings, we estimate that in the day time, around 50,000 dwellings are exposed to background levels over 60 dB.

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5. Future Scenario's 2006–2020

5.1. Road Traffic

In order to assess further possible increase of background noise levels in the next decades, noise maps were determined for a traffic growth in 2006–2020 of 30% [15]. This means that the equivalent noise level increases with an amount of $10\log(1.3) \approx 1$ dB. Background noise levels however may increase stronger, as more traffic decreases the variance of the statistical distribution of noise levels. For example, double traffic volumes lead to 3 dB increase of L_{Aeq} values, but can cause up to 7 dB increase of background noise nearby the sources. A possible result for the future development is illustrated in Figure 11.

Figure 11 shows a simulation of traffic growth on the major motorways in the Randstad region in the Netherlands, which is the most densely populated. Where the equivalent noise levels will increase with roughly 1 dB, the background noise levels show an increase of over 2 dB at certain motorways. The increase is limited on motorways which already have high traffic numbers, such as the motorway between Utrecht and Amsterdam, the motorway between Utrecht and The Hague, and the ring roads around Amsterdam and Rotterdam. However, the motorways just outside the Randstad region show larger growth of background noise. These can be considered more rural and near quietness sanctuaries. It is likely that with a steady increase of traffic numbers, the region with high background noise levels will spread outside the Randstad.

For this scenario also an estimate was made of the number of dwellings exposed to levels over 60 dB. We believe that around 110.000 dwellings will be exposed to these levels, a doubling compared to the current situation.

5.2. Backgound noise from Schiphol Airport 2008–2020

Using the approach outlined in this paper NLR investigated background noise future development around Schiphol, assuming a traffic growth of 19%. To analyse the average impact on dwellings of the equivalent and background noise levels, an average noise level L was determined over the region of interest (55 × 71 km^2 around Schiphol). This is done according to

$$\langle L\rangle = 10\log\left(\sum_i 10^{0.1L_i}N_i\right) - 10\log\left(\sum_i N_i\right). \quad (14)$$

In equation (14), N_i is the number of dwellings exposed by a noise level L_i the index i refers to the location in the noise map and the summation is taken over the entire region of interest.

Basically the dose indicator is proportional to the average noise level over all dwellings in the region of interest. The noise level chosen can be the L_{Aeq} as well as the L_{90}, resulting in an equivalent and a background dose. These were determined for 2006 and 2020 and the results are shown in Table I.

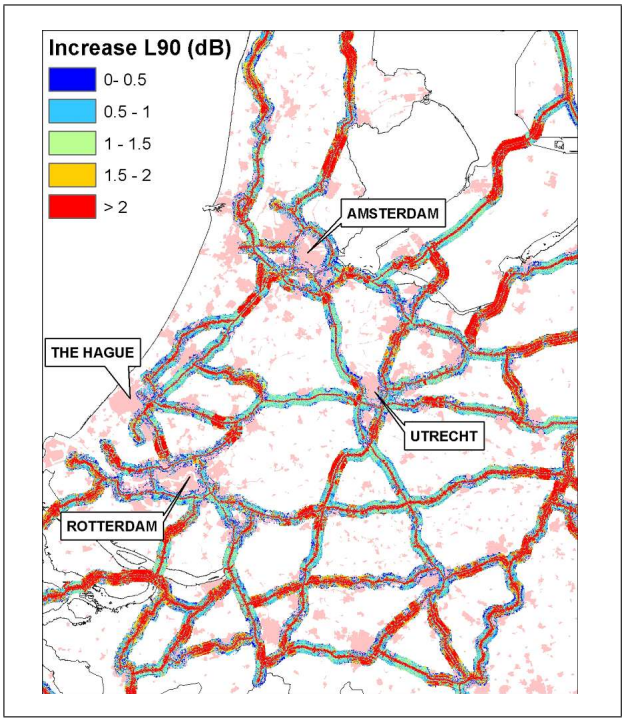

Figure 11. Noise Map of the increase 2008–2020 of background noise on motorways assuming an increase of traffic flow of 30%.

Table I. Average noise levels in dB for a region of 55×71 km^2 around Schiphol airport, for 2006 and 2020.

		Day	Ev.	Night
$\langle L_{\mathrm{Aeq}}\rangle$ [dB]	2006	45.8	45.1	35.6
	2020	46.8	46.1	36.6
	increase	**1.0**	**1.0**	**1.0**
$\langle L_{90}\rangle$ [dB]	2006	31.5	30.0	16.9
	2020	33.2	31.6	18.6
	increase	**1.7**	**1.6**	**1.7**

Table II. The increase of the area around Schiphol airport where the L_{Aeq} and L_{90} exceed 55 dB and 40 dB respectively, for 2006 and 2020.

		Day	Ev.
Area $L_{\mathrm{Aeq}} > 55$ dB [km^2]	2006	143	117
	2020	195	164
	increase	**52**	**47**
Area $L_{\mathrm{Aeq}} > 40$ dB [km^2]	2006	90	56
	2020	463	107
	increase	**373**	**51**

As shown in Table I, the dose levels for the equivalent noise levels increase with 0.8 dB, consistent with the increase of the flights. The average background levels show an average increase of 1.6 dB, showing that background noise levels increase more with increasing flight numbers.

This increase is also shown by looking at the area in which noise threshold values are exceeded. The results

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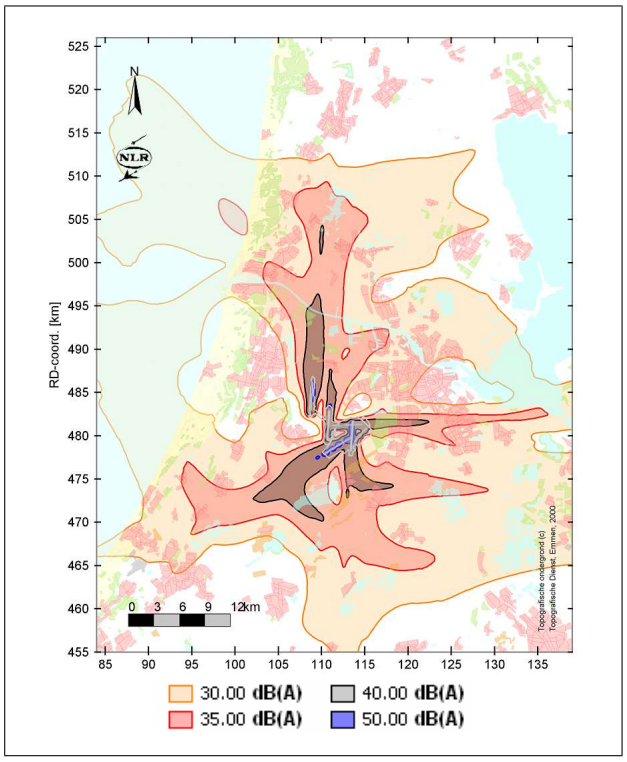

Figure 12. L_{90} contours in the vicinity of Schiphol Airport for 2006.

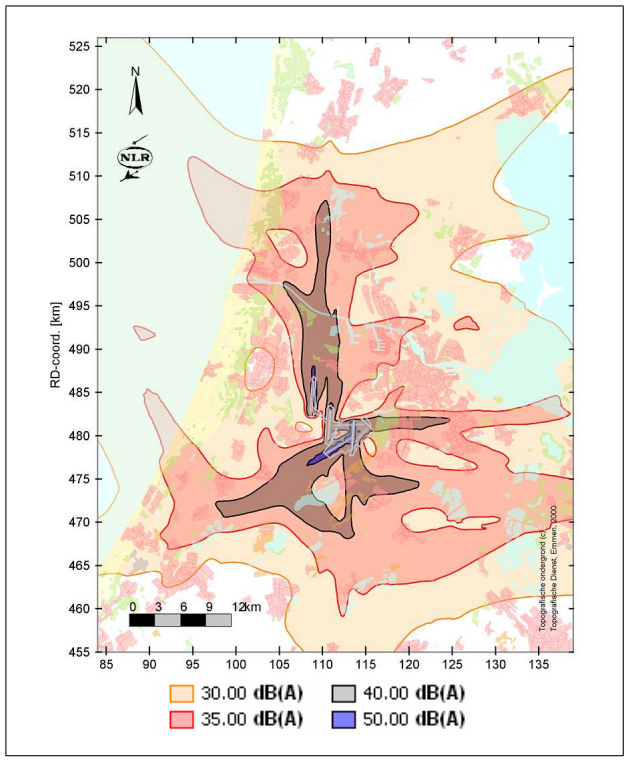

Figure 13. L_{90} contours in the vicinity of Schiphol Airport for 2020.

of the increase in area are shown in Table II. The assumed growth results in a five times larger area during the day time where the background level exceeds 40 dB. This growth is shown in Figures 12 and 13, where the grey areas indicate the regions with the 40 dB exceedence. The Figures also shows the contours for the 30, 35 and 50 dB exceedence, for all of which an increase can be seen as well.

6. Conclusion and Discussion

To first order approximation, environmental background noise from road traffic and airport traffic can be predicted using the model as discussed. Background noise may be of increasing importance for both annoyance and sleep disturbance [3] effects if the number of sources continues to increase.

This study shows that background noise levels will increase faster than equivalent noise levels if traffic numbers keep growing. Currently in noise annoyance studies, background noise is considered to be much less important than equivalent noise levels or peak levels as people tend to be more easily annoyed by single high noise events than an omnipresent 'sound blanket'. In situations where background levels are relatively high, policymakers should be thoroughly aware of consequences of traffic growth. Although an increase of 3 dB in equivalent noise level due to doubling of traffic can be compensated by a silent road surface with 3 dB reduction with respect to a normal pavement, such a measure will only partly compensate for the 7 dB increase of the background level. The soundscape as perceived by residents after this measure will have changed significantly, as the background noise level will have increased by 4 dB as compared to the old situation.

Therefore, the meaning of an increase of background noise levels for environmental quality, speech intelligibility, sleep- and health effects should not be underestimated. Also further increase of background noise might lead to increased disturbance of outdoor social activities and deterioration of areas that are now considered to be quiet sanctuaries. Therefore noise abatement in particular by developing and improving source measures (new and better silent pavings, silent tires, quiet aircraft etc) will be most important in the next years.

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