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Abstract

In order to minimise the differences in noise exposure between forecast and control in specific control points, a new forecast model is described, based on historical noise data at the control points. By clustering the noise data of individual flights as function of aircraft type (or category), runway, route and flight procedure, energetically averaged noise levels are obtained. From traffic forecasts the number of flights for the same cluster of parameters can be extracted. By combining the traffic forecast and the averaged noise levels, a consistent noise exposure forecast in L_{den} is obtained for each control location. First verifications of this concept show a significant reduction of the differences between forecast and enforcement.

1 Introduction

With the realisation of a fifth runway at Amsterdam Airport Schiphol (AAS) in the year 2003, the Dutch government has decided to introduce a new system of noise regulations at the same time. In the new system:

- The Dutch Kosten noise load descriptor (Ke) will be replaced by the European L_{den} metric.
- Present day noise enforcement using a noise contour (zone), will be replaced by control at a limited number of so called control points located in residential areas around the airport. Based on a forecast traffic scenario, a noise model is used to calculate the noise load at all

control points in order to set the noise exposure limit for each control point. The actual noise exposure at each control point must not exceed the limit.

- In the period 2003-2005+, noise monitoring and enforcement will be based on model <u>calculations</u> with FANOMOS (Flight track and Aircraft NOise MOnitoring System).
- On the long term (2005+), noise monitoring and enforcement, will be based on noise <u>measurements</u> at fixed monitoring sites.

During the establishment of the noise limits at the control points, it is necessary to study the consistency of the new system of noise regulations. Ideally, a traffic forecast, which is realised exactly in the real world, should result in exactly the same predicted noise loads as during enforcement. As long as enforcement is based on model calculations, this necessity can be fulfilled by using identical models in both enforcement and forecast[1]. In The Netherlands at present, the noise model for forecast and enforcement are identical except when it comes to the handling of flight tracks with corresponding dispersion. In forecast models, a Gaussian (symmetric) probability function is used[2] in modelling the track dispersion while in enforcement the actual track of each flight is used (FANOMOS). This leads to inconsistency of the system because the actual dispersion appears to be a-symmetric.

If noise enforcement is to be based on noise measurements, unambiguous results ask for a forecasting model that eliminates possible differences with measurement results. Present day noise models show differences with measurements of several dB's (see for instance [1] and [2]) leading to inconsistencies in the system as well. Reasons for differences between calculations and measurements originate from errors in Noise Power Distance (NPD) tables, errors in aircraft performance data, variations in atmospheric conditions not taken properly into account, variations in track dispersion, reflections at the monitoring site, aircraft categorisation, etc..

This paper describes a forecast model, which minimises the differences between noise exposure forecasts and enforcement by using historical measured data as a reference data set at each control point (chapter 2). The concept of the forecast model is verified in chapter 3.

2 Measurement model

In order to maximise the consistency of the new system of noise regulations, an aircraft noise forecast model is studied, based on a representative reference data set of each specific control point. If this data set originates from measurements at noise monitoring sites this model

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[1] It should be noted that forecasts will always be based on calculations.

[2] In the new system of noise regulation, the dispersion function is input and can also be a-symmetric.

is called *measurement model*. If this data set originates from FANOMOS it is called *hybrid model* (radar tracks are measured and noise levels are calculated).

The L_{den}-value at each control point i is calculated with:

$$L_{den,i} = 10 \log \left(\sum_{j=1}^{N} w_j \cdot 10^{SEL_{i,j}/10} \right) - 75 \qquad (1)$$

where $L_{den,i}$ the L_{den}-value at control point i, N the number of aircraft movements in one year, w_j the weight factor: 1, 3,16 or 10 (day, evening or night), $SEL_{i,j}$ the Sound Exposure Level (SEL) in dB(A) at control point i from flight j, j a dummy. Note that $SEL_{i,j}$ can be obtained from both measurements and calculations.

Each noise event is at least identified by the *aircraft type*, the *route*, the *flight procedure* and the *runway* that was used. Corresponding with this event, the SEL-values are available. By clustering the measured data of individual flights as function of a unique combination of the four given identifiers (cluster), energetically averaged SEL-values can be obtained. The statistically averaged noise levels implicitly contain all variations in route dispersion, atmospheric conditions, aircraft performance, aircraft engines and site dependent circumstances over the ensemble period[3]. Acting like that equation (1) can be rewritten to:

$$L_{den,i} = 10 \log \left(\sum_{k=1}^{N_{cluster}} N_{eff,k} \cdot 10^{SEL_{i,k}/10} \right) - 75 \qquad (2)$$

where $N_{cluster}$ is the number of clusters, $N_{eff,k}$ the number of effective aircraft movements in one cluster k and $SEL_{i,k}$ the energetically *averaged* SEL-value in control point i from cluster k. Note that in the number of effective aircraft movements in each cluster k, the weight factor for day-evening-night is implemented, so $N_{eff,k}$ is equal to $\Sigma(w_j N_j)_{,k}$.

Traffic forecasts usually give the number of flights for the same cluster of identifiers. Combining the traffic forecast with the averaged noise levels results in the noise exposure at the control location.

The main advantage of this forecast model is the minimisation of differences between forecast and enforcement due to the use of statistically averaged site-specific data. As long as for instance the influence of reflections is implicitly embedded in the averaged noise levels of the clustered database, this effect will also be taken into account in the forecast. One can choose for correcting the measured noise levels for reflections but this will not improve the consistency of the noise system, as long as the effects are equally taken into account in both forecast and enforcement.

The main disadvantage of the model is that sufficient measurement data must be acquired, before stable averaged noise levels are obtained for each cluster of identifiers. A possible

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[3] If necessary, the time period of the flight (i.e. day/night) is an additional identifier.

change in e.g. routes asks for new data acquisition, making the old data useless. Another disadvantage of the model is the restricted validity at the considered control points only. The (stability of the) $SEL_{i,k}$-value forms the basis for sufficient accuracy of the new forecast model. If the $SEL_{i,j}$-values are derived from FANOMOS *(hybrid model)*, it implicitly contains track dispersion only (phase 1). If the $SEL_{i,j}$-values are derived from noise measurements *(measurement model)*, it contains track dispersion, operational influences, meteorological and site specific circumstances (phase 2).

3 Verification: a test case (phase 1)

3.1 Reference data set: planning year 2000

In order to verify the presented *hybrid model* for phase 1, the individual $SEL_{i,j}$-values for all flights j to or from Amsterdam Airport Schiphol in planning year 2000 (which runs from November 1st 1999 to September 30th 2000) were calculated with FANOMOS at 34 representative control points around the airport [3]. The results retrieved from this reference set of historical data forms the basis of the hybrid model. The control points are all located in (the vicinity) of residential areas. The distance between control point and airport varies between approximately 1,5-20 km. Table 1 shows a selection of the average SEL-values at each control point (CP) for each cluster, obtained from planning year 2000[4].

Nr	Clusters				Control Point						
	Runway	Route	Category	Procedure	CP1	CP2	CP3	…	…	CP33	CP34
1	04	AND	004	0000	29,1	31,6	45,8	…	…	35,1	75,1
2	04	AND	004	1000	8,1	12,6	20,4	…	…	62,7	37,9
3	04	AND	012	0500	49,8	46,3	51,6	…	…	42,2	65,1
…	…	…	…	…	…	…	…	…	…	…	…
3632	27	VLS	004	000	26,6	37,0	68,1	…	…	34,8	36,2

Table 1: Example of retrieved cluster information for planning year 2000 (AAS)

Applying the presented cluster procedure for planning year 2000 results in 3632 clusters of equal 'runway-route-aircraft category-flight procedure-combination'.

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[4] Rather low averaged SEL noise levels are obtained at control points, which are located at large distances from the source, due to the lack of a threshold level in L_{den} calculations.

3.2 Verification with planning year 1999

The noise exposure metric L_{den} for AAS planning year 1999 can now be calculated by combining the reference data set (AAS planning year 2000) and the number of effective aircraft movements for the considered year (AAS planning year 1999):

$$\{L_{den,1} \cdots L_{den,34}\}_{1999} = 10\log\left(\{N_{eff,1} \cdots N_{eff,3632}\}_{1999} \cdot \begin{bmatrix} 10^{SEL_{1,1}/10} & \cdots & 10^{SEL_{1,34}/10} \\ \vdots & \ddots & \vdots \\ 10^{SEL_{3632,1}/10} & \cdots & 10^{SEL_{3632,34}/10} \end{bmatrix}_{2000}\right) \quad (3)$$

3.3 Results

Table 2 shows a selection of the results from the noise load calculation L_{den} for planning year 1999 with the use of the *hybrid model* (phase 1), compared to the original FANOMOS calculation for 1999 and the calculation using modelled routes with Gaussian dispersion.

CP	*Hybrid model* (1)	FANOMOS (2)	Modelled routes (3)	Δ (2)-(1)	Δ (2)-(3)
1	51,25	51,18	52,25	-0,07	-1,07
2	55,15	55,18	56,04	0,03	-0,86
3	50,99	50,99	51,76	0,00	-0,77
4	61,97	62,10	64,26	0,13	-2,16
5	56,44	56,55	57,56	0,12	-1,01
6	51,43	51,66	52,20	0,23	-0,54
7	56,30	56,24	55,70	-0,06	0,54
8	52,85	52,74	54,55	-0,11	-1,81
9	57,73	57,57	57,92	-0,16	-0,35
10	54,59	54,98	54,33	0,39	0,65

Table 2: Results from the L_{den} calculations (in dB(A)) for AAS planning year 1999 using the measurement model phase 1 (1), FANOMOS (2) and modelled routes with Gaussian distribution (3)

The remaining differences between the hybrid model and FANOMOS are due to variations in route dispersion between the planning years 1999 and 2000.

Conclusions and future work

A first validation of the measurement model concept shows promising improvements in reducing differences between forecast and enforcement calculations. The *hybrid model* (phase 1) can be used to eliminate the effect of differences in route dispersion (predicted and actual) on the noise load L_{den} [dB(A)]. Compared to modelled routes, the absolute differences of the L_{den} calculations with FANOMOS are significantly reduced at all considered control points. In the near future the *measurement model* will be validated using noise measurements from noise monitoring sites (phase 2).

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