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A method to quantify the noise annoyance in an airport community

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ABSTRACT

Most methods for quantifying annoyance from aircraft noise only consider residents that are highly annoyed. The much larger population that are annoyed to a lesser degree are usually neglected in such calculations.

A method has been proposed that combines the noise level and the number of exposed people in order to give a single-number quantification of the total annoyance experienced by an airport community. The method is particularly useful for assessing the effect of changes in airport operations.

1. INTRODUCTION

Noise from aviation impacts the community around an airport in various ways (World Health Organization, 2018). The most prominent impact, *i.e.,* the impact that is experienced by most residents, is "annoyance", and, if the airport is open for night-time operations, also sleep disturbance. Several methods have been launched to predict the annoyance impact based on measurements or predictions of the physical noise environment (World Health Organization, 2018), (Miedema & Vos, 1998). Such methods, however, can only be used to get a broad overview of the general situation. They fail to give a detailed description, especially of the effect of changes in the airport operations. The main reason for this is that the annoyance response is only partly dependent on the cumulative noise exposure. About two-thirds of the variance in the annoyance response can be explained by other non-acoustical factors (Basner, et al., 2017). The only way of getting a reliable description of the annoyance situation is to conduct a social survey (Fidell, et al., 2011), preferable using standardized methods for easy inter-survey comparisons (ISO, 2021).

The result of an aircraft noise annoyance survey is typically a dose-response curve, valid for that particular airport, showing the prevalence of highly annoyed people among the noise exposed population. This is the preferred way of characterizing the annoyance situation (FICON, 1992), but this dose-response curve gives no information about residents that are annoyed to a lesser degree than highly annoyed, nor does it give any information about the real extent of the annoyance in terms of number of people that are actually affected.

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For transportation noise sources (road, rail, air) the annoyance score function can be described by the following equation (within given exposure limits):

$$AS = k\,(L_{den} - X) \qquad \text{[annoyance score]} \qquad \text{Eq. 1}$$

The slope of the linear function, k, is similar for all transportation noise sources. A mean value for k for road, rail and aircraft noise is $k = 0.0158$. For aircraft noise alone the slope has been found to be slightly steeper, $k = 0.016$.

The linear function indicates that a certain increase in the noise level results in a corresponding increase in the annoyance score regardless of the absolute noise level. This confirms the assumption by Schultz (1978) that the annoyance increases as does the loudness function.

The value of the annoyance score is dependent on the zero-crossing (X dBA) of the linear function. Values for X from different aircraft noise surveys can vary ± 10 dB or more. This can be attributed to the effect of non-acoustic factors (Fidell, et al., 2011). Miedema and Vos (1998) based their dose-response curve for aircraft noise on 20 different surveys. The average value for the zero crossing for these surveys is X = 33.4 dB. However, if the task is to monitor changes in the noise annoyance situation at one particular airport, the absolute value of the annoyance score is not critical. The annoyance score is a quantification of the annoyance experience by a person exposed to noise. Similarly, the sum of the annoyance scores from all the residents around an airport, can be used as a quantification of the total annoyance experienced by that community. This quantity is therefore useful for noise management and control.

When the total annoyance impact on the community can be expressed by a single number, the following noise management measures is possible:

- The airport and the individual airlines may be granted permission to operate only within quantifiable impact limits
- Landing rights may be awarded and possibly priced based on individual impacts
- Limits for future expansions may be easily quantified
- Targets for noise mitigation measures may be quantified

The *total annoyance quantity* can be used for regulatory purposes. Permission to operate an airport can, for instance, be granted on the condition that the total annoyance impact on the neighborhood community is kept within agreed limits, expressed by the total annoyance quantity. An expansion may be accepted provided that the increase in the total annoyance quantity does not exceed a certain level, and targets for impact mitigations can be expressed in numbers that are easily understood, etc.

In the following discussion the annoyance quantity will be expressed in units of MIMEs (after the initial EU project). The quantity "1 MIME" is equal to one person extremely annoyed by aircraft noise, (annoyance score 1.0) or two persons moderately annoyed (annoyance score 0.5), etc.

3. CALCULATION EXAMPLE

The total annoyance quantity for an airport community can be found by following this simple procedure:

1. Establish a "grid" of cells around the airport, for instance 100 m by 100 m. The grid must include all the impacted residents in the community
2. Measure or predict a noise level that is representative for each grid cell, for instance the noise level in the middle of the cell

on average the impacted population around this airport is a little less than moderately annoyed (AS = 0.44).

3. PRACTICAL USE OF THE TOTAL ANNOYANCE MODEL

The model is particularly useful for assessing the effect of various changes in airport operations as illustrated in the examples below.

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3.1. Redirecting traffic

A visual inspection of the data in Figure 2 shows that the noise situation seems quite symmetrical with an equal amount of traffic in each direction, see panel 1. The population on the other hand, is higher on the west side than on the east side of the runway. The population on the west side of the symmetry line amounts to 20,200, and on the east side 16,700. The concept of the total annoyance quantity, AQ_t, can be used to see how a re-directing of the traffic will affect the annoyance situation.

Increasing the noise levels in less populated areas while reducing it in densely populated areas will reduce AQ_t. Let us assume that the traffic can be redirected so that all noise levels on the west side is reduced by 3 dB and at the same time the levels on the east side will increase by 3 dB. This will yield the following change in AQ_t:

Reduced $\Delta AQ_{t,\,west} = 0.016 * 3 * 20{,}200 = 970$ MIMEs
Increased $\Delta AQ_{t,\,east} = 0.016 * 3 * 16{,}700 = 802$ MIMEs
Net reduction $\Delta AQ_t = 970 - 802 = 168$ MIMEs

In the original situation we had $AQ_t = 16{,}382$ MIMEs. The net reduction in the total annoyance quantity amounts to only 1.0 percent. In this particular case redirecting traffic has very little effect with regard to the noise situation and is probably not worth considering.

Similarly, a visual inspection of the population density reveals that there are less people living north of the runway than on the south side. What would be the change if the traffic could be redirected so that the noise levels in the cells in direct extension of the runway (east-west) are kept constant, but all the levels north of this line are increased by 3 dB and the levels on the south side are reduced by the same amount? A calculation like the above example shows that the net decrease will be only 115 MIMES or about 0.7 percent.

In this example redirecting traffic will have little impact on the total annoyance. However, in case there are large unpopulated or sparsely populated areas near the airport, a redirecting of the flight paths may reduce the total annoyance considerably.

3.2. Replacing the aircraft fleet

The noise emission from different aircraft within the same category (similar passenger capacity, range, etc.) may vary. So, what would be the effect of replacing the entire aircraft fleet with more quiet planes, that on average will reduce the noise level in each cell by 2.5 dB? The reduction can be calculated as follows:

Reduction $\Delta AQ_t = 0.016 * 2.5 * 36{,}900 = 1476$ MIMEs

This reduction amounts to an almost ten percent change from the original situation with 15,408 MIMEs, which is likely to have a significant impact.

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