

# How to Forecast Community Annoyance in Planning Noisy Facilities

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**When planning the development or reduction of large traffic facilities, acoustic calculation procedures are used to forecast the noise load in the affected residential areas. Then, existing dose/response relationships for steady state situations are used to predict noise effects in future years. Planners often assume that (1) noise annoyance reactions of residents do not change over the years, and (2) annoyance is not affected by the change itself. Both of these assumptions are questioned in this paper, and a procedure for estimating future annoyance in changed noise situations is proposed. This includes the analysis of possible statistical trends of the annoyance reactions over the years - even for steady-state noise loads, and with changing state situations, the effects of the change should also be accounted for.**

*Keywords: Community noise; Annoyance; Dose/Response relationships; Trends over time; Effects of Noise Change.*

## Introduction

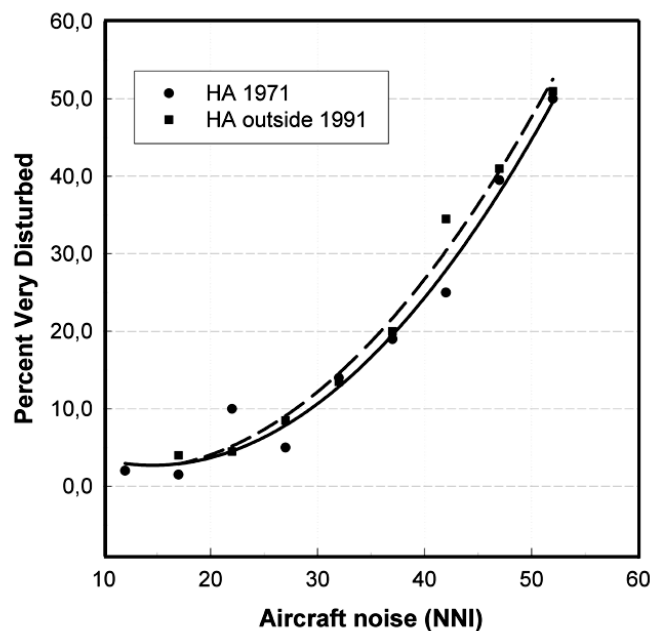
When planning the development of traffic facilities like airports, roads, and railway tracks, acoustic calculation procedures are used in order to forecast the noise load in the vicinity of the new or changed facility, especially in residential areas nearby. With large developments, the delay between the planning and the opening of the new or changed facility may take several years. In forecasting the effects of noise in the future, it is necessary to know (a) whether dose/response relationships established some years ago are valid today, and will be valid in the future, and (b) whether changing a noise situation (e.g. opening a new airport runway) has special annoying effects on residents which are not seen in steady state noise situations. Planners often assume that (1) noise annoyance reactions of residents do not change over the years, and (2) annoyance is not affected by the change itself. Both of these assumptions can be questioned.

## Does annoyance change over the years?

In many countries, large-scale traffic or industrial developments require an Environmental Impact Statement (EIS) before constructions can start. The EIS requires detailed analyses of any action that may significantly

affect the quality of the environment, and the complete statement comprises many volumes. Two parts of the EIS should contain predictions of the noise situation in residential areas after opening the new (or changed) development: one part should forecast the acoustic situation (e.g., noise contours in the residential neighborhood), and the other part should forecast the health and noise annoyance situation. Both of these tasks require considerable skills and assumptions; for instance, predicting the acoustic situation after opening a new airport runway in 10 years requires good knowledge (or, at least a good guess) of the mix of aircraft types at this airport in 10 years, their relative contribution to the total noise load, their operating characteristics, flight paths, and so on. Forecasting the health and noise annoyance situation after opening the new runway is not less complicated, because data on trends of noise annoyance and trends of noise related health over time is rare, and data on the effects of changing the noise levels is partially conflicting.

When planning for new noisy developments or noise abatement programs, planners and consultants like to use published dose-effect



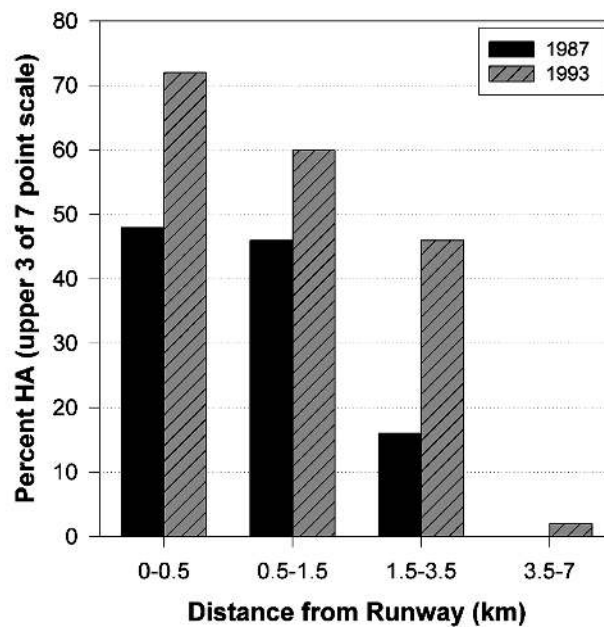
**Figure 1. Dose/response relationships for three Swiss airports (1971/1991). Please note that the disturbance questions are not identical.**

relationships like the well-known curves from the TNO data set (e.g. Miedema and Vos 1998). This data set comprises annoyance and disturbance data from 55 international systematic field studies which have taken place between the late 50s and the early 90s of the last century. This data set is very comprehensive, but we should not forget that the mean age of data is 23 years. In other words: the average vintage of data is 1980. In the mean time, the structure of the noise load has changed – even with equal energy noise levels – for some noise sources, especially for aircraft and road traffic noise: the average noise level of individual vehicles decreased, but the number of events increased, and the duration of quiet periods decreased. When planners use dose/response data from 1980 in order to forecast noise effects in 2010, they should make certain that the dose/response relationship between noise level and annoyance did not change in the mean time.

In order to test for long-term developments of noise annoyance in residential areas, an ideal study design would include repeated measurements (using exactly the same questions and measurement procedures) of reaction variables over several years in several areas comprising a range of noise levels. The areas should not change over time, i.e. they should

keep the noise sources (and their respective composition) constant over several years. Unfortunately, no such study does exist, and it is questionable whether such a study could be performed at all, because residential areas without any change in noise levels are rare. A less ideal study design would include repeated measurements over several years in several residential areas which underwent not more than the typical gradual change in noise levels which can be observed all over the industrialized world. In this case, both noise exposure and reaction variables should be measured repeatedly in the same way, such that repeated dose/response relationships could be established. The updated catalogue of social surveys on noise (Fields 2001) mentions one French study and a Swedish one (Jonsson, Sörensen, Arvidsson, and Berglund 1975). The French reports are not available any more, and the Swedish report is rather short and does not give details of the measurement procedures and of dose-response relationships; however, it does say that during the eight years between 1963 and 1971, the average fraction of “rather or very disturbed” persons increased about 3 per cent.

The Fields catalogue does not mention the partial repetition of the initial Swiss study on aircraft noise (Grandjean et al. 1973, containing data



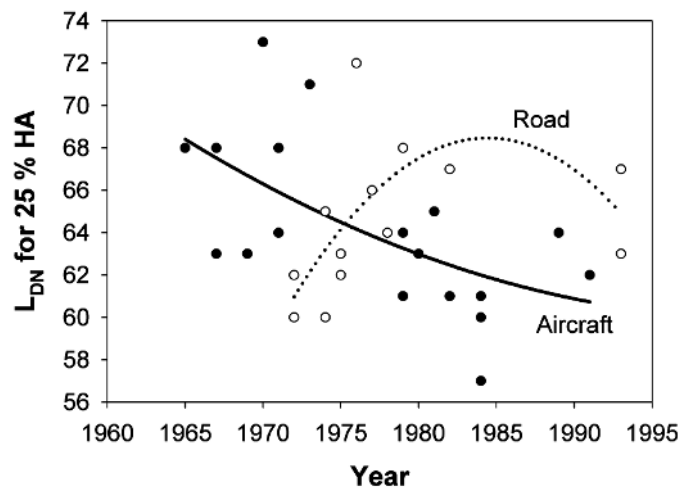
**Figure 2. Percentage of Highly Annoyed residents at Düsseldorf Airport 1987-1993. After Kastka et al. (1995).**

from 1971) which has been reported by Oliva (1998). This is by no means an ideal comparison study: The three airports (Basel, Geneva and Zurich) underwent a considerable change, the aircraft noise calculation procedure changed from NNI to  $L_{eq}$ , and the questions to respondents changed too. The old study asked for “disturbances due to aircraft noise” without mentioning a specific reference to the location (e.g., inside/outside the house). The later study (containing data from 1991) posed different questions for different locations, and Oliva (1998) thinks that responses to “outside” questions are comparable with responses to the old questions without specific location reference. If we agree on this assumption, there is little difference between dose/response relationships for aircraft noise in Switzerland: Only above  $NNI > 30$ , there is a small increase in the percentage of disturbed people within 20 years (see Figure 1). This small (and statistically insignificant) increase gets some added value if we consider that sound insulation had been installed between the two studies in residential areas with noise loads greater than  $NNI=42$ . Sound abatement programs are usually expected to decrease disturbance and annoyance judgments, and if the percentage of highly disturbed persons was the same or slightly higher in 1991 as compared to 1971, this could mean (a)

that the sound abatement program was not effective, or (b) that aircraft noise annoyance increased in the mean time.

There is another example from aircraft noise: Kastka et al. (1995) report repeated surveys in residential areas at Düsseldorf Airport (Germany) in 1987 and 1993. This comparison is of particular interest, because  $L_{Aeq}$  for daytime landings decreased about 2.1 dB(A) between 1987 and 1993, but annoyance judgments increased (see Figure 2). Global annoyance was measured on a 7-point scale, and those persons who chose one of the upper three points on this scale were counted as “Highly Annoyed”. The fraction of highly annoyed residents increased during the 6 years about 20 percent. Unfortunately, the data do not allow for calculating a statistical trend over time.

The least ideal approach for answering the question of an annoyance trend over time is to use data sets from different studies performed at different times in different countries. This approach ignores systematic differences between studies, but since most comparisons of dose/response relationships do so, we could as well take the dose/response relationships for aircraft noise and road traffic noise given by Miedema and Vos (1998), select data for a

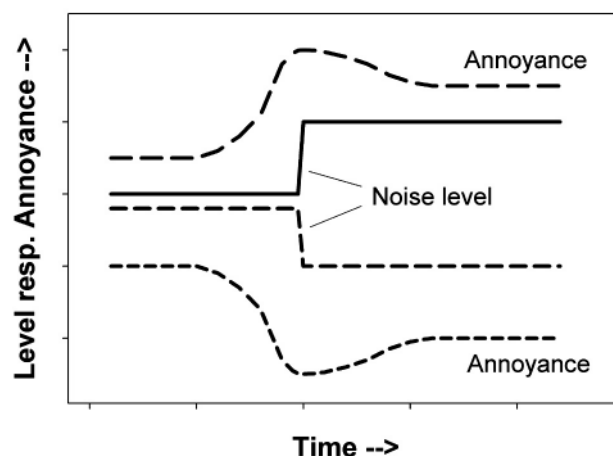


**Figure 3. Noise levels for a constant proportion (25%) of highly annoyed residents. Data from Miedema and Vos (1998).**

constant fraction of highly annoyed residents, and rearrange the results according to age of publication. In doing so, we find a decrease of the day/night level necessary for evoking a constant percentage of 25% respondents being highly annoyed by aircraft noise, and inconsistent results with respect to road traffic noise (Figure 3).

It should be noted that the regression lines in Figure 3 are calculated without weighting the number of respondents in each of the studies included. This may bias the result, and a closer look into the data may be necessary, but the first impression is that the annoyance of residents exposed to aircraft noise increased over the years, while the road traffic annoyance increased

between 1970 and 1983, and kept a rather constant level afterwards. Although there is considerable variation between different studies within the same year, the nonlinear regressions fit significantly to the data points ( $r^2 = 0.38$  for aircraft, and  $r^2 = 0.36$  for road traffic): The annoyance change for aircraft noise is equivalent to 6 dB DNL between 1965 and 1985. When planning a noise load that will be effective in several years, it may be necessary to calculate the annoyance trend over the last 20 years, and provide for a potential change of annoyance in the future – e.g., by extrapolating the statistical trend. In the case of aircraft noise, this would mean to adapt land use planning and noise abatement programs to the statistical trend of



**Figure 4. Schematic view of community annoyance changes with step changes of noise level.**

community noise annoyance. (It should be noted that no trend was estimated for railroad annoyance, because the number of available data is too small for this purpose).

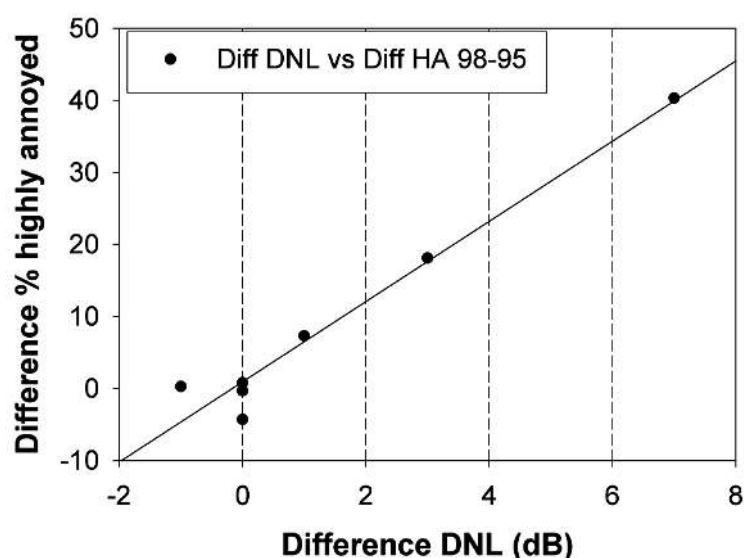
#### **Annoyance in changing noise situations:**

When planning for a new or significantly changed noise situation in the future (e.g. opening or closing a road, or opening or closing an airport runway), an additional effect should be taken care of: Residents react to the *change* of the noise situation. When the noise situation is abruptly and permanently changed the annoyance of residents usually changes in a way that cannot be predicted by steady-state dose/response relationships (cf. Fidell et al. 2002; Raw and Griffiths 1990): Most studies show an „over reaction“ of the residents, i.e., with an increase of noise levels, people are much more annoyed than would be predicted by steady-state curves, and with a decrease of noise levels, people are much less annoyed (Figure 4). It should be noted that the annoyance level changes already before the change of levels: Residents expecting an increase of levels react more annoyed, and residents expecting a decrease in levels react less annoyed than would be predicted in the steady state condition (Hatfield et al. 1998, 2002).

The amount of “overshoot” depends on the abruptness of change: Horonjeff and Robert

(1997) assume that the “evolutionary” expansion of Heathrow Airport (which mainly took place between 1961 and 1965) contributed to the fact that dose/response curves established 1967 were almost the same as in 1961. On the other hand, the step change at Vancouver Airport 1996 provoked 41 % more highly annoyed residents in one area which underwent an increase of 7 dB (DNL) from one day to the next (Fidell et al. 2002, see Figure 5).

The amount of “overshoot” also depends on the amount of change at each location: Fidell et al. 2002 report a follow-up study two years after the opening of a new runway at Vancouver Airport. It turned out that in 3 residential areas which did not undergo a measurable change in noise levels, the percentage of highly annoyed residents stayed about the same as before (or even decreased about 5%). In one area which underwent a decrease of 1 dB, the percentage of highly annoyed residents stayed about the same as before, but in all areas which underwent an increase of noise levels, the increase of the percentage of highly annoyed residents depended on the amount of increase in noise levels (see Figure 5). It is uncertain whether future studies will support this clear change effect, but forecasting annoyance in changed noise situations should take care of overshoot reactions.



**Figure 5. Differences in the percentage of highly annoyed residents in relation to the difference of DNL levels after a step change at Vancouver Airport in 1996 (after Fidell et al. 2002).**

A last point should not be neglected: Almost all papers on change effects assume that overshoot reactions will decay with time (e.g., Fields et al. 2000). But we do not know how long this decay will take, and which variables will contribute to a rapid decay. Raw and Griffiths (1990) claim that some effects can be seen up to 9 years after the change. We can hypothesize that “soft noise abatement programs” (like planning participation by residents, see Flindell and Witter 1999; Stallen 2000) will reduce the overshoot reaction, because such an effect can be predicted by a psychological stress theory. But long-term data on changing noise situations is very rare.

## Conclusion

Predicting future annoyance should include possible statistical trends of the annoyance reactions over the years – even for steady-state noise loads, and with changing state situations, the effects of the change should also be accounted for. This could mean that many current impact assessments of future noise situations underestimate the actual annoyance of the residents – at least with respect to aircraft noise.

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