



## Executive summary

# Analyses of measurements to enforce and to reduce aircraft noise



### Problem area

Aircraft noise in the Netherlands is restricted by calculations only. Advantages of using calculations are its good predictability and its fairness. This predictability helps to plan the operations by taking into account the noise beforehand. Its fairness is expressed in the univocal way of calculating the noise levels. However, the experience of people living in the vicinity of airports is not always in line with the outcome of the noise calculations: they have more faith in noise measurements.

### Description of work

This paper looks into the possibilities of using noise measurements for enforcement purposes, similar as with fining a driver for exceeding the speed-limit.

### Results and conclusions

This paper discusses practical downsides to implement noise measurements for enforcement in

the outer area of Schiphol. It is studied whether the high noise level can be ascribed to the airline or could be the result of factors outside the control of the airline. As it turns out a 10 dB(A) correction (having a reliability of 99%) is to be subtracted from the measured noise levels. This leaves no airline to get any fine at all in the outer area of Schiphol, rendering this measure meaningless. Instead it is suggested that incorporating monitored noise levels to communicate noise issues to airlines seems a better way to reduce the number of noisy events now and in the future.

### Applicability

The investigation gives us more sight to include measurements in enforcements. Although some founding's are considered weak (as expert judgements are done), the results supports the policy making process.

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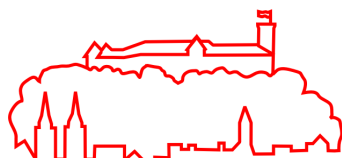
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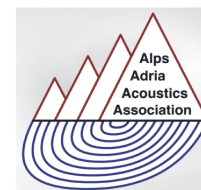


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## **Analyses of measurements to enforce and to reduce aircraft noise**

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### **ABSTRACT**

Aircraft noise in the Netherlands is restricted by calculations only. Advantages of using calculations are its good predictability and its fairness. This predictability helps to plan the operations by taking into account the noise beforehand. Its fairness is expressed in the univocal way of calculating the noise levels. However, the experience of people living in the vicinity of airports is not always in line with the outcome of the noise calculations: they have more faith in noise measurements. Investigations are therefore done to use measurements for enforcement purposes. As this paper shows, practical downsides make implementing noise measurements to uphold the law difficult. Incorporating monitored noise levels to communicate noise issues to airlines seems a better way to reduce the number of noisy events now and in the future.

### **1. INTRODUCTION**

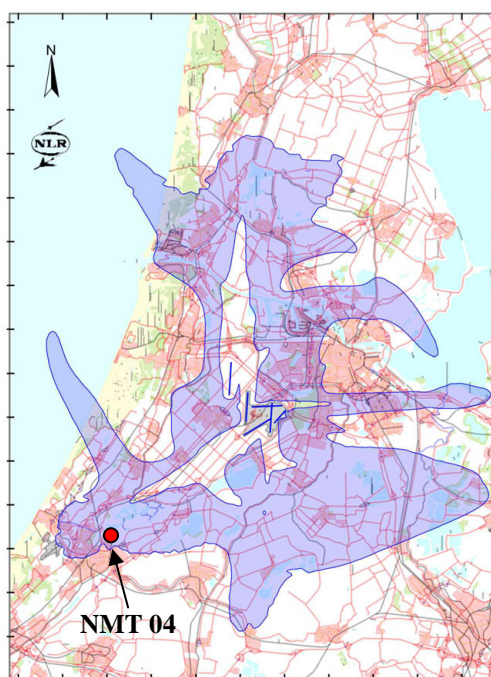
“Measuring results in knowing the truth”. With this motto, residents around airports would like to see noise measurements being used for law enforcement. This is natural and the idea seems simple, however the implementation is rather difficult as there are practical downsides. The current Dutch environmental Act to protect residents from aircraft noise provides noise limits based on calculations only. The method to calculate these noise limits is prescribed [1]. Limits are given in annual doses like the  $L_{den}$  and  $L_{night}$ . The advantages of using noise calculations in contrast to noise measurements are its predictability and its fairness. Airport operations are often restricted by noise regulations. Knowing the environmental operational margins in advance is crucial for a continuous and a reliable airport operational management. The fairness of protecting residents is expressed by the univocal way of calculating: both the limits and the yearly results are based upon the same calculation method. However, the experience of people living in the vicinity of airports is not (always) in line with its yearly outcome. In this paper, analyses of measurements are studied to investigate ways for incorporating measurements in upholding the law.

## 2. APPROACH

As mentioned in the introduction, measurements to uphold the law have practical downsides. Standards like [2] guarantee measured noise levels to be accurate within 1 dB if the right equipment is used and the measurements were carried out within a certain range of weather conditions. The measured truth (i.e. reality in this paper) and the result of the noise measurement may therefore have an offset of  $\pm 0.5$  dB maximum. For an airport like Amsterdam Airport Schiphol with more than 400.000 flights a year, having a negative offset of 0.5 dB in the  $L_{den}$  noise contour means an allowance of at least 48.000 additional flights. From an environmental protection policy point of view these uncertainties are considered unwanted. For noise calculations while using a uniform method this uncertainty does not exist and limits are easily expressed in more than one decimal.

In the above example of having an offset of 0.5 dB it was assumed that measurements can take place all year round. Standard [2] particularly states that noise is to be measured while it is dry. This means that noise measurement results may even have a bigger offset when it rains. One may decide to leave those events out, but this means that during rainy conditions there are no noise restrictions at all. From an environmental protection policy point of view this is again considered undesirable, as residents should have a minimum environmental protection at all times.

Taking into account these practical downsides, noise measurements for restricting the yearly number of operations seem impracticable. Therefore ways have been suggested to set-up a mechanism to fine airlines for individual events that are “too” noisy in order to stimulate them to reduce the number of noisy events. This mechanism can be compared with fining a driver for exceeding the speed-limit.



**Figure 1.** Indicative outer area of Schiphol

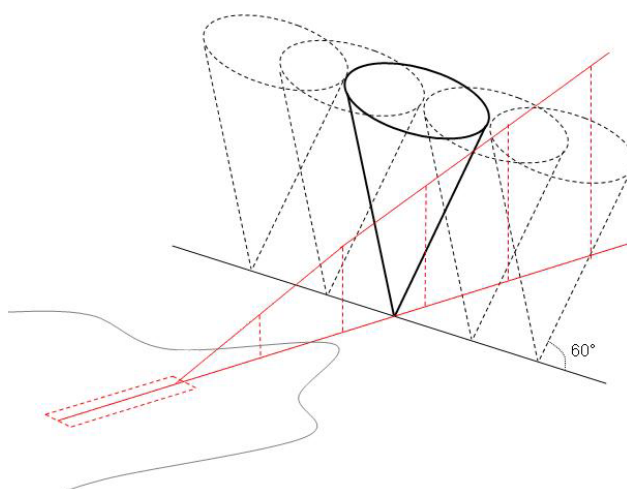
Such a mechanism is already operational at London Heathrow where at 6.5 km from the runway noise levels from passing aircraft are measured (close to a certification point location [3]). Airlines can be fined if they make more noise than allowed at that point. Typically only heavy and large aircraft flying deviant procedures can exceed the allowed noise level, resulting in a few penalties a year. At 6.5 km from Schiphol’s runways however there are no

large densely populated areas. As the mechanism aims to protect residents in the so called “outer area” the noise measurement location is to be chosen further away than 6.5 km (Figure 1). This means also that setting a limit for “too much” noise becomes less comparable with certification noise levels. Certification noise levels are typically measured at 6.5 km from the runway.

For a fine to be legal, it must be proven that something was done wrong (i.e. bad behaviour). The pilot flying the right procedure and following the instructions of the air traffic controller should not be punished. With this in mind “too much noise” should be quantified. Thereby a discussion on the measured result itself should be prevented. With speed cameras for instance, 3 km/h is being subtracted of the measured speed to correct for inaccuracies of the measurement. By applying this correction, the outcome will have the necessary reliability of more than 99%.

For the mechanism suggested in this paper the approach is similar, whereas the correction will be in decibels. Analyses of measurements around Schiphol are done to study what the necessary correction might be for the suggested way of using measurements for enforcement purposes. To keep the correction for reliability as low as possible the following boundary conditions are defined:

- Wind conditions during measurements have to be lower than 8 m/s, assuming aircraft passages result in noise levels at the measurement locations higher than 60 dB(A), and background noise levels caused by wind do not affect the measurements.
- To determine “too much noise” the microphone’s position is in the point of a cone and aircrafts have to pass through this cone (see Figure 2). This boundary condition limits the influence of lateral disturbances, i.e. crosswind or ground effects.
- Noise is to be measured with full reflections, in order to be able to eliminate the influence of (variable) ground reflections.
- Measurement locations are to be chosen in a way that building reflections do not influence the result.
- If the maximum noise level of the measured aircraft noise event does not exceed the background noise by at least 10 dB(A) the event can not be used for enforcement. In this way the airline is not fined due to high noise levels from other sources.



**Figure 2.** Flying through cones

### 3. ANALYSES OF MEASUREMENTS

The correction applied to measured noise levels before fining will depend on legal requirements and is not discussed here. However, to indicate what the correcting might be, the margin of measurement with its reliability is determined using the Guide to the expression of Uncertainty in Measurement (GUM) [4] & [5]. For this, data of Noise Monitoring Terminal (NMT) 04 (see Figure 1, left) are used, having wind conditions between 0 and 8 m/s. First different influence factors of the uncertainty in NMT 04 measurements are appointed:

1. Instrumentation  $(\mu_1)$
2. Noise disturbances  $(\mu_2)$
3. Ground reflections  $(\mu_3)$
4. Building reflections  $(\mu_4)$
5. Weather conditions  $(\mu_5)$

Second, for each influence factor the margin of the uncertainty has been set either by estimation or by analyses of measurements. The influence factor  $(\mu_i)$  factor multiplied with its squared individual sensitivity coefficient  $(c_i)$  summed under the square root gives the combined margin of the uncertainty:

$$u_c = \sqrt{\sum_i c_i^2 u_i^2} \quad (1)$$

The expanded uncertainty  $U$  having a reliability of 95% or 99% is calculated by the covering factor  $(k_p)$ , assuming a Gaussian distribution.

$$U = k_p u_c \quad (2)$$

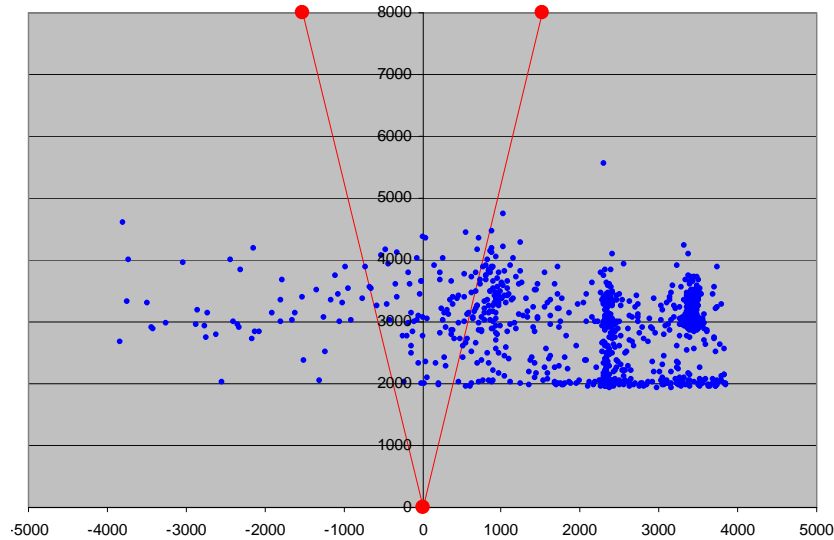
**Table 1.** Coovering factor  $(k_p)$  assuming a Gaussian distribution

Reliability $p$ (%)	95	99
Covering factor $(k_p)$	1.960	2.576

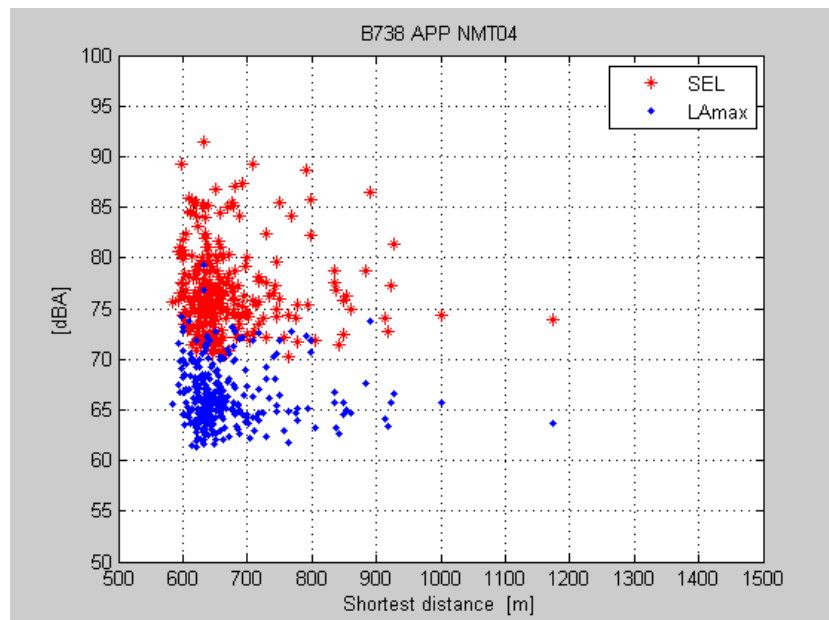
While using first class measurement equipment the uncertainty for instrumentation errors is given by the manufacturer:  $\mu_1 = 1$  dB(A). NMT 04 has an automatic detection determining aircraft noise events. Errors due to disturbances of other noise sources may occur which makes  $\mu_2 = 0.5$  dB(A) when doing an expert judgment. The influence of reflections however is estimated by performing calculations at different angles of incidence, but in accordance with the cone conditions (see Figure 2) giving  $\mu_3 = 0.5$  dB(A) &  $\mu_4 = 0.2$  dB(A). The uncertainties due to weather influences are determined by analyses of measurements.

Figure 3 shows aircraft flying through the NMT 04 cone with a perpendicular cut of flying direction heading runway 06. Every dot is an aircraft flying through this surface in the month October 2006. Below in Figure 4 the measurement results are plotted in SEL and  $L_{Amax}$  of B737-800's flying through the NMT 04 cone in the months October 2006, January 2007, April 2007 and July 2007.





**Figure 3.** Approaches through NMT 04's cone (x-axes in metres, y-axes in ft)



**Figure 4.** Noise results of B737-800 approaches through NMT 04's cone

The  $L_{Amax}$  noise data consisting of 275 samples has been used to determine the uncertainty due to different weather conditions (i.e. all B737-800 events in the months October 2006, January 2007, April 2007 and July 2007 flying trough NMT 04's cone). To exclude weather conditions (as good as possible) the noise data is corrected for distance based on spherical spreading and atmospheric absorption. All flights are assumed to pass on the average shortest distance of the 275 flights. Differences in engine thrust, bank angle, etc. could not be corrected for. Influence factor  $\mu_5$  will therefore be overestimated making the expanded uncertainty U a 'worst case' value. With the standard deviation of the 275 corrected  $L_{Amax}$ 's  $\mu_5$  becomes 3.7 dB(A). Taking all the mentioned influence factors into account, while having a reliability of 95% or 99%, will result in a correction to be applied before fining of respectively 8 dB(A) or 10 dB(A). This is only applicable for aircraft flying between 2000ft and 4000ft trough the cone (see table 2) and having wind conditions between 0 and 8 m/s.

**Table 2.** Indicative reliability margins of aircraft flying between 2000ft and 4000ft through the cone

<i>Reliability</i>	95%	99%
<i>Correction</i>	8 dB(A)	10 dB(A)

#### 4. CONCLUSIONS

The influence of having different weather conditions dominates the correction to be subtracted before imposing a fine. With the suggested boundary conditions, the correction may decrease further in contrast with the GUM study for NMT 04. However, if any discussion on the legitimacy is to be prevented, a high reliability like 99% is desirable. This means that 10 dB(A) is to be subtracted of the measured noise level before considering whether the noise event was “too” loud (i.e. bad behaviour). This leaves no airline to get any fine at all in the outer area of Schiphol, rendering this measure meaningless. As mentioned earlier, implementing measurements to uphold the law seems a simple idea but is actually rather complex. Despite of this the wish of the residents to implement measurements to uphold the law and to reduce aircraft noise remains.

#### 5. CONTINUANCE

New steps are taken leaving the stringent legal requirements off side. The new suggested manner is a mechanism where airlines are being selected based on causing the highest monitored noise levels in residential areas around Schiphol. After having made the selection, a dialogue must start between these airlines and the authorities to determine the cause and to look for solutions for reducing the number of high noise levels. This process will most likely draw great attention from the public and should therefore be conducted very carefully. With this mechanism in place the noisy events of today may become quieter tomorrow (assuming something can be done to reduce the noise). This path, also followed by other airports including San Francisco [6], seems a promising method for incorporating monitored noise levels in addressing noisy events.

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