INTERPRETING FINDINGS ABOUT COMMUNITY RESPONSE TO ENVIRONMENTAL NOISE EXPOSURE: WHAT DO THE DATA SAY?

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ABSTRACT

How much specific, quantitative information can those who must assess environmental noise impacts find in the technical literature on the effects of noise on people? How may metrics, criteria, guidelines, standards and regulations be derived from the findings of studies of community response to noise exposure? What research directions are suggested by difficulties in resolving actual noise controversies? This paper reviews familiar and alternative approaches to answering these questions. Although none of these approaches is fully satisfactory from all perspectives, it is helpful to understand the advantages, disadvantages, and differences among them.

INTRODUCTION

Many papers and sessions at this and similar meetings concern metrics, criteria, standards, guidelines, legislation, and regulations for environmental noise exposure and its effects. It is helpful to distinguish among these terms. A **noise metric** is simply a measure of some physical attribute(s) of noise. Most reasonable metrics of environmental noise (of which an embarrassingly large number have been proposed) correlate better with each other than with the noise effects which they are intended to predict. It is clear after a half a century of psychoacoustic research that the critical problems are not problems of acoustic measurement *per se*, but rather problems of deciding what is worth measuring. To discuss the relative merits of alternative noise metrics without explicit consideration of the goals and purposes of measurement places the cart squarely before the horse.

A **criterion** in the present context is a statement of an effect of noise exposure upon people or their property. Criteria which summarize what is known about the consequences of a range of noise exposure values may take the form of quantitative dosage-response relationships. Criteria are merely descriptive, and are not intended to be either prescriptive or proscriptive.

A **standard** in the present context is a statement of an agreed-upon procedure for measuring or assessing some aspect of noise or its effects; for example, the magnitude of exposure or the compatibility of noise with some activity. Standards are developed by voluntary or governmental organizations, generally after prolonged consideration, and are often incorporated into legislation and regulation.

Guidelines are generic interpretive statements issued by bodies with regulatory or other interests in noise or its effects. They reflect the charters and perspectives of the agencies issuing the recommendations, and are advisory only. **Regulations** are issued by government executive agencies to implement laws passed by legislative bodies. Regulations, unlike metrics, criteria, standards and guidelines, have the force of law.

It is helpful to keep these distinctions in mind while considering the manner in which guidelines and regulatory policy have been developed from noise effects criteria. Some further background about the nature of typical noise assessment controversies may be helpful as well.

BACKGROUND

Noise is sound that someone considers too expensive or otherwise inconvenient to control. Understandably, perspectives of those who create noise and those who are exposed to it may differ about what efforts should be made to control it, about the efficacy of measures intended to mitigate noise exposure impacts, about benefits of noise control in quality of life and economic terms, and about allocation of noise control costs. Those exposed to community noise, as well as regulatory agencies, standards organizations, researchers, noise source operators, commercial interests, and local government officials worldwide, have been struggling for decades with these matters. Leaving aside legalisms and technical jargon, the central questions in most community noise controversies generally include these:

- How much noise is too much noise, and how do you know?
- Who decides how much noise is too much noise?
- What should be done, who should do it, and who should pay for doing it?

Local and global perspectives on noise controversies and appropriate answers to these questions are often inconsistent with one another. Communities often believe that their noise problems are unique, that their sensitivities to noise are greater than other communities', and that someone else should pay to mitigate noise impacts. Proprietors of noise sources tend to believe that the benefits communities derive from their operations are under-appreciated, that communities' reactions are not always based on noise exposure alone (and may sometimes be exaggerated), and that someone else should pay for mitigation measures. Governmental agencies tend to believe that communities and noise controversies are rather similar, that noise problems are susceptible to generic solutions, and that someone else should share costs to resolve controversies--preferably in ways prescribed by regulation.

Parties to noise controversies sometimes become well acquainted with the technical literature on community response to noise exposure. These parties often feel that it is helpful to quote from scientific scriptures, particularly when citations can be found to support their positions. The impression that the scientific establishment has something to contribute is especially strong among researchers and consultants, many of whom (including those of us here today) view themselves as standing at the crossroads of science and social policy.

Sadly, the technical literature offers fewer specific answers to the central questions noted above than many of us would care to admit. Even the most doctrinaire technocrat would concede that the literature offers no clear guidance on how much noise is too much noise, for whom, and for what periods of time. Little can be gleaned from studies of the effects of noise on people about what *should* be done to mitigate noise impacts, or about how to pay for exposure mitigation. Although regulatory policy on community noise exposure may appear at first glance to be firmly and logically based in technical findings, closer examination sometimes reveals only a loose interpretive basis.

BASIS FOR LAND USE COMPATIBILITY GUIDELINES

In the United States, for example, the position endorsed by the Federal Interagency Committee on Noise (essentially that of the appendix to ANSI S12.40-1990, "Sound Level Descriptors for Determination of Compatible Land Use") with respect to noise limits for land use compatibility planning is often regarded as a natural consequence of the findings of research on noise effects. The approach taken to quantifying land use compatibility guidelines in the appendix to the ANSI standard is worth understanding in detail, if only to clarify the approach and assumptions that it embodies.

Put simply, this approach treats the issue of compatibility as one that is fully captured in an index of long term noise exposure. The appendix asserts that "compatibility of a land use with the outdoor noise environment is assessed by comparing the predicted or measured yearly day-night average sound level at a site with values given in Fig. A-1." The appendix (which contains the advisory that the guidelines "are for information only, and do not constitute an official part of the standard") refers only to itself for this definition of compatibility.[1]

This straightforward treatment of compatibility rests on several levels of unstated assumptions[2]. Some of the more obvious assumptions include:

- that the preferred measure for expressing land use compatibility is not one of noise *effects* on residents, but rather of noise *exposure*[3];
- that noise exposure is to be quantified on a long term, cumulative basis for purposes of assessing compatibility;
- that the basic issue in assessing noise impact for planning purposes is the compatibility of land use *with the noise source*; and
- that ambient sound levels, multiple sources of intruding noises, and other acoustic and non-acoustic factors may be safely ignored in assessments of compatibility.

There is much to be said for this approach and the tacit assumptions on which it rests. DNL is one of a relatively few noise metrics well suited to predictive modeling. Limiting assessments of "compatibility" to comparisons of land use categories with noise exposure threshold levels provides a simple and direct basis for regulatory policy which has proved very useful to government agencies involved in noise controversies.

Generic recommendations about noise-compatible land uses and noise mitigation measures serve largely to render an existing community with established land uses compatible with a noise source. Re-zoning residential land to commercial or industrial uses can in fact reduce the size of a heavily noise impacted residential population near an airport. However, such re-zoning might also affect a community's character, composition, quality of life, and tax base in ways which some decision makers would consider unacceptable. In the extreme, treating compatibility as a simple matter of exposure may be seen as implying that the only tool needed to assess a community noise exposure problem is a sound level meter (or perhaps a computer program to predict future exposure levels), and that the only remedies ever needed are acoustic insulation or changes in zoning.

The body of the ANSI standard notes that the DNL[4] values identified for residential land uses in the appendix were derived from consideration of the annoyance of noise exposure, and those for non-residential land use were derived from consideration of the findings of speech interference studies. The standard does not, however, reveal the manner in which the annoyance and speech interference data were considered, nor how the tabled values were actually selected. It is therefore important to examine the data themselves to determine how information about the prevalence of noise-induced information may be interpreted to yield land use compatibility guidelines for residential neighborhoods. A digression into the nature of noise-induced annoyance and its predictability from measurements of noise exposure is a pre-requisite to this examination.

NOISE-INDUCED ANNOYANCE AND ITS MEASUREMENT

Annoyance is the most robust, widely acknowledged, thoroughly studied, and best understood of the effects of noise on people in residential neighborhoods. Residential annoyance provides the impetus for most community noise impact assessments, and is the *de facto* basis for much community noise planning and many attempts to mitigate noise impacts.

Within a few years of the start of commercial jet air transport service at the end of the 1950s an initial round of large scale social surveys had been conducted in the vicinity of major international airports. Interpretations made in the early 1960s of the findings of the first generation of social surveys alarmed many. Aircraft noise exposure was viewed by some as seriously impairing important aspects of residential living. Many additional surveys were conducted throughout the 1960s with little or no standardization of survey methods, questionnaire items, noise measurements, or analysis techniques. Meanwhile, large numbers of laboratory studies were undertaken of the annoyance and other effects of noise, from which an alphabet soup of noise metrics arose. There was essentially no agreement among researchers on which acoustic and which nonacoustic variables were worth measuring, little understanding of their relationships to one another, and little communication among researchers in different countries.

Variability was found to be an intrinsic aspect of the relationship between noise exposure and annoyance. This characteristic variability occurs whether annoyance is considered in the context of individual noise intrusions or cumulative, long-term exposure, and whether annoyance is considered as an individual or a group phenomenon. The variability of individuals' judged short term annoyance with specific noise intrusions is often so great that it defies reliable prediction on the basis of acoustic measurements except under laboratory conditions. Judgments of groups of people about the long term annoyance of cumulative noise exposure tend to be more stable.

Figure 1 shows the great variability in the information from which relationships between noise exposure and annoyance are inferred. Each dot plotted in the figure represents a paired observation of the noise exposure level and the prevalence of annoyance in a community. If all communities were alike in their reactions to aircraft noise exposure, then the prevalence of annoyance would be the same at each noise exposure level, and the dots at each level would lie on top of one another. The fact that they do not indicates that one or more factors other than noise exposure influence a community's reactions to noise.

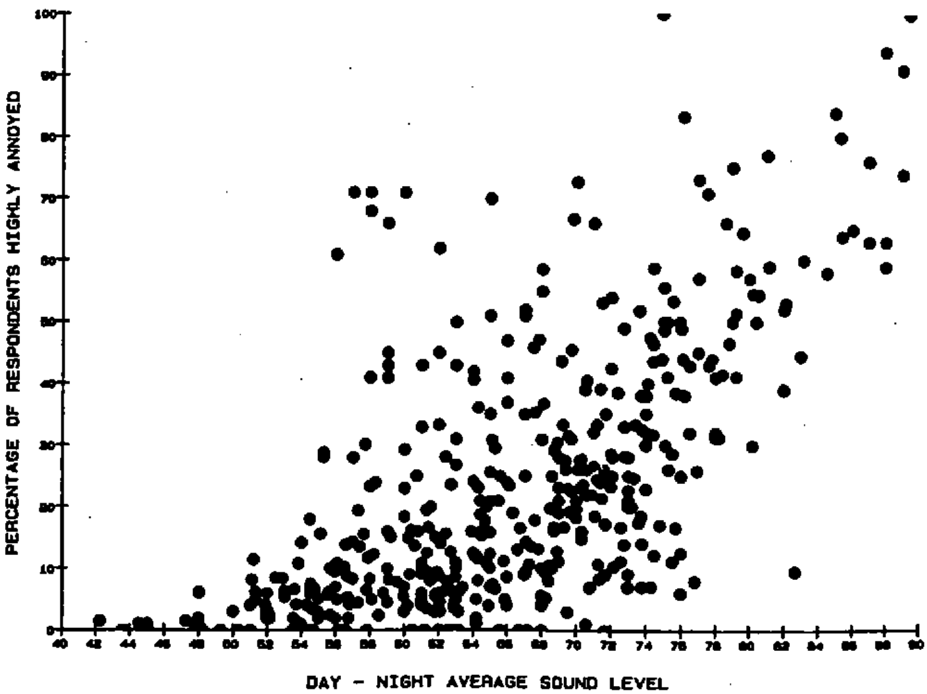

Figure 1: Observations of the prevalence of a consequential degree of annoyance and Day-Night Average Sound Level at 453 sites (adapted from Fidell, Barber and Schultz, 1991)

Fields (1991) estimates that more than 300 social surveys of community response to noise exposure have been conducted since 1943. Relatively few of these have measured both noise exposure and annoyance in ways which support detailed comparative analyses. Nonetheless, several empirical dosage-response relationships between DNL (as an independent or predictor variable) and the prevalence of a consequential degree of self-reported annoyance (as the dependent or predicted variable of interest) have been developed. All are based on interpretations of paired observations made in social surveys of noise exposure levels and the prevalence of annoyance in varying degrees.

The first well documented quantitative dosage-response relationship between noise exposure and annoyance was not synthesized until the mid-1970s. The fundamental problem was to make sense of a large and disorganized literature: to attempt to distill whatever systematic trends might be hidden in a riot of facts and figures. In an early meta-analysis, Schultz (1978) was able to develop a dosage-response relationship from information contained in dozens of studies by converting acoustic measurements made in various units into DNL values, and by converting annoyance data from different researchers' questionnaires in different languages into a single quantity—the prevalence of a consequential degree of annoyance.

Schultz's relationship was based on 161 observations made in eleven studies selected from a large collection of published and unpublished sources. This first synthesis of the literature was debated vigorously. Some researchers seem to have feared that publication of a quantitative dosage-response relationship would put an end to the conduct of further field studies on community reaction to noise exposure. Hindsight has shown that these fears were unwarranted, since publication of the dosage-response relationship in 1978 was followed by a proliferation of additional surveys of noise exposure effects. The number of data points available for a recent updating of Schultz's relationship (Fidell, Barber, and Schultz, 1991) has nearly tripled.

By confirming the predictability of annoyance from noise exposure measurements, Schultz's synthesis established a plausible rationale for defining land use compatibility via a surrogate measure - noise exposure. Prior to Schultz's work, community response was widely viewed as a complex and incomprehensibly "subjective" phenomenon that was both difficult and expensive to measure reliably. However, thanks to a foundation of much good acoustic engineering in the previous two decades, community noise exposure was seen by the 1970s as a much more objective and comprehensible phenomenon that was more readily, reliably, and inexpensively measured than annoyance. Schultz's success suggested to some that since annoyance could be predicted from noise exposure with useful precision, there was little point in measuring it directly.

Schultz's synthesis thus lent considerable respectability to the curve fitting approach to predicting annoyance from noise exposure. A semi-empirical, curve fitting approach was enthusiastically embraced for several reasons. First, Schultz's curve provided a basis for defining "compatibility" in units of noise exposure. Who could argue with a simple and inexpensive solution to what had previously been a complex and intractable problem? Second, in a technical field with a decades-long tradition of engineering expedients, many preferred the goal of prediction to the goal of understanding. The former goal avoided the need to address what were widely regarded as yet more intractable issues—including identification of factors which influence self-reports of noise-induced annoyance.

Third, it was quickly recognized that a sufficiently labile fitting function could be bent to reflect not only the data, but also certain exigencies of policy. Fourth, the curve fitting approach had no competition from any systematic effort to development of a dosage-response relationship from first principles. Finally, predicting community annoyance through a surrogate variable made it possible to avoid explicitly identifying an officially "acceptable" prevalence of annoyance in a community. In essence, a determination that residential life is fully compatible with noise exposure expressed as a value of DNL is tantamount to a judgment that it is tolerable for some proportion of the community to be highly annoyed by noise. An assertion that some value of DNL is compatible with residential land uses is somehow less challengeable, however, than an assertion that it is permissible in somebody's judgment for some fraction of a community to be highly annoyed by the operation of a noise source. The former assertion discourages challenge by those unfamiliar with environmental acoustics, whereas the latter virtually invites challenge on obvious non-technical grounds.

AD HOC (SEMI-EMPIRICAL) APPROACH TO PREDICTING ANNOYANCE

It is interesting to compare the percentages of a community which various fitting functions for dosage-response relationships associate with DNL values in the range of interest for policy purposes. In part to maintain consistency with U.S. EPA policy[5], Schultz (1978) selected a third order polynomial fitting function to represent the relationship in his original 161 point data set between DNL and the prevalence of a consequential degree of annoyance (roughly the upper third of the distribution of intensity of self-reported annoyance):

$$\%HA = 0.8553L_{dn} - 0.0401L_{dn}^2 + 0.00047L_{dn}^3 \quad \text{(Eq. 1)}$$

Because Equation 1 was forced to predict a complete absence of annoyance below L_{dn} = 45 dB, it cannot be meaningfully evaluated below this level. It is also positively accelerated above L_{dn} = 45 dB. However, since there was little question that regulatory agencies' policies would treat noise exposure at levels in the vicinity of L_{dn} = 80 dB as intolerable in any community setting, there was little concern about the shape of the function at high noise exposure values.

The U.S. Air Force adopted a logistic fitting function to express the relationship between noise exposure and annoyance in the data set assembled by Schultz:

$$\% HA = 100/(1 + \exp(10.43 - .132L_{dn})) \quad \text{(Eq. 2)}$$

This fitting function rectifies the obvious shortcomings of Schultz's function. The asymptotic behavior of the logistic function is purchased, however, through a transformation applied to the ordinate. A logistic transform expresses the prevalence of annoyance in terms of the natural logarithm of the odds ratio of dichotomous proportions (those highly annoyed and those not highly annoyed). This stretches the extremes of the scale while compressing the center.

A recent review (Fidell, Barber and Schultz, 1991) identified 292 additional data points published since the conduct of the Schultz (1978) synthesis which met the same selection criteria as the original 161 points. An unconstrained quadratic least squares fit (one which is not forced to zero at L_{dn} =

45 dB) to all 453 of these data points is given by:

$$\% \text{ HA} = 0.0360L_{dn}^2 - 3.2645L_{dn} + 78.92 \quad \text{(Eq. 3)}$$

Equation 3 accounts for almost half of the variance in the combined data set. This equation for a piece of a parabola shares with Equation 1 the disadvantages of positive acceleration at higher exposure levels and meaninglessness at low levels. Its primary virtue is parsimony: it imposes no constraints other than those of regression analysis and does not transform either axis.

The U.S. Air Force revised its initial logistic fit (Eq. 2) to the 161 point Schultz data set by developing the relationship of Eq. 4 from an analysis of 400 of the 453 data points of Fidell, Barber and Schultz (1991):

$$\% \text{ HA} = 100/(1 + \exp(11.13 - .141L_{dn})) \quad \text{(Eq. 4)}$$

Like Equation 2, Equation 4 has the virtue of behaving asymptotically at very low and very high exposure levels.

Table I shows that the differences in the prevalence of annoyance in communities predicted by the four dosage-response relationships derived by curve fitting are generally within ± 3% over the range of DNL values of greatest interest. For example, for L_{dn} = 65 dB, the original Schultz relationship predicts that 15.2% of the residents of a community will describe themselves as highly annoyed by noise exposure. The comparable figures for the logistic fit to Schultz's (1978) 161 data points, the unconstrained quadratic fit to the 453 data points, and the logistic fit to the 400 data points are 13.6%, 18.8%, and 12.3%, respectively. Furthermore, there are no notable differences in the predictive accuracy (variance accounted for) or proximity of the fitting functions to the data points over the range of DNL values of greatest practical interest. (The estimates of prevalence of annoyance in the last two rows of Table 1 are discussed below.)

Table I **Percentage of Community Highly Annoyed ("% HA") Predicted by Several Dosage-Response Relationships over a Range of DNL Values**

FITTING FUNCTION	DNL				
	55 dB	60 dB	65 dB	70 dB	75 dB
$\% HA = 0.8553L_{dn} - 0.0401L_{dn}^2 + 0.00047L_{dn}^3$ [Schultz (1978)]	3.9%	8.5	15.3	24.6	36.9
$\% HA = 100/(1 + \exp(10.43 - .132L_{dn}))$ [USAF logistic fit to Schultz data]	4.0%	7.5	13.6	23.3	37.0
$\% HA = 0.0360L_{dn}^2 - 3.2645L_{dn} + 78.92$ [Fidell, Schultz, and Barber (1991)]	8.3%	12.7	18.8	28.8	38.6
$\% HA = 100/(1 + \exp(11.13 - .141L_{dn}))$ [USAF logistic fit to subset of Fidell, Schultz and Barber (1991)]	3.3%	6.5	12.3	22.1	36.5
$D^* = 70.2$ (Aircraft Noise) [Green and Fidell, 1991]	5.7%	13.2	23.9	36.3	48.6
$D^* = 75.5$ (Surface Transportation Noise) [Green and Fidell, 1991]	1.6%	5.4	12.7	23.2	35.5

DATA DRIVEN APPROACH TO SUMMARIZING ANNOYANCE FINDINGS

None of these curve fitting approaches to estimating the proportion of the population highly annoyed by noise exposure is purely empirical. A truly data driven approach (one which would not require the use or defense of any fitting function to support policy decisions) is also possible. The untransformed data in the vicinity of noise exposure values of interest for policy purposes could simply be left to speak for themselves. Consider, for example, the observations plotted in Figure 2. These include all of the data (tabulated in Appendix A) in the vicinity of $L_{dn} = 65$ dB reviewed by Fidell, Schultz and Barber (1991) which meet the original requirements of Schultz (1978) for consideration. (Recall that this value of DNL represents a threshold of noise exposure below which no incompatible land uses are recognized by many government agencies.)

IMPLICATIONS OF VARIABILITY IN COMMUNITY RESPONSE DATA

None of the foregoing approaches to assessing annoyance is fully satisfactory from all perspectives. Dosage-response relationships which rely exclusively on measures of cumulative noise exposure as predictor variables account for only about half of the variance in observations of the prevalence of annoyance in communities. Communities trying to decide whether to support or oppose construction of new facilities which may change their noise exposure are rarely satisfied with this degree of uncertainty.

One indication of the magnitude of the intrinsic variability noted earlier is the mean to standard deviation ratio of community response data. In the vicinity of the threshold noise exposure level for land use compatibility assessments in the United States (L_{dn} = 65 dB), this ratio is uncomfortably close to unity. This level of imprecision reassures neither proprietors of noise sources nor local

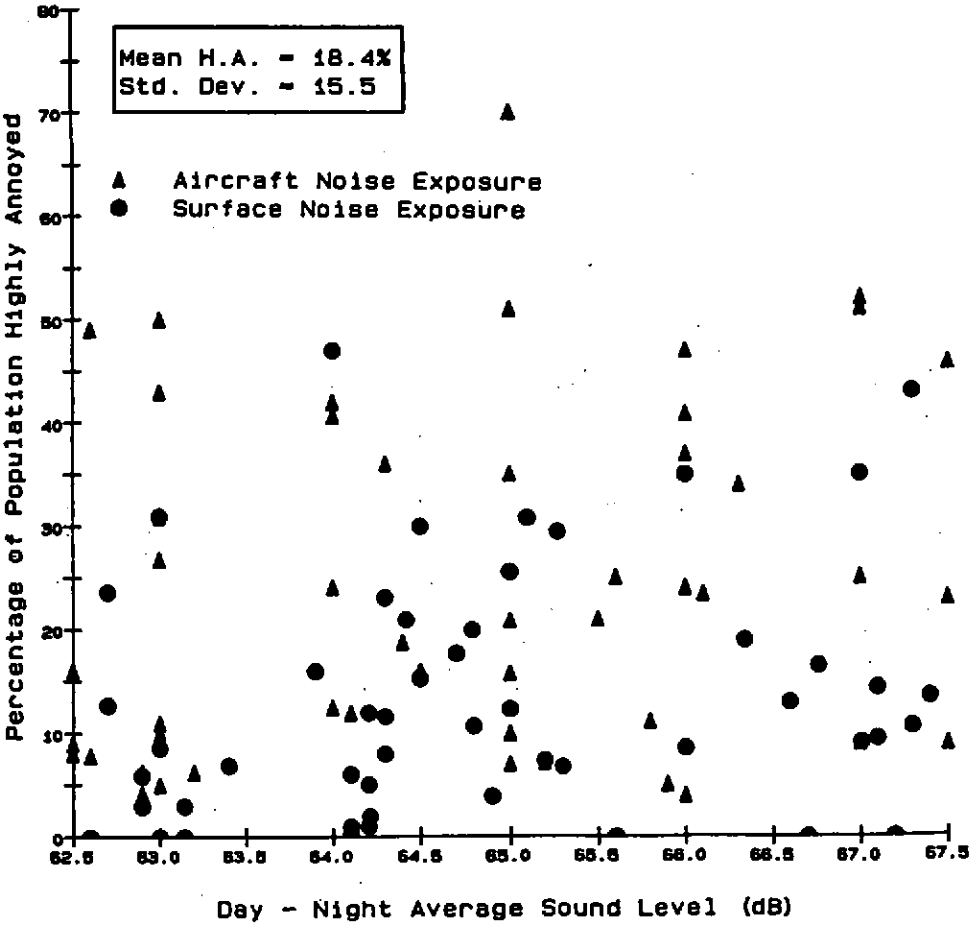

Figure 2: Observations of the prevalence of a consequential degree of annoyance and Day-Night Average Sound Level in the vicinity of L_{dn} = 65 dB

governments about the likely consequences of decisions based on generic policy guidance. Furthermore, annoyance predictions based on curve fitting or on pure empiricism do not permit identification of the sources of errors in predicting the prevalence of annoyance, and do not explain the origins and mechanisms of noise-induced annoyance. Curve fitting approaches account only for the acoustic determinants of annoyance, even though self-reports of annoyance are affected by both acoustic and nonacoustic factors (Fidell, Schultz and Green, 1989).

Various parties to noise controversies attach different importance to global and local approaches to dealing with the fundamental variability in community response data. A systematic explanation for variability in community response is most important at the global level, if only to justify interpretations of criteria, defend policy decisions, explain guidelines, and make them all more understandable to those who must implement them. A site-specific approach may be more useful at the local level. Long term uniformity of policy is of lesser concern to many at the local level than the immediate costs and payoffs of decisions about expected community reactions.

The U.S. Environmental Protection Agency (1978, p. 25) notes that "Decisions about how much noise is too much noise for whom, for how long, and under what conditions demand consideration of economic, political, and technological matters...." EPA goes on to note the need for local government "... to reconcile local economic and political realities with scientific information. People who formulate local noise abatement programs [i.e., officials elected to bodies such as city councils] cannot escape the responsibility of making such economic and political compromises for their constituencies."

Both local and global perspectives on noise exposure assessment are recognized in the latest draft report of the U.S. Federal Interagency Committee on Noise (dated 15 April 1991). FICON notes that while it considers noise exposure levels lower than L_{dn} = 65 dB to be "compatible with most residential land uses" (the global perspective), it is also true that "For populated areas, there may be appreciable numbers of persons highly annoyed by exposure below L_{dn} = 65 dB" (the local perspective). FICON then draws the conclusion "thus, evaluation of the noise impact in such areas, in terms of highly annoyed, may be appropriate."

DIRECT MEASUREMENT OF THE PREVALENCE OF ANNOYANCE

This conclusion - that evaluation of noise impacts in terms of annoyance rather than exposure may sometimes be appropriate - suggests the utility of direct measurement of the prevalence of annoyance in a community. Direct measurement of noise-induced annoyance is the most straightforward and uncomplicated approach to determining the compatibility of a noise source with a particular community, since it avoids assumptions and arguments about indirect predictions made through surrogate variables.

Whereas guidelines based on nationwide policy can provide generic advice for those involved in local noise controversies, direct measurement of noise-induced annoyance can assist local decision makers with specific information about circumstances of immediate interest to them.[6] For example, if future airport expansion and the attendant increase in noise exposure in a community is of concern, it can be helpful to establish the prevalence of annoyance prior to construction of new facilities. Agreements between airport authorities and airport communities based on limiting further degradation in quality of life can then be monitored on the basis of actual rather than predicted changes in annoyance.

Two concerns are often expressed about direct measurement of the prevalence of annoyance. The first is the cost of designing and conducting a worthwhile social survey. While it is undoubtedly more expensive to conduct a social survey than to look up a recommendation in a table, a round of interviews (and attendant short term noise measurements) can be less expensive than extensive long term noise monitoring. The second concern is the feared vulnerability of social survey findings to manipulation by interest groups. This concern may be allayed by theory-based interpretations of social survey data, as described below.

THEORETICAL APPROACH TO ACCOUNTING FOR PREVALENCE OF ANNOYANCE

Derivation of a dosage-response relationship from first principles is useful from both global and local perspectives. One example of this approach has recently been developed under U.S. Air Force sponsorship (Fidell, Schultz, and Green, 1988; Green and Fidell, 1991). This approach follows from recognition of two separable components in self-reports of annoyance: a component directly linked to noise exposure and an entirely independent component associated with individual willingness to describe oneself as annoyed in some degree. The two components are confounded in a verbal report of the form "I'm very annoyed by that aircraft flyover", since the self-report alone provides no way to distinguish the contributions of the acoustically related factors from the contributions of response bias to the expressed degree of annoyance. Since acoustic and nonacoustic determinants are confounded in individual self-reports, it follows that they are also confounded in the proportion of respondents in a neighborhood who describe themselves as highly annoyed by noise exposure.

The prevalence of noise-induced annoyance in a community may be derived from a simple mathematical model which considers noise exposure to be a form of treatment administered to a community. The response of the community to the treatment reflects its citizens' average criterion for reporting annoyance to the noise dose. The effective dose produced by noise exposure is assumed to grow at a rate similar to the growth of loudness with sound level.

A difference between the observed prevalence of annoyance in a community and that predicted by the assumed rate of growth of annoyance with the effective noise dose is attributed in this approach to the net influence of all nonacoustic factors. Among the nonacoustic factors that may affect the willingness of individuals to describe themselves as highly annoyed by noise independently from their dose are attitudes toward noise sources and their operators (approval, fear, distrust, etc.), socioeconomic levels of individuals, and economic dependence on operation of noise sources. The mathematical model quantifies the aggregate influence of these nonacoustic determinants of annoyance so that they may be considered separately from the acoustic determinants of annoyance. Thus, it is possible to determine how much of the observed prevalence of annoyance in a community is due to noise exposure and how much is due to nonacoustic factors.

More specifically, reactions of individuals in the community to noise exposure are assumed to be exponentially distributed with a mean population value m. The value of m is assumed to be related to the Day-Night Average Sound Level by:

$$10 \log m = 0.3 L_{dn} \quad \text{Eq. 5}$$

Thus, noise exposure creates a distribution of reactions within a community with a mean value that increases with the level of noise exposure. Individuals describe themselves as highly annoyed when their reactions to noise exposure exceed a fixed value of a criterion value (A) for reporting annoyance. The net effect of the nonacoustic factors on the decision-making process may be regarded as a form of response bias. The proportion of the population describing itself as highly annoyed is predicted as follows. Suppose

$$P = e^{-(A/m)} \quad \text{Eq. 6}$$

where P is the probability of reporting high annoyance, m is defined as in Eq. 5, and A is the criterion value for reporting annoyance. The value of A may vary from neighborhood to neighborhood for any of a number of nonacoustic reasons. For example, this criterion value may differ because the residents of one neighborhood value the commerce or convenience associated with operation of a noise source more highly than residents of another neighborhood; or because greater media or political attention has been focused on environmental problems in one neighborhood than in another; or because non-environmental problems are more pressing to residents of one neighborhood than of another, etc.

One feature of this approach is that it can distinguish response bias associated with different noise sources. The bottom two rows of Table 1 show estimates of the prevalence of annoyance associated with two types of transportation noise (cf. Green and Fidell, 1991). Another feature of this approach is that it permits detection (and correction) of shifts in response bias between successive rounds of interviews in the same community. Suppose, for example, that a round of interviews is conducted prior to the start of an airport expansion project, at a time when the community is neither favorably nor unfavorably disposed toward the project. The horizontal displacement of the observed prevalence of annoyance with respect to the position predicted by Eq. 6 establishes the nominal response bias of the community.

In subsequent rounds of interviews conducted after construction has been completed, the prevalence of noise-induced annoyance in the community may be either greater or less than in the original round of interviews. If noise exposure and annoyance increase following the completion of construction, it is possible to determine how much of the increase is due to the change in noise exposure and how much of the increase is due to a change in response bias relative to the response bias detected in the first round of interviews. This capability for identifying separable acoustic and non-acoustic contributions to community response makes it possible for local officials and airport proprietors to negotiate agreements about limits of acceptable change in quality of residential life in community-specific terms.

SUMMARY

In summary, there are at least as many approaches to resolving noise controversies as there are parties to such controversies. Generic criteria, guidelines, and standards serve a useful role in providing policy-based recommendations for tolerable noise exposure values and predictions of likely community response. These recommendations and predictions remain imperfect, in part because of the underlying variability of community response data, and in part because of their intentionally global nature.

Further advances in the accuracy and precision with which community response to noise exposure can be predicted are unlikely to come simply from novel curve fitting exercises or from collection of more field data. They are more likely to result from genuine improvements in understanding of the mechanisms which control the arousal and decay of noise-induced annoyance in communities.

Specific information about local circumstances has a recognized role in resolving noise controversies. Quantitative means are beginning to emerge for separating the contributions of acoustic and non-acoustic factors to the observed prevalence of noise induced annoyance in communities. This information can assist in evaluating the degree to which noise controversies are amenable to acoustic and non-acoustic mitigation measures.

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APPENDIX A

TABULATION OF SOCIAL SURVEY FINDINGS ON THE PREVALENCE OF ANNOYANCE DUE TO SURFACE AND AIR TRAFFIC NOISE AT EXPOSURE LEVELS WITHIN ± 2.5 dB OF L_{dn} = 65

STUDY	NOISE SOURCE	DNL (DB)	HIGHLY ANNOYED (%)
Alexandre, 1970	French Aircraft	64.1	12.0
Aubree et al., 1971	Paris Traffic	63.9 66.6	16.0 13.0
Fidell, 1978	U.S. Urban Noise	62.7 62.7 64.3 64.5 67.3	12.7 23.6 23.1 15.3 10.6
Aubree, 1975	Rail	66.0	8.6
Grandjean et al., 1973	Swiss Traffic	65.0	12.3
Grandjean et al., 1973	Swiss Aircraft	64.5	16.0
Langdon, 1976	London Traffic	64.3 65.1	11.6 30.8
MIL Research, 1971	British Aircraft	65.0 65.0	7.0 10.0
McKennell, 1963	British Aircraft	65.0 65.0	20.9 15.8
Rohrman et al., 1974	Munich Aircraft	63.0 63.0 67.0	5.0 10.0 9.0
Rylander et al., 1972	Swedish Aircraft	62.5 65.5 66.0	8.0 21.0 4.0
Borsky, 1965	U.S. Military Airbases	64.3 65.0 65.6 65.8	36.1 35.1 25.0 11.1
Fidell et al., 1985*	Burbank Airport	63.0 64.0 65.0 66.0 66.0	31.0 42.0 70.0 47.0 37.0
Fidell et al., 1985	Orange County Airport	63.0 63.0 65.0 67.0 67.0	50.0 43.0 51.0 51.0 52.0

STUDY	NOISE SOURCE	DNL (DB)	HIGHLY ANNOYED (%)
Hall et al., 1981	Canadian Street Traffic	63.0	8.6
		65.0	25.6
		67.0	35.0
Hall et al., 1981*	Canadian Aircraft	64.0	40.7
		66.0	40.9
Schomer, 1983	Small U.S. Airport	63.0	11.0
		66.0	24.0
Rylander, 1977*	Swedish Light Rail	64.2	5.0
		64.2	1.0
Fields and Walker, 1982	British Rail	67.0	9.1
Myncke et al., 1977	Antwerp Street Traffic	63.4	6.9
		64.8	10.7
		65.2	7.4
		67.1	14.3
		67.1	9.4
		67.2	0.0
Hall and Taylor, 1977	Canadian Road Noise	63.0	0.0
		64.3	8.0
Myncke et al., 1977	Brussels Street Traffic	66.7	0.0
		64.7	17.7
		64.9	3.9
		65.3	6.7
		65.6	0.0
		62.6	0.0
		62.9	5.9
Hede and Bullen, 1982	Australian Airports	62.6	7.8
		62.9	3.6
		62.9	4.2
		62.9	6.3
		63.0	26.8
		63.2	6.3
		64.0	12.5
		64.0	24.1
		64.4	18.8
		65.2	7.1
		65.9	5.0
		66.1	23.4
		67.5	45.9
Sorensen and Hammer, 1983	Swedish Rail	64.2	12.0
		64.1	21.0
		64.8	20.0
		66.8	16.5
Rylander, 1977*	Swedish Street Traffic	63.1	0.0
		63.1	3.0

STUDY	NOISE SOURCE	DNL (DB)	HIGHLY ANNOYED (%)
Lamure and Bacelon, 1976	French Expressway	63.0 64.5 66.6 67.3	31.0 30.0 35.0 43.0
Bruckmayer and Lang, 1967	Vienna Street Traffic	64.0	47.0
Rylander et al., 1976	Swedish Road Traffic	64.1 64.1 62.9 64.1	1.0 6.0 3.0 0.0
Patterson and Connor, 1973	Large U.S. Airports	62.5 67.5	16.0 23.0
Conner and Patterson, 1972	Small U.S. Airports	62.5 67.5	9.0 8.0
Anderson et al., 1982	Danish Rail	63.1 64.2 65.3 66.3 67.4	0.0 2.0 29.5 19.0 13.5
Fidell and Silvati, 1991	Atlanta Airport	66.3	34.0
Fidell and Silvati, 1989	Long Beach Airport	62.6	49.0

*Correlation between noise exposure and prevalence of annoyance does not differ significantly from zero.

ENDNOTES

1. The appendix to the ANSI standard does not claim that the guidelines are strictly and universally applicable in all communities. It also explicitly notes the desirability of modifying the guidelines to reflect local conditions.

2. For example, reliance on any integrated energy metric to predict individual and community response to aircraft noise in turn requires acceptance of the "equal energy" hypothesis. The equal energy hypothesis expresses the notion that the number, level and duration of noise events are fully interchangeable determinants of annoyance as long as their product (energy summation) remains constant. In other words, quantification of noise in cumulative exposure units for purposes of predicting annoyance requires the additional assumption that people are indifferent between the annoyance of small numbers of very high level noise events of short duration and the annoyance of large numbers of compensatingly lower level and/or longer duration noise events.

3. Sound exposure at a specified location is the time integral of sound intensity. Intensity is the rate of flow of sound energy per unit area per second. At distances from sound sources that are of interest in environmental analyses, sound intensity is directly proportional to the square of sound pressure. Thus, sound exposure is usually represented as the time integral of squared sound pressure. This process is often referred to informally as"energy summation". Magnitudes are reported in logarithmic terms. For example, sound exposure level is 10 times the logarithm to the base 10 of the ratio of sound exposure to a reference exposure of 400 μPa^2-seconds. In logarithmic form, squared sound pressure is called sound level and expressed in units of decibels. Sound exposure in decibel notation is most often expressed as average (equivalent) sound level over a specified time interval (usually 1 hour or 24 hours). Single events are usually described by sound exposure level (SEL) with a reference time interval of one second.

4. DNL is the abbreviation (and L_{dn} the symbolic representation) for the Day-Night Average Sound Level, a noise metric popularized by the U.S. Environmental Protection Agency in the early 1970s. DNL differs from a 24 hour L_{eq} only by a 10 dB "penalty" imposed on nighttime (2200 - 0700) noise exposure.

5. At the time Schultz was developing his synthesis of social survey findings, the U.S. Environmental Protection Agency had recently issued its "Levels Document", in which a DNL value of 45 dB is identified as adequate to protect public health and welfare with a reasonable margin of safety.

6. General policy guidance is most useful in predicting future noise impacts on as-yet undeveloped areas. In areas with existing land uses, guidelines often function only to document obvious incompatibilities.