Aircraft Noise Annoyance

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RECENT DEVELOPMENTS

Researchers have tried for half a century to identify predictive statistical relationships between transportation noise exposure levels and human annoyance levels. A number of curves have been developed to illustrate this relationship since the Schultz' initial general dose-response curve in 1978[1]. Although most researchers agree that the annoyance of aircraft noise is only partially determined by noise exposure levels, many still believe that a single "correct" dosage-response relationship can be used to predict annoyance in all airport communities.

Researchers continue to feed the ever-growing database of social survey results into correlational software which yields regression functions that only statisticians understand, and which lack causal interpretability. Noise-induced annoyance depends on a variety of survey-specific, non-acoustic factors that move dose-response curves back and forth, or up or down[2]. For each new survey, claims are then made that a new and more "correct" dose-response relationship has been established.

However, a scatter plot of the results from 63 different surveys of aircraft noise annoyance conducted between 1961 and 2017, comprising 653 paired responses from more than 100,000 individuals (see Figure 1) is convincing documentation that a dose-response curve derived from these data points using conventional regression techniques is a very poor predictor of the prevalence of highly annoyed persons at most airports. At a noise level of L_{dn} = 55 dB, the prevalence of highly annoyed varies between 0 % and 90 %. Conversely, a 10 % prevalence rate of "highly annoyed" has been observed at exposure levels between 35 dB ≤ L_{dn} ≤ 70 dB[3].

After more than fifty years of meager success in predicting community reaction to transportation noise, it is time for a new approach. The first step in developing a more sophisticated understanding of community response to transportation noise is to formally acknowledge that responses to questions such as, "How annoyed are you by aircraft noise?", are determined not only by the noise exposure itself, but also by a variety of non-acoustic (or more specifically, "non-DNL") factors. These factors can be personal such as noise sensitivity, fear of accidents, mistrust towards the airport authorities, feelings of misfeasance, and so on, or more physical ones like maximum noise levels, changes in the exposure pattern and the rate at which these changes occur, duration of silent periods between noise events, *inter alia*. As Basner *et al*. have noted[4], noise exposure alone accounts for only about a third of the variance of individual responses. Since the aggregate influence of these non-acoustic factors varies from one airport community to the next, it may be irrelevant to seek a single function that accurately describes the relationship between noise exposure and prevalence of annoyance in all airport communities. In fact, such attempts ignore the effect of non-acoustic factors and effectively prevent us from finding out how they affect the annoyance response[5].

THE COMMUNITY TOLERANCE LEVEL

As a further development of observations made by Schultz in his original synthesis, Fidell *et al*. launched the Community Tolerance Level ("CTL") analysis[6]. They observed that the growth of annoyance with noise exposure seemed to follow the effective loudness function, but the onset of the annoyance, *i.e.* the location of the "starting point" on the abscissa of the response curve varied and was determined by a community-specific annoyance decision criterion. In other words, the shape of the dose-response curve is the same for all aircraft noise situations, but the position of the curve relative to the noise axis depends on the non-acoustic factors. The position is defined by the CTL-value.

Any arbitrary point on the dose-response curve ("the effective loudness function") could be selected to anchor it to the noise axis. Since the choice is arbitrary, the midpoint of the function—the point corresponding to a 50 % high annoyance prevalence rate, and the point with the steepest growth —was selected as a convenient anchor point. This choice of anchor point has mistakenly led some researchers to believe that the CTL method only considers annoyance at very high levels (50 % HA "highly annoyed"). On the contrary, a single CTL value is associated with a complete dose-response curve from 0 % HA to 100 % HA, and the corresponding noise levels at which these responses can be observed.

So, instead of finding an arbitrary mathematical function to fit a set of empirical field measurements that lacks any physiological, psychological or other interpretability (as in standard regression analysis), the CTL method seeks to fit an *a priori* function (*i.e.*, a duration-adjusted loudness function) to the survey data. This method is further explained in the International standard ISO 1996-1.

Each community is treated separately in the CTL analysis and characterized by a single CTL value. The results from different surveys can be combined simply by calculating means and standard deviations of individual CTL values. Each CTL value is associated with a unique dose-response function. Thus, the complete noise situation with respect to annoyance can be described by a single quantity, and differences between communities and situations can be quantified by comparing their respective CTL values.

An example of CTL analysis is shown in Figure 2. Two datasets from Figure 1, with somewhat extreme responses, have been identified. In one of the surveys (triangular markers), the prevalence of "highly annoyed" is very low, whereas in the other survey (square markers), the annoyance response is much higher. The two dashed dose-response functions are identical functions but their position relative to the x-axis varies. The CTL values are 83.6 dB and 63.8 dB, respectively. In other words, people at one airport (triangles) "tolerate" 20 dB higher noise levels in order to express a certain degree of annoyance than the residents at the other airport (squares). The limit for 10 % prevalence of highly annoyed residents at this first airport is L_{dn} 66 dB, whereas this limit is reached already at a noise level L_{dn} 46 dB at the other one.

PRACTICAL USE OF CTL

The dose-response curves developed by Miedema & Vos have been widely accepted as a standard for annoyance from transportation noise[7]. Their aircraft noise curve is based on the results from 20 different surveys. A closer look at the Miedema & Vos curve for aircraft noise annoyance shows that this curve is very similar to a curve corresponding to L_{CT} 73.5 dB. The average value for all 63 surveys presented in Figure 1 is L_{CT} 74.5 dB. This is very similar to the Miedema & Vos curve, but there is a very wide spread in the survey results, 63.0 dB < L_{CT} < 87.6 dB. The community tolerance level shifts by almost 25 dB between the two extremes, a shift that is caused by non-acoustic factors. A community with a CTL value of about L_{CT} 75 dB displays an average response to noise. Communities with higher CTL values are less annoyed, and lower CTL values indicate annoyance higher than average.

Most airports are in a constant change-mode. These changes may be gradual, or they can happen abruptly. Janssen and Guski have proposed a classification of airports for survey purposes that groups them according to their rate of change. High-rate-change airports (HRC) have experienced large operational changes (but not necessarily changes in the noise exposure) within 3 years prior to the survey. An airport is also characterized as HRC if plans have been launched to alter the current operations within 3 years after the survey, and/or if the airport has received controversial public attention. Low-rate-change (LRC) is the default characterization.

The 63 surveys analyzed above have been characterized as HRC or LRC according to the definition presented by Janssen & Guski. The mean CTL value for the two types were 67.5 dB (HRC) and 76.4 dB (LRC), making the difference in the annoyance response between the two types of airports to be about 9 dB. Remembering that a shift of 10 dB represents a doubling of the subjective loudness, one may say in popular terms that residents at an LRC airport "tolerate almost twice as much noise" as those living near an HRC airport. The rate-of-change is thus an important non-acoustic factor.

Other factors that may modify the annoyance response have also been studied. The traffic volume characterized by the number of aircraft movements can play a role for the annoyance assessment. At equal noise levels, the annoyance has been observed to increase with an increasing number of movements. A doubling of movements is equivalent to a shift of 1.8 dB in the CTL value. But this shift can only be observed at LRC airports. At HRC airports the annoyance response seems to be independent of the number of aircraft movements[8]. One explanation may be that few (but louder) noise events leave longer quiet inter-event intervals than many events at lower levels. Quiet periods may be desirable, and the noise situation is therefore considered less annoying. The effect is not very strong. At HRC airports, however, the factor that causes a shift in the CTL value of 9 dB is probably so dominating that the number-of-movement-effect is masked or "overruled".

ARE PEOPLE BEING MORE ANNOYED BY AIRCRAFT NOISE?

Some researchers claim that there has been a shift in the annoyance response over the years; they claim that people today are more annoyed by aircraft noise than they were 25-50 years ago. This conclusion may primarily be based on different selections of surveys. More surveys have been conducted at HRC airports in recent years, so naturally the average CTL value for a selection of new surveys will be lower due to a high percentage of HRC airports. However, if the two types of airports are analyzed separately, there is no indication of a change. A selection of post-2000 surveys yield the following CTL values: 76.9 dB (LRC) and 67.8 dB dB (HRC)[9]. These CTL values are almost identical to those found for the whole set of 63 surveys dating back from 1961 indicating that people today are equally annoyed as they were 25 or 50 years ago, and people at an LRC airport still seem to "tolerate about twice as much noise" as those living near an HRC airport in order to express a certain degree of annoyance.

The World Health Organization (WHO) has recently published new environmental noise guidelines for Europe[10] that state that the annoyance has increased, and it therefore recommends a limit of L_{den} 45 dB for aircraft noise in order to prevent adverse health effects. WHO's newly identified noise exposure levels are an order of magnitude lower than those identified by WHO in 2000[11].

However, this recommendation has been based on a selection of non-representative and non-standardized surveys with results that cannot be applied to a general airport population. The recommendation is therefore unwarranted and unsupported by the reported evidence[5]. As pointed out above, detailed analyses of all available survey results reveal no change over time. WHO's previous recommendation from 2000 leaves about 8 % of the population highly annoyed.

FIGURE 1: Results from more than 50 years of aircraft noise surveys

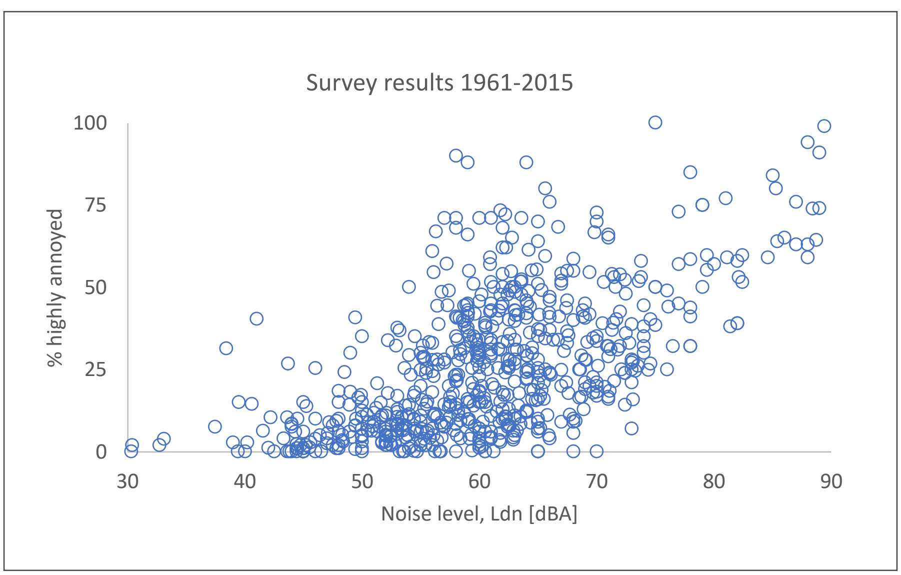
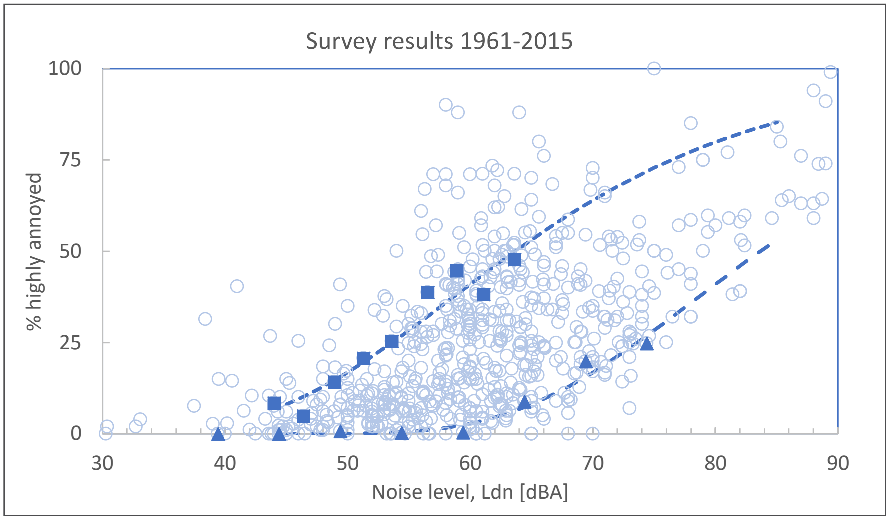


FIGURE 2: Separate dose-response curves for two airports



CONCLUSIONS

There has been no change in people's response to aircraft noise over the past half century. People today are equally annoyed as they were 25 or 50 years ago. However, there is a big spread in the annoyance response. This is due to the influence of various non-acoustic factors.

The Community Tolerance Level method provides a single number characteristic, a CTL value, of the noise annoyance situation around an airport, which represents a quantification of all non-acoustic factors that govern the annoyance response. A study of the CTL values for different airports may yield important information on how to manage the annoyance within the constraint of a given noise situation.

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