Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

A method to calculate ambient aircraft background noise

Problem area
Noise limits in the Netherlands for civil airports are defined in L_{DEN}. More aircraft movements are allowed when the aircraft itself become quieter. The stimulus that comes with that i.e. reducing the noise source itself, will be in anyway effective to minimise the noise impact on the ground. But what about the way people experience the noise? In the old days aircraft passages were experienced as incidental events and so was the noise. With an increase in movements this incidental character might be lost. In acoustical terms this means that the background noise rises while the L_{DEN} noise level maintains.

Description of work
This article proposes a new method to calculate the ambient aircraft background noise. The method is based on statistics, similar like it has been proposed in the seventies to estimate road traffic noise.

Results and conclusions
A first validation, considering a site near Amsterdam Airport Schiphol, shows a good match with predicted results.

Applicability
Now that the first technical step to estimate the ambient aircraft background noise is taken new input opportunities rise when doing nuisance studies.

Report no.
NLR-TP-2009-213

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Report classification
UNCLASSIFIED

Date
June 2009

Knowledge area(s)
Aircraft noise

Descriptor(s)
Noise
Background noise

This report is based on a presentation held at Euronoise, Edinburgh, UK, 26-28 October 2009.

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A method to calculate ambient aircraft background noise

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This publication has been refereed by the Advisory Committee AIR TRANSPORT.

Customer	NLR
Contract number	----
Owner	NLR
Division NLR	Air Transport
Distribution	Unlimited
Classification of title	Unclassified
	November 2009

Approved by:

Author	Reviewer	Managing department
10/11/2009	10/11/09	

Contents

Edinburgh, Scotland
EURONOISE 2009
October 26-28

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ABSTRACT

Noise limits in the Netherlands for civil airports are defined in L_{DEN}. More aircraft movements are allowed when the aircraft itself become quieter. The stimulus that comes with that i.e. reducing the noise source itself, will be in anyway effective to minimise the noise impact on the ground. But what about the way people experience the noise? In the old days aircraft passages were experienced as incidental events and so was the noise. With an increase in movements this incidental character might be lost. In acoustical terms this means that the background noise rises while the L_{DEN} noise level maintains.

This article proposes a new method to calculate the ambient aircraft background noise. The method is based on statistics, similar like it has been proposed in the seventies to estimate road traffic noise. A first validation, considering a site near Amsterdam Airport Schiphol, shows a good match with predicted results. Now that the first technical step to estimate the ambient aircraft background noise is taken new input opportunities rise when doing nuisance studies.

1. INTRODUCTION

Noise limits for airports are typically given by equivalent (average) noise levels i.e. L_{DEN}. Due to industries effort it is expected that over the years the noise radiated from individual aircraft will be reduced. This development is in anyway most effective. Reducing the noise at its source will also reduce the noise impact. A reduction of three decibel at the source results allows for doubling air traffic volumes without increasing the equivalent noise level. But in this case, will people living in the vicinity of major airports really experience the same noise burden if air traffic grows?

In the sixties when Dutch aircraft noise regulation came into place, noise from aircraft had an incidental character. In comparison with today's movements only a few aircraft each hour entered or left the airport. After many years of traffic growth, the incidental character of the noise soundscape has shifted towards a more continuous, ambient picture. To express this in technical terms, you may say that for some areas around the airport the ambient background noise has raised over the year due to the noise impact of aircraft. Taking a step into the future when aircraft may become quieter and air traffic may rise further, this could mean that although the equivalent average noise level L_{DEN} will remain constant, aircraft background noise levels may continue to rise.

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To study the impact of the noise climate change above the Dutch National Aerospace Laboratory (NLR) together with National Institute for Public Health and the Environment (RIVM) has developed a method to calculate the aircraft background noise. The method is a first step that enables one to study the development of background noise in the vicinity of airports. Following this step new input opportunities rise when doing nuisance studies.

In the next paragraphs of this paper successively the background aircraft noise methodology, a one-point validation and a case study are discussed. Within this case study the method to calculate the aircraft background noise level is applied on a 2006-scenario and on an indicative 2020 scenario. In the end of this paper conclusions are drawn based on the results of the case study and a discussion paragraph is added.

2. METHODOLOGY

The L_{90} (or L_{95}) is a widely used parameter to indicate the background noise. This percentile noise parameter indicates the noise level, which exceeds 90% (or 95% for L_{95}) during a certain time interval. Figure 1 gives an example in which the blue line indicates a recorded noise level for period of 360 seconds. Due to a flight of an aircraft over the microphone the noise level rises and fluctuates in figure 1 (LAS is the noise level A-weighted measured in 'slow' mode). The horizontal lines represent the percentile noise levels L_{10}, L_{50}, L_{90} and L_{95}. Respectively 10%, 50%, 90% and 95% of the time the noise level is above this line during this period.

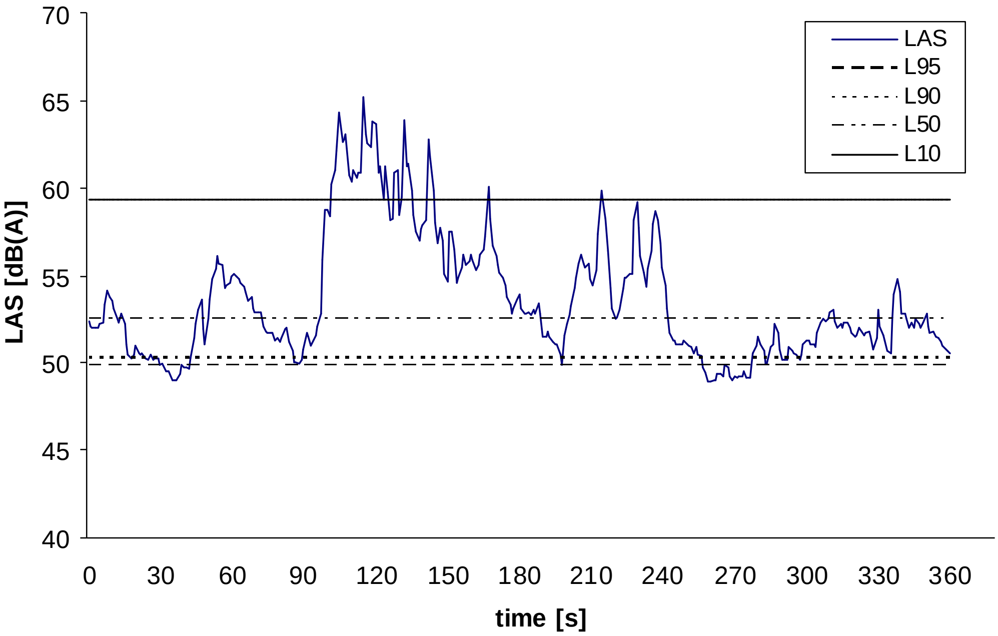


Figure 1: Visualising percentile noise parameters

The proposed method to calculate the background noise level estimates these fluctuations of the noise signal for a year's period. This estimation of fluctuations is based on statistics similar like it has been proposed in the seventies by Kurze [ref.1] for road noise. Jabben [ref.2] has used Kurze's statistics to estimate the background noise for road noise. This approach forms the starting point of the method to calculate the ambient aircraft background noise in this paper.

If traffic is projected on a line source (see figure 2) the relative variance of the sound intensity I: ξ_I can be determined with the left part of equation 1:

$$\xi_I = \frac{\mathrm{var}(I)}{\langle I \rangle^2} = \frac{\langle s \rangle}{2 \cdot \pi \cdot a} \text{ [-]} \tag{1}$$

Where <*I*> is the average sound intensity over the time interval considered.

Taking Kurze's [ref.1] approach it can be shown that for a line source with a Poisson[a] distributed traffic flow density the relative variance ξ_I can be determined using only the distance *a* between the line source and the receiver and the average distance <*s*> between the vehicles (see the right part of equation 1).

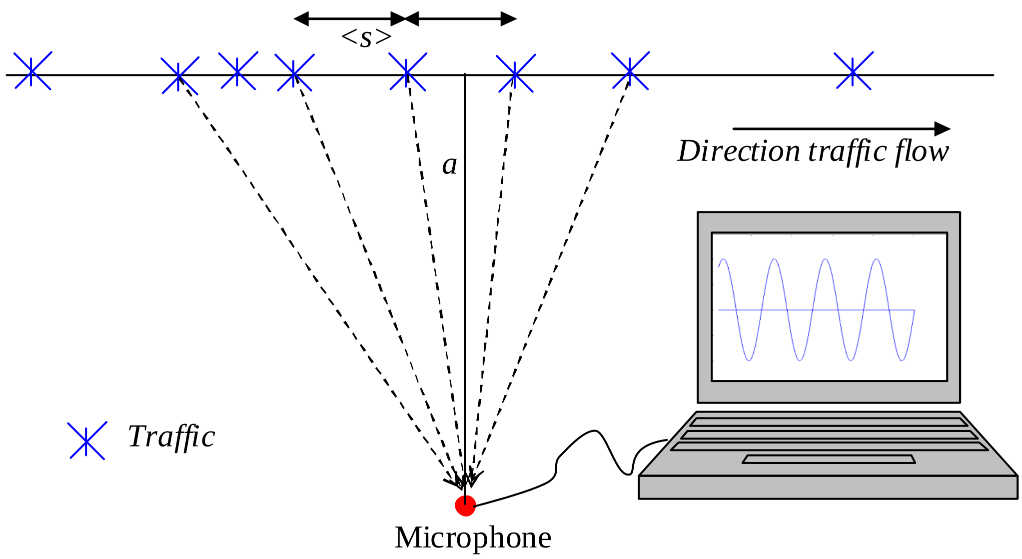


Figure 2: Line source with Poisson distributed traffic flow

Regular aircraft noise models (i.e. INM [ref.3]) do not express source data by intensity levels *I*. Therefore the left part of equation 1 is unusable to calculate the aircraft background noise. Source data for aircraft models is typically given in pressure levels.

Using the variance (as defined by the right part of equation 1) together with the L_{Aeq} given by the outcome of an aircraft noise model, the L_{90} can be estimated according to Kurzes theory by equation 2. Note that L_{Aeq} is related to L_{DEN}. The L_{DEN} is the average noise level (L_{Aeq}) with penalty factors for evening- and night.

$$L_{Aeq} - L_{90} \approx 10\,\mathrm{lg}(1 + 10 \cdot \xi) \text{ [dB]} \tag{2}$$

This difference between the L_{Aeq} and the L_{90} given by equation 2 is not available in analytical form, but only by first order approximation. To estimate the L_{90} of aircraft two additional assumptions are to be made. First: for every runway all takeoffs and landings are projected on an average track. Second: the average sound power and average speed for all average tracks are considered statistically constant. Both these assumptions are

[a] In this case the distance between the sources s, is a statistical variable with probability density function

$$f_{\underline{s}}(s) = \frac{1}{\langle s \rangle} e^{\frac{-s}{\langle s \rangle}}$$

discussed in [ref.5]. Subsequently, for each average track *i* the sound intensity I_i is as follows:

$$I_i = c\frac{N_i}{a_i} \text{ [dB]} \tag{3}$$

Where *N* is the number flights and *c* is a constant. The contribution ratio of the average track *i* to the average sound intensity level over the time interval considered becomes:

$$\frac{I_i}{\langle I \rangle} = \frac{c\frac{N_i}{a_i}}{c\sum_i \frac{N_i}{a}} = \frac{\frac{N_i}{a_i}}{\sum_i \frac{N_i}{a}} \text{ [-]} \tag{4}$$

Therefore the average noise level contribution $L_{Aeq.i}$ can be written as:

$$L_{Aeq.i} = L_{Aeq} + 10\lg\left(\frac{\frac{N_i}{a_i}}{\sum_{i..n}\frac{N_{i..n}}{a_{i..n}}}\right) \text{ [dB]} \tag{5}$$

For each average track *i*, the $L_{90.i}$ is estimate by equation 2. The final L_{90} for the aircraft traffic can be obtained using the following equation:

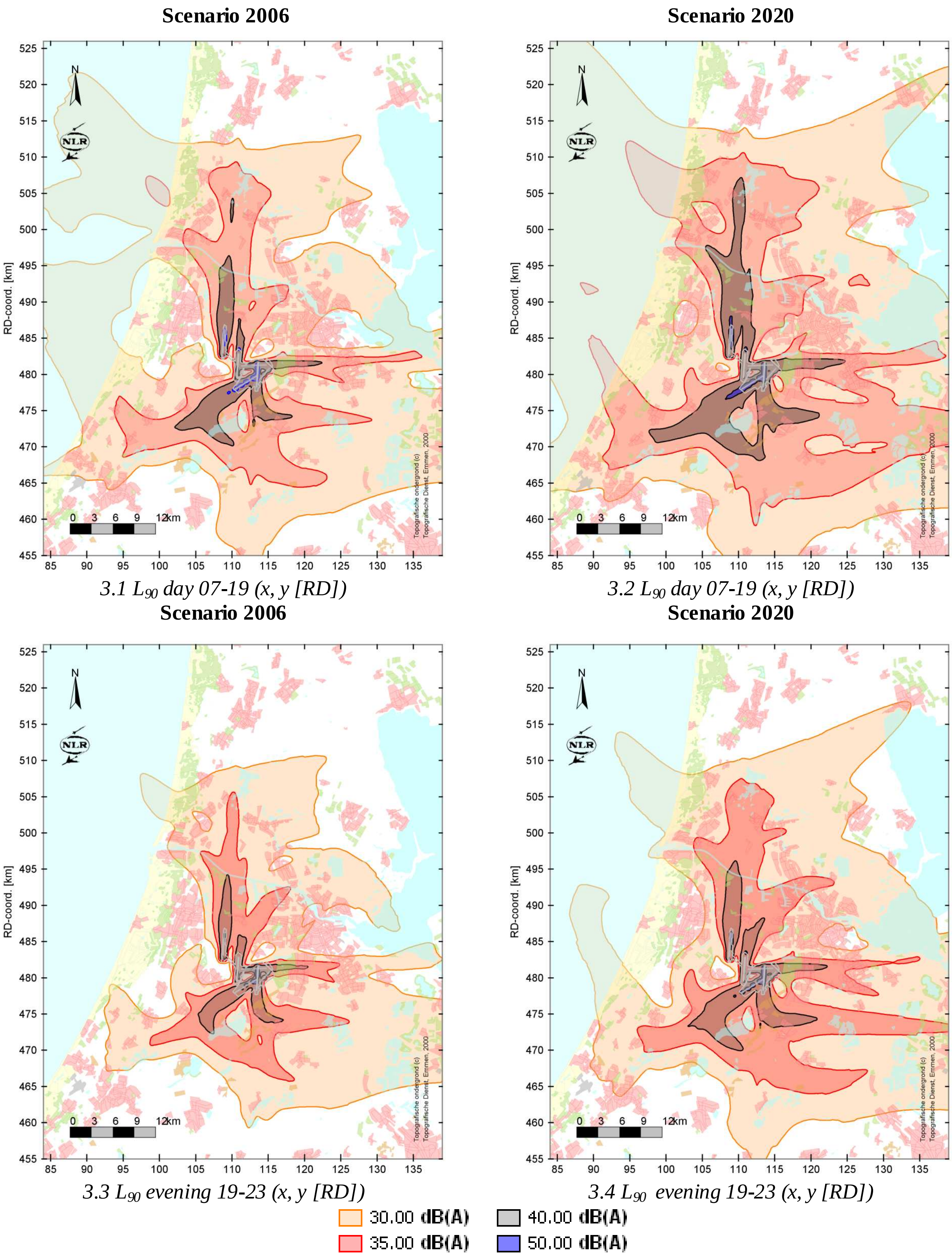
$$L_{90} = 10\lg\left(\sum_{i..n} 10^{\frac{LAeq.i..n}{10}}\right) \text{ [dB]} \tag{6}$$

3. CASE STUDY

A traffic scenario of Amsterdam Airport Schiphol 2006 has been used as input for a case study. Thereby a 30 % traffic growth over 2006-2020 was assumed i.e. from 430.000 flights movements in 2006 to 510.000 flight movements in 2020. In addition, further input data for the case study were:

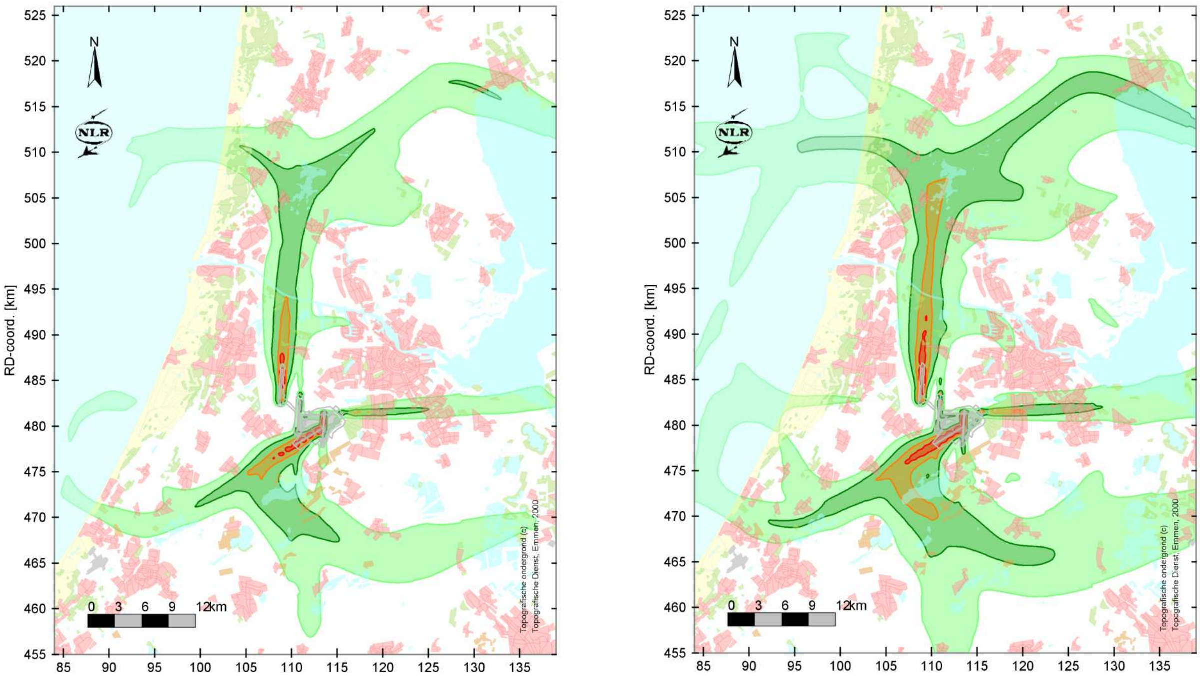
- The average noise level L_{Aeq} in 2006 (for the day-, evening- and nigh time periods), determined by the Dutch calculation for airport noise method [ref.6]
- Nominal ground paths based on numerous flights
- Average height profiles, determined by weighing the appearances of so-called standard height (flight) profiles of the total traffic during the period considered (same traffic and height flight profile data is used as has been used to calculate the L_{Aeq})

Using the above input together with the methodology as described in chapter 2 background noise maps for the daytime (6:00h – 19:00h), evening (19:00h – 23:00h) and night time (23:00h – 6:00h) were calculated. The contour plots of these maps are shown in Figure 3.



3.1 L_{90} day 07-19 (x, y [RD]) — Scenario 2006
3.2 L_{90} day 07-19 (x, y [RD]) — Scenario 2020
3.3 L_{90} evening 19-23 (x, y [RD]) — Scenario 2006
3.4 L_{90} evening 19-23 (x, y [RD]) — Scenario 2020

Figure 3.1-3.4: L90 contours in the vicinity of Amsterdam Airport Schiphol



3.5 L_{90} night 23-06 (x, y [RD]) *3.6 L_{90} night 23-06 (x, y [RD])*

20.00 dB(A) 30.00 dB(A)
25.00 dB(A) 35.00 dB(A)

Figure 3.5-3.6: L90 contours in the vicinity of Amsterdam Airport Schiphol

Results of the case study (as the validation study in the next chapter) were also shown in the congress paper *'Background noise: An increasing Environmental Problem'* [ref.4], in which aircraft background noise were accumulated with the results for background noise produced by road-, rail- and aircraft noise. As outlined in [ref.4], in general the contribution from airport noise to the total environmental background noise is much less than from motorways, as the source densities of the latter are much higher; the impact of background noise from aircrafts especially around motorways is therefore negligible.

Table 1: *L_{90} and L_{Aeq} contours in sq.km^2 by a traffic growth of 30%*

		contour [dB(A)]	2006 [km2]	2020 [km2]	2020/2006 [-]
Day	LAeq	50	394	538	1.4
		55	143	195	1.4
	L90	35	464	989	2.1
		40	90	463	5.1
Evening	LAeq	50	332	445	1.3
		55	117	164	1.4
	L90	35	270	533	2.0
		40	56	107	1.9
Night	LAeq	40	438	600	1.4
		45	169	221	1.3
	L90	25	154	347	2.3
		30	21	59	2.8

In this paper, solely the aircraft background noise contribution is presented. This shows the typical behaviour of ambient noise in case the number of sources increases. Viewing the contour plots in Figures 3.1-3.4 it is noticed and expected that:

- The background noise level rises when traffic growths
- The impact of the traffic growth is bigger of flight movement towards or from the most used runways (i.e. the Polderbaan (18R-36L) and the Kaagbaan (06-24)).
- In general and in line with the results of [ref.4] the calculated ambient aircraft background noise levels are considered to be low. Therefore the background noise levels will be lower in despite of aircraft being louder than Lorries and cars.

The contours plots give us the general results when using the new proposed method and the scenarios 2006 and 2020, but what about the change of the noise climate? In other words will the difference between the average noise level and the background noise level change in the vicinity of airports?

Table 1 gives an overview of the development of noise level contours in square kilometres. Hereby the average noise level of the 2020 scenario has been calculated by increasing the 2006 traffic by 30% assuming aircrafts will not become quieter. The contour area of the 2006 versus 2020 average noise level will approximately increase up to 140%. This increase is low compared to the background noise levels. The contour area for the background noise rises at least 190% for 2020.

4. VALIDATION

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 real time data, based on the flight tracks as obtained from the flight and aircraft noise monitoring system FANOMOS. These comprise of a set of calculated SEL values at known distance between the source and receiver. Although the level data is calculated instead of measured, the real passages times are taken into account, which allows one to accurately determine the time behaviour of the noise level at a certain location. The time series was modelled according to:

$$L_p(t) = 10\lg \sum \left(\frac{10^{0.1 \cdot L_{w,k}}}{4\pi \sqrt{a^2 + v^2 \cdot (t - t_k)^2}} \right) \text{ [dB]} \tag{7}$$

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:

$$L_w = SEL + 10\lg(4av) - D_{air} \tag{8}$$

In which a is the shortest distance between the source path and the receiver, v is the source speed and D_{air} the attenuation factor. To save computation time, the summation is limited to the 20 nearest planes at the time t of interest only. Figure 2 gives an example of the behaviour of the instantaneous level $L_p(t)$ at a receiver located 5 km west of the 'Buitenveldert' (09-27) runway from Amsterdam airport Schiphol from 16.00-17.00 hr at January first of 2007.

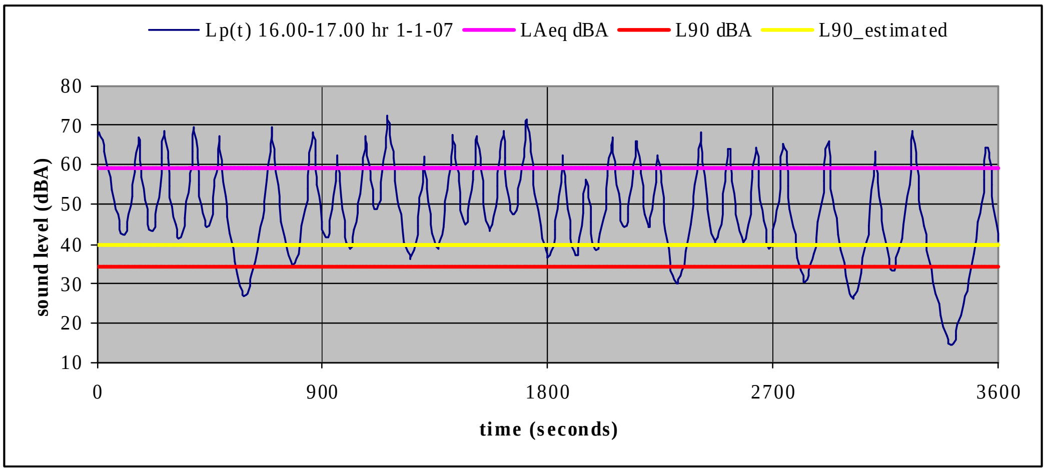


Figure 4: Time behaviour of the sound level due to aircraft passing

Figure 4 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 dBA. This simulated L_{90} can be compared with the predicted background noise level as defined by Equation 2. The relative variance as defined by equation 1 comes at 7.1 and subsequently equation 2 predicts a background level L_{90} of 40 dB. In this case the 90% percentile value is overestimated by 6 dB. The estimated value of 40 dB 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 so as to give an average 24-hour distribution of the observed and predicted background level. Both are given in Figure 5.

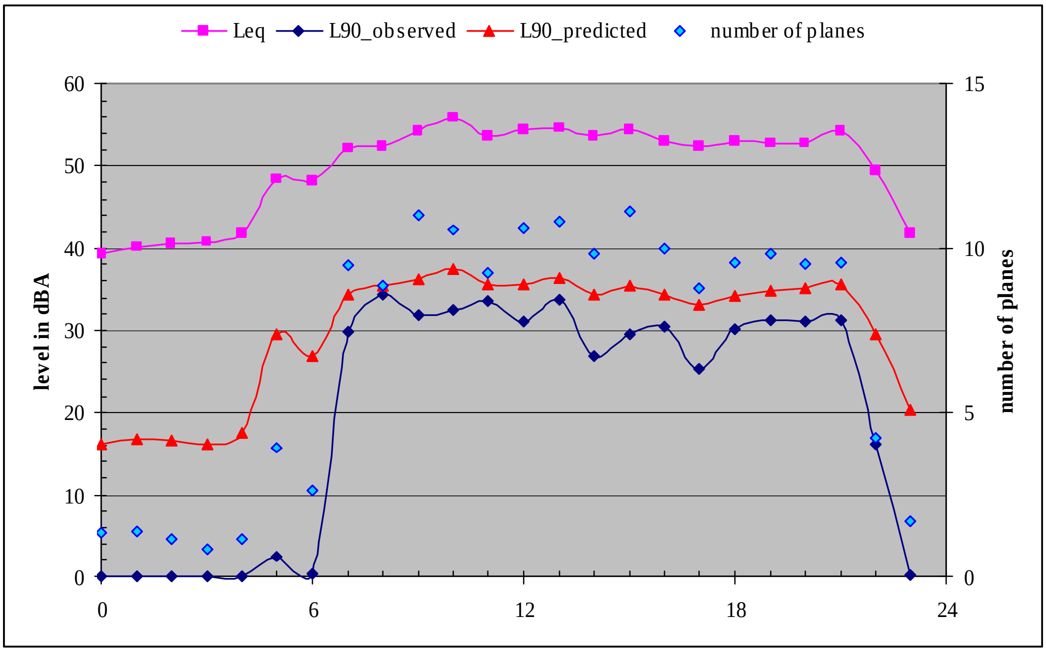


Figure 5: Comparison of the measured and simulated background noise levels

Figure 5 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 21.00 h. 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 road traffic noise. This is probably due to the number of sources involved. As the relative variance becomes larger, the first order approximation as given by equation 2 is less accurate and eventually a more sophisticated statistical model is needed. However with regards to periods in relatively many planes are passing by, the model gives a useful first approximation of the behaviour of background levels.

CONCLUSION

With the method to calculate the ambient aircraft background noise a case study has successfully shown trends in the way background noise develops. However the method has not fully been validated (only for one location point). It is believed that it gives useful first approximations.

If air traffic will grow further it is expected the noise climate changes. The background noise levels will rise stronger than the average noise level. Taking into account that aircraft becomes quieter this noise climate change i.e. differences between average noise and background noise will become smaller.

DISCUSSION

The accuracy as well as the need for a method to calculate the ambient aircraft background noise can be doubted. First the accuracy: The method is designed as a peel on an existing method to calculate the average noise contours around airports. The method to calculate average noise levels by itself has not a high reputation regarding the accuracy in relation with in-situ measurements. This means that methods based on this become even less accurate. Thereby extra assumptions were made to apply the background noise method for road traffic. Every extra assumption will add uncertainties and therefore may have influence on its outcome. Therefore the proposed method in this paper must be considered as a rough approximation of the ambient aircraft background noise and can only give an indication of developments.

Second the need to calculate the ambient aircraft noise levels: results show the impact of aircraft to the overall background noise (incl. road-, rail- and industrial noise) is low. The aircraft background noise is just visible in [ref.4], therefore it might influence the way people experience aircraft noise. The first technical step to estimate the ambient aircraft background noise has now been taken and maybe it gives new input opportunities and views while doing nuisance studies.

Besides the constant need by scientists to express nuisance in a better way, policy makers are also keen to set limits using one metric for different environmental noise sources. Nowadays the L_{DEN} is mainly used for road-, rail and aircraft noise, but only gives a limited description of the full soundscape. The metric L_{90} (together with the L_{DEN}) might be well-liked as it comes to setting limits for soundscapes. The L_{90} is one metric that's widely used for different environmental noise sources.

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