On Normalizing DNL to Provide Better Correlation with Response

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Day-night average sound level (DNL), first developed by the U.S. Environmental Protection Agency, is commonly used to quantify and assess environmental noise. A keystone to noise assessment is the dose-response relationship. However, the dose-response relationship is not an absolute; there is great scatter to the data on which it is based. In an attempt to reduce the scatter to the DNL data, the EPA suggested the use of 'normalized' DNL. Normalized DNL is the basic DNL value with a number of adjustments added to account for specific characteristics and factors of the sound. This article reviews and analyzes the concepts inherent in normalized DNL and provides an updated set of normalization factors that can reduce the scatter to dose-response relationships.

Day-night average sound level (DNL), first developed by the U.S. Environmental Protection Agency,[1] is commonly used to quantify and assess environmental noise.[2] A keystone to noise assessment is the dose-response relationship. With such a relationship, one can relate community response to noise level. Since the seminal work by Schultz,[3] "high annoyance" has been the response measure of choice – especially in the United States. Figure 1 shows the relationship developed by Schultz between the DNL for various transportation noise sources and the corresponding community response expressed as the percentage "highly annoyed." One hallmark of this figure and many like it, is the large amount of scatter to the data. The 90% prediction intervals are quite large. In this figure, they are about 20 to 25% wide at mid levels. The prediction interval can be understood to mean that if one were to survey many communities where the DNL was, for example, 65 dB, then one would expect to find that the rate of high annoyance was between about 5 and 28% in 90% of the communities surveyed.

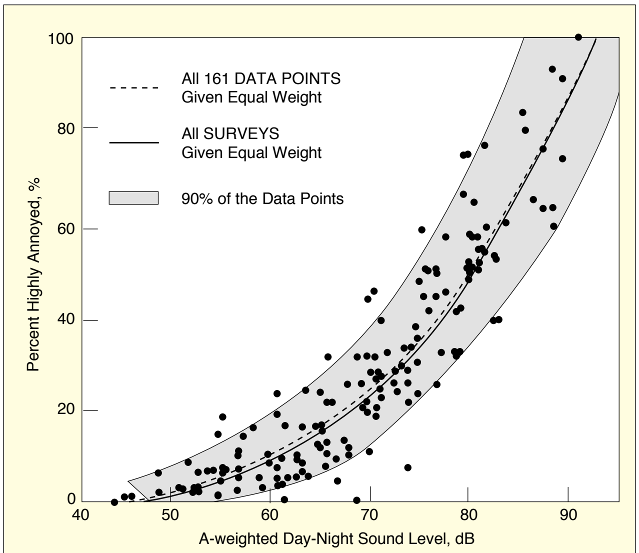

Figure 1. The Schultz relationship between percent highly annoyed and DNL for transportation noise sources.

Schultz was not the first to develop a dose-response relationship. Rather, his contribution was to gather the results from a wide variety of community attitudinal surveys and translate them all to a common metric, DNL. One of the first dose-response relationships (Figure 2) was created by Kryter and republished by the Federal EPA.[4] In Figure 2, the noise metrics are Composite Noise Rating (CNR) and the Noise Exposure Forecast (NEF), two of the forerunner metrics to DNL. One factor is clear in Figure 2: for the same noise level, there can be a wide range to the probable community response. For example, at an NEF of 20 dB, predicted reaction in Figure 2 ranges from "no complaints" and 5% rating the noise as unacceptable to "group appeals to stop noise" and 25% rating the noise as unacceptable.

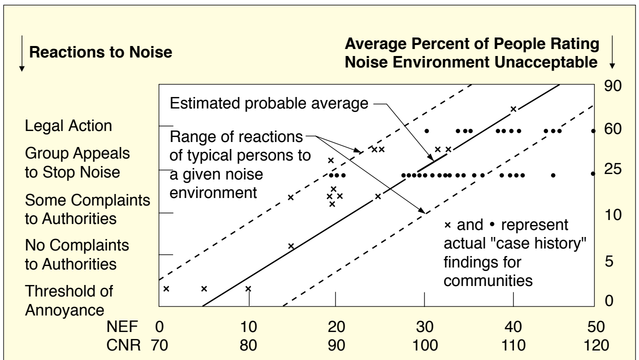

Figure 2. "Relations between community noise levels (measured in CNR or NEF), judgments of unacceptability, and community responses are shown." (After EPA, 1971.)

The EPA developed the DNL metric and attempted the first dose-response relationship for this metric[1] (Figure 3). There are several salient points to this figure. This is among the first uses of the term "highly annoyed." Like Figure 2, this figure attempts to show both annoyance and complaints on one figure. Figure 3 shows the 95% confidence interval at ±10 dB. Note: the confidence interval shows where the relationship or the function is likely to be. Figure 3 does not include the prediction interval. The prediction interval shows where any one data point is likely to be. The prediction intervals are always larger and usually significantly larger than the confidence intervals.

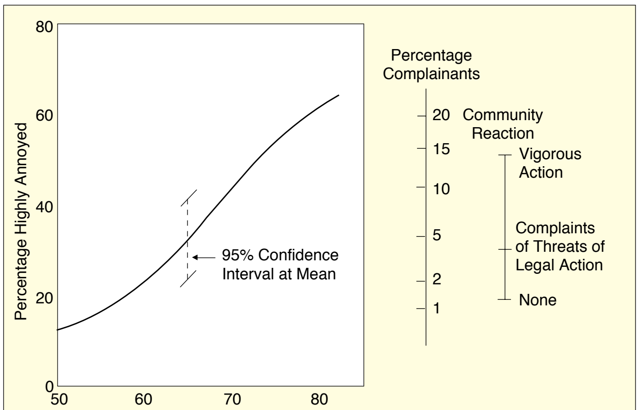

Figure 3. "Intercomparison of various measures of individual annoyance and community reaction as a function of the day-night average noise level." (After EPA, 1973.)

Comparison of Figures 1 and 3 shows marked differences between the two relationships. In general, the Figure 3 relationship predicts higher levels of annoyance for the same DNL than does the Schultz relationship. But there is no clear indication that the two studies used the same definition for what is

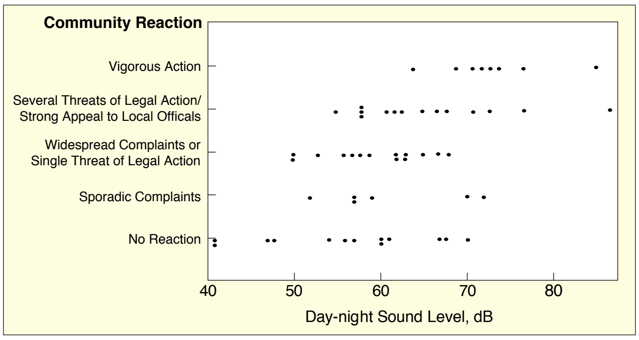

Figure 4. Community reaction for the non-normalized DNL indicated. (After EPA, 1974.)

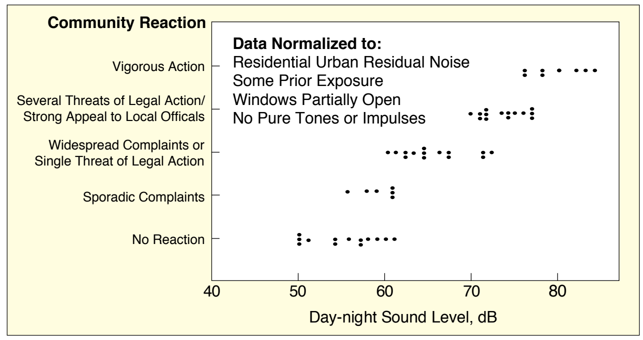

Figure 5. Community reaction for the normalized DNL indicated. (After EPA, 1974.)

"highly annoyed." One of Schultz's major contributions was a clear definition of "highly annoyed" for a variety of situations. According to Schultz the "highly annoyed" group is about the top 28% of respondents when using a numerical scale – typically with adjectival endpoints. It can also be the top 1 to 3 choices on an adjectival scale.

The EPA adopted the use of DNL for noise assessment.[5] In their report they again attempted to relate noise levels with community reaction as measured by complaints and legal actions. Figure 4 presents basic data available at that time showing community reaction versus DNL. There is a great deal of scatter to these data. At 55 DNL, reactions range from "no reaction" to "severe threats of legal action or strong appeals to local officials to stop noise." Some may question the usefulness of graphics like Figure 4 in view of the large amount of scatter to the data. There is just too much scatter to the DNL data.

Like high-annoyance data, complaint data also exhibit a great deal of scatter when plotted against DNL. In fact, two studies of complaints, Luz, *et al*., and Mabry and Carey each finds that complaints correlate better with new and unusual events than with DNL.[6,7]

In an attempt to reduce the scatter to the DNL data, the EPA suggested the use of 'normalized' DNL.[5] Normalized DNL is the basic DNL value with a number of adjustments added to account for specific characteristics and factors of the sound. Table 1 shows the EPA-suggested adjustment factors and the amounts of the adjustments. Factors include seasonal corrections, corrections for the setting, corrections for previous exposure and community relations and corrections for sound character (tonal or impulsive). Figure 5 shows the data from Figure 4 after they have been normalized using this procedure. Clearly, in Figure 5 the data compress and there is much less scatter to the data than in Figure 4.

In reality, the Table 1 normalization factors were in use long before the EPA's Office of Noise Abatement and Control (ONAC). The adjustment method was incorporated in the first Air Force Land Use Planning Guide in 1957 and was later simplified for ease of application by the Air Force and the Federal Aviation Administration.[8] An identical table, except for the title, was published in 1971 as "Corrections to be Added to the Measured Community Noise Equivalent Level (CNEL) to Obtain Normalized CNEL."

Today, the same issues exist as in the 1950s, 60s and 70s. Dose-response relationships are used to relate DNL to high annoyance and to complaints, but there is great uncertainty to these relationships. Figure 6 shows a more recent analysis of attitudinal survey data including the original Schultz-studied surveys and many additional surveys.[9] If anything, with more data, the scatter is greater and the prediction intervals are larger still. At DNL 65, the 90% prediction interval ranges from about 1 to 40%. Yet few have pursued the concept of normalized DNL even though the indication is that it will reduce scatter and afford a better prediction of the reactions in any given commu-

Table 1. Corrections to be added to the measured DNL of intruding noise to obtain normalized DNL.[5]

Type of Correction	Description	Correction Added to measured DNL (dB)
Seasonal Correction	Summer (or year-round operation)	0
	Winter only (or windows always closed)	–5
Correction for Outdoor Noise Level Measured in Absence of Intruding Noise	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking.	+10
	Normal suburban community (not located near industrial activity)	+5
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas)	0
	Noisy urban residential community (near relatively busy roads or industrial areas)	–5
	Very noisy urban residential community	–10
Correction for Previous Exposure and Community Attitudes	No prior experience with little intruding noise	+5
	Community has had some previous exposure to intruding noise but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to the intruding noise and the noisemaker's relations with the community are good.	–5
	Community aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	–10
Pure Tone or Impulse	No pure tone or impulsive character	0
	Pure tone or impulsive character present	+5

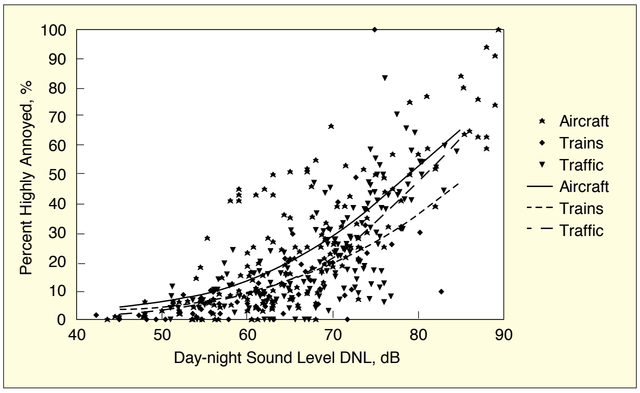

Figure 6. A recent compilation of attitudinal survey results including the original Schultz data and many additional surveys. Note the large amount of scatter to the data.

nity. The purpose of this article is to review and analyze the concepts inherent in normalized DNL and to provide an updated set of normalization factors that may reduce the scatter to dose-response relationships.

This article is concerned with two situations. Situation 1 is when a sound source and a community have existed together for a long time (at least a few years). This might be termed a steady-state situation. Situation 2 is when a sound source is being introduced to (or removed from) a community. This might be termed a transient situation. Two types of reactions are considered: complaints and (high) annoyance.

EPA Corrections for Normalization

The EPA normalization procedure is reproduced in Table 1. This procedure is organized into 4 factors, but the third factor covers two topics, so there are really 5 factors. These are: seasonal adjustments, the community setting (ambient sound), previous community experience, community attitudes towards the noisemaker, and sound character (tonal or impulsive).

Seasonal Correction. The 'seasonal' factor as given in the EPA report is really a "windows state" factor. In effect, the EPA was assuming that if the windows are normally closed when the noise occurs, then there should be a –5 dB adjustment to the DNL. This is generally a true statement. When windows are closed, people are generally somewhat less bothered or annoyed by outdoor sounds. Bowsher included both subjects indoors and out-of-doors[10] and Schomer and others have performed tests with windows shut or open a little (about 2-3 cm).[11-12] Both the 1994 and 1995 studies found changes on the order of 5 dB in the subjective response.

Some may wonder why the change is only 5 dB when the indoor sound goes up by 10 dB or more when windows are opened, even only a little. One explanation is that people are not sound level meters. Their expectations add to their response. When someone chooses to open a window, they expect the sound level to go up. Therefore, their criterion for what is annoying shifts. This shift partially compensates for the increase in noise, so although the sound level indoors may increase by 12 dB, the annoyance grows by only something like 4 to 6 dB. Possibly, expectations account for the other 6 to 8 dB – people expect the sound level to increase due to their action of opening the window.

These laboratory findings are corroborated by social surveys in noisy communities. Fields carried out a meta-analysis of the effect of 22 personal and situational variables in noise annoyance surveys.[13] The majority of studies reviewed showed people being less annoyed if they were relatively isolated from sound around their home. Thus, if the noise exposure occurs only in the winter when people keep their windows closed, it is reasonable to expect a reduction in annoyance.

At the same time, if noise forces people to keep their windows closed year-round, there is no reason to expect closed windows will reduce annoyance. In a question specific to windows, Bronzaft, *et al.*, queried residents of Staten Island about how noise interfered with specific life activities.[14] About half of the respondents were inside an aircraft DNL 65 contour and the other half were outside the DNL 65. About 50% of those exposed to DNL 65 or higher reported having to keep their windows closed compared to 33% outside the DNL 65 contour. The authors note that 32% of the residents that lived within the flight pattern area compared to 14% in the non-flight area stated they were bothered by noise a great deal. It should also be noted that the windows open/closed difference is not the same across all frequencies. At low frequencies, the transmission loss of the windows is very low.

Correction for Outdoor Noise Level Measured in Absence of Intruding Noise. The second correction depends on two measures: the ambient background level and 'intruding' noise. The first is relatively well defined; the second is ambiguous.

Calculating ambient background level is straight forward. If the site in question is near a major noise source, the ambient can be calculated with a computer model (e.g., INM for airports, FHWA Traffic Noise Model for highways, etc.). If the site in question is isolated from major noise sources, then the ambient background can be calculated from the EPA's equation relating the number of people per square mile to background DNL. Although this equation is a quarter-century old, Stewart, *et al.*, showed that it is still valid,[15] using 50 sites in the Baltimore Metropolitan Area.

In contrast to background, defining "intruding noise" poses a problem. Does "intruding noise" refer to the DNL/LEQ of the noise being assessed or to the single event levels of the noise being assessed? The answer is unclear.

Fields evaluated the evidence for the first interpretation through direct reanalyses of over 57,000 interview responses to 35 noise sources in 20 social surveys and reviews of publications for over 12,000 additional responses to 16 noise sources in 13 social surveys.[16] He used DNL (or equivalent level, LEQ) as the measure of the intruding noise, and DNL (or LEQ) as the measure of background noise, and concluded that the background has a negligible effect on noise annoyance.

Evidence for the second interpretation comes exclusively from laboratory studies. Gjestland and Oftedal had subjects assess the annoyance of 30-minute exposures to different kinds of traffic noise,[17] i.e., distant superhighway, nearby road with many trucks, city street with passenger cars, etc. The noise was presented with a very low constant background noise as a masker. They found that noise was judged differently even though the 30-minute LEQ for each listening session was the same. They concluded that the best metric was LEQ calculated over noise events above a certain threshold. Fields reviewed 10 other laboratory studies in which subjects rated the target noise.[16] Nine out of 11 findings indicated that reactions to the target noise were reduced by ambient noise. To account for the reduction of the annoyance of an intrusive sound from background sound, the American National Standards Institute (ANSI) S12.9 Part 4 recommends not including noises that are masked by the ambient in a source specific analysis.[2] Basically, the ANSI procedure says, "Do not include sounds that cannot be heard."

Although the background does not appear to be a strong determinant of noise annoyance, the EPA levels document still comes close to hitting the mark. One can think of this factor not as a background correction but as a correction for community setting. Expectations in different settings are distinctly different, and these differences in expectation affect the level of community annoyance. For example, Schulte-Fortkamp and Nitsch asked subjects living in different urban *soundscapes* to judge the unpleasantness of tape-recorded neighborhood noise.[18] When the noises were presented to the people living in the area where the noises had been recorded and to people not living there, differences in the judgments of up to one category on a five-point scale were observed.

Willits, *et al.,* has studied community expectations in rural settings.[19] Table 2 reproduces Willets' data. Many potentially positive attributes of rural living are given. Of these, the number one expectation to rural living is "peace and quiet." This positive attribute of rural living ranks far above virtually all other perceived rural attributes. For example, peace and quiet are much more expected than is a low crime rate. These expectations are about the same for rural, urban and suburban respondents. That is, everyone expects rural areas to be bastions of peace and quiet.

Fields and others who study noise annoyance by developing dose-response relationships cannot consider this situation of community expectations because the data do not permit it. By definition, there is no steady-state situation where the setting is rural and quiet. The residents expect the community to be quiet, but they are near a noisy expressway or airport. If the community is next to an expressway or airport, the residents remaining after several years no longer expect quiet.

One cannot use the steady-state dose-response relationship gathered from data taken by roads and airports to predict annoyance in a quiet rural setting without significant adjustments. Here expectations relate to transient situations, to the siting of a new airport, highway or factory. DNL 60 may imply less than 10% highly annoyed in an urban situation; but DNL 60, if it is a new airport, factory or highway in a quiet rural area, may yield 100% highly annoyed.

In conclusion, the EPA normalization factor of +10 dB for quiet rural settings is justified and needed not on the basis of the background sound but on the basis of the community expectations for a quiet environment.

Correction for Previous Exposure and Community Attitudes. The third factor in Table 1 is really three sub-factors grouped together: previous experience, community attitudes toward the noisemaker (public relations), and "increased tolerance" for short-term noises (e.g., construction noise). The common thread running through these factors is that they, like expectations, are "mental processes." In hindsight, it is obvious that they are: (a) different categories of mental processes; and (b) are not a complete list of important categories.

For the first category of mental process, previous experience, the EPA suggests three levels of previous experience: none, some and considerable. With reference to noise sources, the terms none and some are clearly different. But the distinction between some and considerable is more difficult to understand in this context. This previous experience normalization factor seems to imply a transient situation. There was no road but a new expressway will be built, or there was no airport but a new airport will be built. These would seem to be examples of the "no prior experience" state. Alternatively, there is an airport but a closer runway will be added, or there is an expressway but another lane of traffic will be added. These would seem to be examples of the "some prior experience" state. However, the distinction in this context, between 'some' and 'considerable' is difficult to make.

The previous experience normalization factor recognizes that naive communities will be more annoyed by the introduction of a new noise source than can be predicted by steady-state assessment of the annoyance in established communities where the noise has existed for a long time. Several examples in the section on Case Studies illustrate this point. We suggest, however, that this factor be simplified to two states: (virtually) no prior experience and (some) previous experience. Further, we suggest that the EPA normalization factors of +5 dB be applied to situations where the community has (virtually) no prior experience.

The remaining EPA adjustments for previous experience are not borne out by experience. It does not necessarily follow that a community with prior experience still is not annoyed by a reintroduction of some noise or by an increase in that noise. In fact, this factor is sort of the mental conjugate to an expectation factor. Whereas one may expect opening a window to increase the noise or one may expect their rural neighborhood to be quiet, this new noise source for which there is (virtually) no previous experience is unexpected.

In the vicinity of noisy military installations, the question of previous experience is especially complex. Evolving national strategic objectives, changing Congressional appropriations and base-realignment and closure (BRAC) can lead to stepwise shifts in community noise exposure. A good example is Westover Air Force Base in western Massachusetts. Westover served as a bomber training base and port of embarkation and debarkation during World War II. In the 1950s, the base was vital in transporting freight and passengers to forces in Korea, primarily with C-47 and C-54 propeller aircraft. From 1955 to 1974, it was a major base of operations for the Strategic Air Command with B-52 bombers generating an SEL of 121 dB at 1000 ft under the takeoff path.[8] From 1974 to 1987, operations shifted to C-130s with an SEL of 91 dB at 1000 ft under the takeoff path.[20] Then in 1987, noise levels shifted up once again upon stationing of the C5A with an SEL of 112 dB at 1000 ft under the takeoff path.[8]

Community response was quick and coordinated. In a 1987 suit, the neighbors argued that the military had underestimated

Table 2. Responses in percent from rural, urban and suburban residents to items dealing with positive images of rural life.[19]

	Rural (N=571)[a]			Urban (N=384)			Suburban (N=284)		
Item	**Agree**	**Undecided**	**Disagree**	**Agree**	**Undecided**	**Disagree**	**Agree**	**Undecided**	**Disagree**
Rural life brings out the best in people.	63.2	20.8	15.9	46.5	27.2	26.4	48.9	26.4	24.6
Rural families are more close-knit and enduring than other families.	71.6	13.0	15.4	61.2	11.7	27.1	66.7	11.3	22.0
Because rural life is closer to nature, it is more wholesome.	85.6	7.2	7.2	73.7	8.1	18.2	72.9	7.7	19.4
Rural communities are the most satisfying of all places to live, work and play.	68.8	13.7	17.5	39.8	18.0	42.2	43.7	13.7	42.6
Rural people are more likely than other people to accept you as you are.	65.7	13.1	21.2	53.4	14.6	32.0	51.4	13.7	34.9
Neighborliness and friendliness are more characteristic of rural communities than other areas.	77.7	8.8	13.5	69.0	11.2	19.8	64.8	10.9	24.3
Life in rural communities is less stressful than life elsewhere.	69.3	8.1	22.6	60.7	8.6	30.7	63.0	8.8	28.2
There is less crime and violence in rural areas than in other areas.	73.4	8.1	18.6	67.4	9.7	23.0	70.8	10.6	18.7
Rural areas have more peace and quiet than do other areas.[b]	**94.6**	**1.9**	**3.5**	**89.3**	**3.4**	**7.3**	**91.9**	**1.8**	**6.3**

* Significant 0.05.
*** Significant 0.001.
a Number of cases varies slightly from item to item due to missing data.
b Emphasis added.

its noise impact on the community. The court found that USAF made a good faith effort in the Environmental Impact Statement (EIS) but also allowed for citizen recourse if the EIS-estimated noise impacts were exceeded. Litigation continued, and in 1994, resulted in a $1.5 million settlement to 42 families who suffered losses to their property values.[21]

In this case, community expectations were far more important than prior experience. Loud noise had gone away and the community did not expect that noise would be reintroduced. Similar situations have occurred when the Army has stopped using firing ranges for a long period of time and then reintroduced the firing of weapons. The communities no longer expected this type of noise. Expectations clearly are a powerful modifier of noise annoyance.

The second sub-factor within the EPA's third correction is that the "the noisemaker's relations with the community are good." This sub-factor is further defined as "people are aware that bona fide efforts are being made to control the noise." The EPA procedure allows a 5 dB bonus for this attitude and the meta-analyses of Fields confirm that this attitude is an important modifier of annoyance.[13] However, this is only one of five attitudes confirmed as important. In addition to "noise prevention beliefs," Fields listed "fear of danger from the noise source," "beliefs about the importance of the noise source," "annoyance with non-noise impacts of the noise source," and "general noise sensitivity."

In a more detailed study of attitudes, Staples, *et al.,* combined elements of Fields' "noise prevention beliefs," "beliefs about the importance of the noise source" and "annoyance with non-noise impacts of the noise source" into a 10-item Environmental Noise Risk Scale.[22] Staples had 351 subjects that were living in the 55 to 60 DNL zone of a former military airfield that had been converted for community use. The dependent variable was a 14-item "noise disturbance" scale which combined activity disturbance questions with annoyance questions. Using stepwise multiple regression, they found that the environmental noise risk scale accounted for 36% of the variation in individual disturbance from noise. Particularly powerful were four items loaded on a statistical factor that they labeled "appraisal of one's neighborhood as inadequately protected and vulnerable to future increases in noise." These items were:

- If airport noise increases, it will make my neighborhood a less desirable place to live.
- My neighborhood is exposed to more noise than other neighborhoods near the airport.
- Airport and government officials are doing all they can to control noise.
- Airport noise probably will not increase much over the next 5 to 10 years.

These four questions accounted for 43% of the variation in individual disturbance from noise ($p<0.0001$), more than what was accounted for by the use of the entire noise scale when it was used in the regression. "Noise sensitivity," one of the attitudes confirmed by Fields, was positively correlated with general annoyance ($r=0.70$, $p<0.001$) but unrelated to environmental noise risk. In addition to confirming the importance of the attitudes identified by Fields, Staples, *et al.*, confirmed the importance of expectations and prior exposure. When added to the stepwise multiple regression, "noise relative to expectations" raised the explained variance to 45%. The addition of "noise relative to prior exposure" as a third variable raised the explained variance to 48%.

In summary, there is little question that this sub-factor is a powerful one. The problem is that this multidimensional factor is far more complex than suggested in the original analysis. More studies like those of Staples, *et al.,* are needed before a complete set of corrections can be developed.[22] However, in the interim the EPA-suggested normalization factor of –5 dB can be used when the "public relations" process is responsive to all of the factors cited above that contribute to negative attitudes. That is, "good relations" are created by a variety of actions that counter those mental processes that lead to increases in annoyance. These include responding quickly, fully and sincerely to noise complaints, educating the public as to the necessity of the noise source and being cognizant of and responsive to non-acoustical factors that can lead to increased 'noise' annoyance. Non-acoustical factors can be such things as educating the public as to the safety of the noise source so that fear will not be a negative factor and being responsive to other sources of annoyance like "the aircraft screws up the TV reception." Clearly, a lot can be done by the noisemaker to counter negative feelings in the community. Good public relations are worth at least –5 dB as a normalization factor.

The third sub-factor is the perception that the noise "will not continue indefinitely" and Table 1 assigns a –10 dB normalization factor if the community is also aware that the "operation causing noise is very necessary." City maintenance workers using a jackhammer to fix a broken water main would certainly fall into this category. However, here the EPA seems to have forgotten that DNL, as defined by ANSI and used by Schultz, is an *annual* average.[3] Strictly speaking, a one-month construction project already receives a –10 dB adjustment because it is only there for about 1/10 of a year. This factor, as given by the EPA, can only be used if one 'forgets' to calculate an annual average and instead calculates DNL only for when the noise is present. But such a process is suspect. Is a one-day construction project the same as a three-month construction project? Should they be assessed as identical? Probably not. Since virtually all of the attitudinal survey data relied upon to create dose-response relationships are annual average data, only the annual average can be quantified for assessment purposes. Thus, this sub-factor should be dropped as vague, incomplete and unsupported by data. As discussed below, the only real recourse if DNL is to be used, is the annual average.

Pure Tones or Impulses. The presence of prominent tones or impulses is known to increase the annoyance of sounds compared to sounds that do not exhibit these special characteristics. Table 1 suggests a simple +5 dB adjustment for the presence of tones or impulses. However, this is an area that has, in part, received a great deal of scientific attention in the intervening 25 years. The current ANSI S12.9 Part 4 and International Organization for Standardization (ISO) 1996 Part 2 Amendment 1 both give more detailed adjustments for impulsive sound.[2,23] In both, the definitions of impulses are divided into the following categories:

- **Impulsive Sound.** Sound characterized by brief excursions of sound pressure (acoustic impulses) that significantly exceed the ambient environmental sound pressure. The duration of a single impulsive sound is usually less than one second.
- **Highly Impulsive Sound.** Sound from one of the following enumerated categories of sound sources: small-arms gunfire, metal hammering, wood hammering, drop hammering, pile driving, drop forging, pneumatic hammering, pavement breaking, metal impacts during rail-yard shunting operation, and riveting.
- **High-Energy Impulsive Sound.** Sound from one of the following enumerated categories of sound sources: quarry and mining explosions, sonic booms, demolition and industrial processes that use high explosives, military ordnance (e.g., armor, artillery and mortar fire, and bombs), explosive ignition of rockets and missiles, explosive industrial circuit breakers and any other explosive source where the equivalent mass of dynamite exceeds 25 grams. Normally, for single impulsive sounds of concern for this Standard, the A-weighted sound exposure level will exceed 65 dB and the C-weighted sound exposure level will exceed 85 dB.
- **Regular Impulsive Sound.** Impulsive sound that is not highly impulsive sound or high-energy impulsive sound.

When sounds can be predicted or separately measured, high-energy impulsive sound receives a +12 dB adjustment and regular impulsive sound receives a +5 dB adjustment. Under ANSI, the normalized or adjusted high-energy impulsive sound exposure level L_{NE} is given in terms of the C-weighted sound exposure level L_{CE} by

$$L_{NE} = 2 * L_{CE} - 103 \quad (1)$$

Under ISO, if highly impulsive noise is measured and it is impossible to separate the highly impulsive sound from other non-impulsive sound, then a +5 dB normalization factor is applied to the entire measurement.

Under both ISO and ANSI, +5 dB remains the typical normalization factor for sounds with prominent discrete tones. Little has been done in the past 25 years to provide better quantification for this normalization factor. Under ANSI, a prominent discrete tone is determined by a method like the following from State of Illinois noise regulations:[24]

"Prominent discrete tone: sound, having a one-third octave band sound pressure level which, when measured in a one-third octave band at the preferred frequencies, exceeds the arithmetic average of the sound pressure levels of the two adjacent one-third octave bands on either side of such one-third octave band by:

"5 dB for such one-third octave band with a center frequency from 500 Hz to 10,000 Hz, inclusive. Provided: such one-third octave band sound pressure level exceeds the sound pressure level of each adjacent one-third octave band, or;

"8 dB for such one-third octave band with a center frequency from 160 Hz to 400 Hz, inclusive. Provided: such one-third octave band sound pressure level exceeds the sound pressure level of each adjacent one-third octave band, or;

"15 dB for such one-third octave band with a center frequency from 25 Hz to 125 Hz, inclusive. Provided: such one-third octave band sound pressure level exceeds the sound pressure level of each adjacent one-third octave band."

If source-specific measurements are corrected for background sound then care must be exercised not to 'accidentally' introduce the appearance of a prominent discrete tone where none exists. For this purpose, ANSI S12.9 Part 3 contains guidance on the measurement of background-corrected one-third-octave-band sound pressure levels and their application to the measurement of prominent discrete tones.[25]

Factors Not in EPA's Normalization Procedures

Up to now, just those factors included within the original EPA recommendations have been discussed. However, data and reason support at least two additional factors. The first of these relates to noticeable noise-induced rattles and the second considers the time period adjustments to DNL. We also consider the time duration over which DNL is calculated.

Noise-Induced Rattle. Not addressed in the EPA's original normalization factors is "noise-induced rattle." Blazier was one of the first to comment on noise-induced rattles in building elements.[26] He was concerned about rattles in an office setting induced by the low-frequency energies generated from heating and ventilating systems. He notes that there is a "high probability that noise-induced vibration levels in lightweight wall and ceiling constructions will be clearly noticeable." ANSI 12.2 has incorporated this suggestion by Blazier both in the Room Criterion (RC) procedure of Blazier and the Balanced Noise Criterion (NCB) procedure of Beranek.[27] In essence, sound levels at or above 75 dB in the 16 or 31 Hz octave band or at or above 80 dB in the 63 Hz octave band are prohibited.

One can translate these indoor criteria to equivalent outdoor criteria. Based on blast noise studies,[11,12,28] and continuous source studies,[29,30] Schomer shows that typical home attenuation in the range from 20 to about 80 Hz is about 10 dB.[31] Hence, the above criteria levels can be translated to outdoor levels by adding 10 dB. That is, outdoor levels in excess of 85 dB in the 16 or 31 Hz octave bands or in excess of 90 dB in the 63 Hz octave band have a high probability that the noise will induce noticeable vibrations in lightweight wall and ceiling elements.

For comparison, Tokita, *et al.*, report on minimum sound pressure levels that generated rattling sounds in windows.[32]

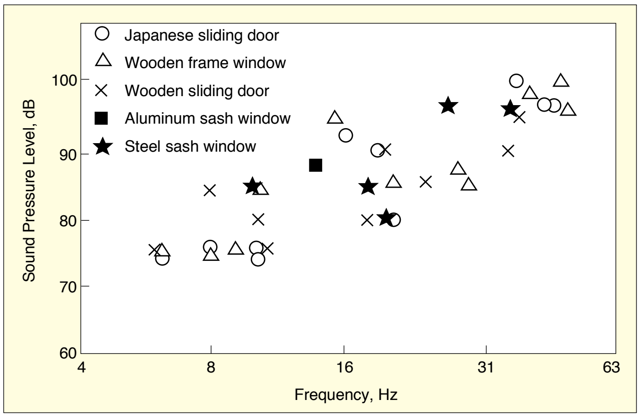

Figure 7. Minimum sound pressure level to induce rattling of windows and sliding doors. (After Tokita, et al., 1980.)

These data are reproduced in Figure 7 and show likely levels for rattles as 80, 85, 90 and 100 dB, in the 8, 16, 31 and 63 Hz octave bands, respectively. Considering that these data are for Japanese windows and sliding doors and the (indoor) Blazier data are for lightweight elements in office settings, the agreement is remarkable. By way of further comparison, Alverson concludes for aircraft that: "a C-weighted maximum level of 80 dB would correctly identify most events having vibration-producing potential."[33] An 80 dB (C-weighted) criterion is virtually identical to the octave band limits developed based on Blazier's data, as long as the energies are in the low-frequency bands (i.e., the C-weighted level exceeds the A-weighted level by a significant amount, typically 10 to 20 dB).

Schomer has specifically studied the equivalent increase in annoyance when there are noticeable noise induced vibrations that can be heard by the subjects. The subjects need only hear elements rattle, there is no tactile perception of vibration. In one study,[34] simulated blast sounds were presented to subjects both with and without noticeable rattle sounds. The blast-sound induced rattle noise was virtually unmeasurable compared with the blast sound yet it increased the equivalent annoyance by 6 dB at low blast levels and by 13 dB at the highest blast levels used in that study. In another study using real helicopters to generate the test sounds,[35] the mere addition of noticeable rattle sounds increased the subjective annoyance judgements by 10 to 20 dB. Again, the rattle sounds were virtually unmeasurable compared with the helicopter sound. Several subsequent studies show an increase in annoyance when A-weighted levels are accompanied by vibration.[36-39]

At this time, +10 dB is recommended for the normalization factor for noticeable rattle sounds (except those that originate from high-energy impulsive sounds), although the evidence suggests that this factor may be a variable and may be larger at times. Based on the work by Blazier and the ANSI S12.2 standard, noticeable rattles should be assumed when the outdoor octave band maximum sound levels meet or exceed 85, 85 or 80 dB in the 16, 31, or 63 Hz octave bands, respectively. Note, rattle sounds may occur at significantly lower levels than those stated herein.[40] The rattle sounds are controlled not by these octave band levels, but by the transfer function between the input (acoustic energy striking the structure) and the output (vibration spectrum of the surface). Some structures (and components of these structures) are more effective in transferring this energy than others. High-energy impulsive sounds are not included within the above framework because Eq. (1) already explicitly includes the effects of noise-induced rattles.

Time-Duration over which DNL is Calculated and Time Period Adjustments to DNL. The Air Force has historically employed "busy day" DNL as a way of going beyond the limits of a steady state prediction. One strong proponent for "busy day" has been Harris, who advocates use of the busy day for all airports using the Air Force definition.[41] He is particularly concerned with general aviation airports where operations can peak on the weekends and with resort airports like Nantucket, MA where operations can peak during a certain season. For busy commercial airports, Harris suggests that the average day will be about the same as the average busy day.

Use of average busy day at first glance seems very logical and appropriate. However, examination of potential results and difficulties leads to second thoughts. Consider the following. A certain police firing range has been used only during the week, five days per week for police training, for the past several years. Noise was assessed using the average busy day. That is, all the firing noise during the week was summed and divided by 5 to compute the average busy day. The park district now proposes to open the range on weekends for sportsmen. An environmental assessment is performed and it is reported that there is no significant impact – the noise impact will not change by the addition of the sportsmen firing on weekends. How can this happen? The firing is 7/5 what it was before. There is a 40% increase in rounds fired. But there is also a 40% increase in busy days, so the firing on the average busy day does not increase. Taken to the extreme, one could go from one firing day per year to 365 and see no increase in impact using the busy day concept.

The above example is hypothetical, but during base closures the U.S. Air Force closed some bases used mainly on weekends by the reserve forces. These reserve activities were moved to regular Air Bases that previously had been used mainly during the week. At these bases, the operations really did go from 5 days per week to 7 days per week and the Air Force had to report no impact when in reality the impact was probably greater than 2/7th more since more people are home on weekends than during the week.

It seems clear that if one adds operations or adds days of operations, then the impact goes up. Communities are not very accepting of the notion that one can double the number of operating days but the impact does not go up because the busy day level has not changed. If adding operations or days of operations increases the impact, then subtracting operations or operating fewer days must decrease the impact. So on this basis, the concept of the average busy day fails.

Another example makes this same point in a different way. Consider a community that is near both a general aviation airfield and a military airfield. The general aviation airport operates mainly during the weekend; the military airfield operates just during the week. The annual average DNL from each airfield at this community is 55 dB. Should the military multiply their operations by 7/5 in computing contours, adding 1.5 dB? Should the general aviation airport multiply their operations by 7/2 in computing contours, adding 4.5 dB? The net result in the community is 55 DNL from aircraft everyday. Why should the contours be increased?

Are there any times when a busy day concept is correct? The simple answer is yes, at least in terms of complaints. Consider the situation of a National Guard training site. Typically, these installations generate the most noise during 2 to 3 summer months of the year with sporadic weekend training during the rest of the year. So for year-round residents, one can argue that the annual average is valid. However, consider a summer vacation community adjacent to the military base. In this instance, the summer visitors and the summer training coincide. To the vacationers, the 3 summer months constitute the whole year. They never see the quiet times. For them, times of relative quiet during the rest of the year would mean nothing. The busy day concept, if there is one, is receiver centered and not source centered. If the receiving community is present only part of the year, then the impact should be assessed on the time period that the receiver is present. One can think of this as a "receiver frame of reference."

Can this same concept be carried to weekend operations? Should we assess noise based only on the weekend since most people are home only on the weekend? What about sources that operate only on the weekend? Is the "weekend frame of reference" a relevant subset to the "receiver frame of reference?" First, the 'weekend' frame of reference is relevant if the community 'arrives' just for the weekend. But if it is just at people's homes where they always reside, then the special frame of reference for the receiver is not valid. Rather, what may be needed is a time period adjustment. Currently, we add +10 dB to sound at night (10 PM to 7 AM). In California there is an evening normalization factor or adjustment of +5 dB (7 PM to 10 PM). Europe currently plans to use the same day/evening/night normalization scheme. Some have suggested day of the week adjustments. This is especially prevalent in Germany. Just as +10 dB is added at night, why not add +5 dB to all daytime weekend noise? Like the nighttime normalization, this would be a weekend, daytime normalization. A value of +5 dB would certainly account for either people or noise only being there on the weekend since 10 times the logarithm of 7/2 is about 4.5. But more importantly, a +5 dB adjustment would emphasize the fact that more people, even though they reside there year round, are actually at home during weekends than during the week.

Case Studies

Although questions relating to attitude remain, use of normalization factors as described above is appropriate and recommended. Three case studies are provided to illustrate this point.

The New Denver Airport. One Colorado community of about 60 people was situated in the countryside many miles from any major road, railroad or airport – until the new Denver airport was built three kilometers away.[42] The DNL from the airport was just below 60 dB, so the assessment suggested low annoyance and that everything was basically OK. Nothing could be further from reality. 100% of this community was highly annoyed. Over half joined in a lawsuit and over 20% moved away in the first year or so, citing noise as their main reason for moving. The DNL is 60 dB, but this community went from quiet to noisy, at least in the eyes and ears of these residents. A +10 dB adjustment for the expectations of a quiet, rural community plus a +5 dB adjustment for no prior experience with the noise source, as in Table 1, would have gone a long way towards providing a correct assessment of this situation.

It is logical to expect that over time the percent highly annoyed in this community will lessen. One group leaves; they sell their houses to new residents with different expectations. The new residents move in knowing they are near the airport (the land is so flat and open that one can see aircraft rolling on the runways and taxiways 3 km away). To the new residents, DNL 60 may be acceptable, especially if they get a good price on the house they purchase. This new airport will bring development and growth and in a few years, the urbanization of the areas will force the airport to impose the same restrictions on operations that they originally moved "out into the country" to get rid of. Areas nearby that are agricultural will transform to commercial, industrial or residential. Those that do not leave will gradually come to terms with the noise, and the percentage highly annoyed can be expected to decrease. Griffiths and Raw found a major part of the effect from a change in noise level to be visible 7 to 9 years after the change.[43] But 10 or 20 years from now, an attitudinal survey might show less than 10% highly annoyed.

The Expanded East Coast Plan. The Expanded East Coast Plan (EECP) of the Federal Aviation Administration (FAA) is another example of the breakdown in predictions of annoyance. Under this plan, the FAA decided to fan out aircraft departing Newark and LaGuardia airports to ease congestion in the airspace near the New York and New Jersey airports. The predictions of aircraft DNL in the New Jersey countryside ranged from the mid- to upper 40s to the low 60s.[44] They give the predicted former and then current DNL levels at 11 communities (Table 3). They note: "Ten of these (communities) involved the dispersion of aircraft over neighborhoods previously unexposed to aircraft noise or the overflying of areas at lower altitudes or the consolidation of LaGuardia traffic into corridors previously used only for Newark." Reaction to the EECP was quick. Complaints were almost immediate, widespread and have continued for several years. Numerous legal actions and complaints to state and federal representatives ensued. The reaction from the community was and is simply far more adverse than expected by the FAA and the New York/New Jersey Port Authority.

What happened? Muldoon and Miller suggest that the change in DNL is a better predictor than the DNL itself in this situation. While this is plausible, community expectations offer a simpler, more direct answer. The originally very quiet areas (42 to 45 DNL) should be very rural in character. These rural areas of New Jersey have expectations of peace and quiet. Many of the residents work in the New York City area. They commute 1 to 2 hours each way to work. These commuters have chosen this commute to live in the countryside. Apparently, one of their expectations when choosing such a commute is peace and quiet in their home setting. The EECP, at least in their minds, has taken their peace and quiet. As Willits, *et al.*, show in Table 2 herein, peace and quiet are the number one expected positive attribute of rural living. Apparently, at least in the eyes of these residents, the northeast plan has taken away their peace and quiet. The normalization procedures suggested herein would add +10 to +15 dB to the measured or predicted DNL. This adjustment would include +10 dB for the quiet rural setting and, in many cases, +5 dB for no prior experience with frequent aircraft overflights. For example, as Table 3 shows, a DNL of 48 would be adjusted to a DNL of 63, a level that would much better explain the widespread complaints and dissatisfaction with the situation.

Marine Corps Air Station (MCAS), Miramar, CA. Following the recommendation of the Defense Base Closure and Realignment Commission, MCAS El Toro was closed and its operations moved to NAS Miramar, north of San Diego. NAS Miramar had long been famed for its Top Gun School and its F-14 Tomcats. The Top Gun School was moved to Fallon, NV, and the Tomcats were assigned to other bases. In their place, the Marines brought in F-18 aircraft. Noise contour maps developed for the before and after conditions showed little difference in the noise environment from substituting F-18 for F-14 aircraft.[45] Also included in the transfer were helicopter operations. Almost from the beginning, residents have complained about noise and pollution and expressed concern over possible helicopter crashes. A subsequent study demonstrated that helicopter noise at the homes of complainants was so close to the ambient that only maximum levels, not SEL, could be measured.[46] No prior experience with helicopter noise is a major factor in this situation. Also, helicopter sounds frequently induce building vibrations and rattles.

People who complained emphasized the low frequencies: "prolonged, penetrating, low-frequency pounding of a Super Stallion helly-whopter,"[47] "both longer in duration and stronger in vibration."[48] In February 1999, the Marines shifted the helicopter route a mile south to avoid the town of Del Mar and other suburbs. In response, other citizens complained, and in September 1999, the mayors of four cities in the flight path met to discuss ways to reduce the noise.[49] If the Air Force had included a +15 dB adjustment (+10 dB for helicopter noise-induced rattles and +5 dB for no prior experience with the helicopter noise source) in their assessment, then their prediction of community response would have been much closer to reality.

Table 3. Estimated annual average DNL values before and after EECP implementation, along with estimated normalized DNL.

Rank*	Site No.	Community	Annual Average DNL Before	After	Change	%**	Normalized DNL***
1	2	Long Valley	42	49	+7	6	64
2	1	Cranford	52	57	+5	7	62
3	3	Tewksbury	42	47	+5	-	62
4	5	Denville	45	49	+4	3	64
5	6	Allendale	42	46	+4	-	61
6	10	Mendham	45	47	+2	2	62
7	7	Short Hills	53	55	+2	-	60
8	11	Colt Neck	50	51	+1	-	56
9	9	River Edge	53	53–54	0 to +1	-	53–54
10	8	Kearny	65	65	0	0.4	65
11	4	Readington	49	47	–2	-	47

* Absolute number of complaints without regard to population.
** Percent of population complaining – not all values reported by the authors.
*** Only positive change considered as 'new' sources and given a +5 dB "no prior experience" adjustment. Quiet rural status (+10 dB adjustment) only given to communities where the 'before' DNL was 45 dB or less.

Achieving the Intent of the Normalization Factors

Of the two military and two civilian case studies discussed here, three were predictable from the normalization factors (Westover AFB, EECP and Denver Airport) and the fourth (MCAS Miramar) is predictable if a 10 dB penalty to A-weighting is applied for vibration. Nevertheless, the original EPA factors are confusing and incomplete so a set of revised factors is suggested. The revised factors provide normalization adjustments that correlate with experience and are based on previous practice.

Table 4 contains the recommended quantitative normalization factors to be applied to DNL. Table 4 is divided into three parts. The first part deals with the acoustical factors relating to sound character and sound-induced rattles and vibration. There is supporting evidence for each of the acoustical factors. The remaining four "types of corrections" relate more to attitudes than to physical measures of the sound. These four are split into two groups of two each: general attitudinal factors

Table 4. Corrections added to measured or predicted DNL to obtain normalized DNL.

Factor Type	Type of Correction	Description	Correction Added
Acoustical-Physical	Sound Character	Highly impulsive sound[1]	+12
		Regular impulsive sound[1]	+5
		High-energy impulsive sound[1,2]	see Eq. (1)
		Prominent discrete tones[1]	+5
	Sound Induced Rattles	Audible rattles induced by the sound[2]	+10
Acoustical-Psychological All Situations	Time period for Computing DNL	Affected community only present during certain times of the year (e.g., summer)	Compute DNL on the basis of the time-period that the affected people are present
		Affected community present year-round	Compute annual average
		Nighttime (per current DNL formulation)	+10
		Weekends, daytime	+5
	Community Attitudes	Noisemaker has an on-going, effective relations program, responsive to all major attitudinal factors that increase negative response to noise sources	–5
Acoustical-Psychological Only Transient Situations	Setting	Quiet rural community (remote from large cities and from industrial activity and trucking)	+10
		All other communities	0
	Prior Experience	(Virtually) no prior experience with the specific noise	+5

[1]See ANSI S12.9 Part 4
[2]Except high-energy impulsive sounds

and transient situation attitudinal factors. Unlike the two acoustically based factors, these four attitudinal factors, like the widely used 10 dB nighttime adjustments, are more difficult to justify on the bases of evidence.

These four attitudinal factors are time period (nights, weekends) and observer orientation, setting (rural), prior experience, and other attitudinal factors that are currently, and provisionally, represented collectively by the catchall, "community relations." Of these, all except the last are a state and thus can be readily accounted for by normalization factors. Either an area is quiet and rural or it is not, a sound has a tone or not, a community has prior experience or not, etc. In contrast, community relations represents the active and continuing institution of a process to achieve and maintain good community relations by being attentive and responsive to those attitudes that are known to be significant modifiers to noise annoyance. These include responding quickly and effectively to complaints, education to counter the concept of misfeasance (the noise source is unnecessary), education to counter fear, and responding to and solving nonacoustical problems created by the noise source. In Table 4, the two general attitudinal factors are the time-period related factors and community attitudes. The two transient situation factors are setting and prior experience.

The reader will note that we have shifted our perspective when dealing with the issue of community relations to include not just annoyance but also complaints, adding a whole additional dimension to community response. It is not our purpose to deal with the understanding or prediction of complaints in this article. In fact, "As any airport noise abatement officer will attest . . . complaints are short-term responses to individual noise events, and particularly to unusual ones."[50] A similar conclusion was reached in two studies of complaints.[6,7] Our only reason for including any discussion on complaints is that failure to deal effectively with complaints as part of a public relations program will seriously degrade that program and eliminate much of the benefits that can be realized by an effective program.

Conclusions

It is concluded that normalization to DNL can remove much of the scatter in results from community to community and from setting to setting. Further, normalization will provide for better, more precise assessments. The EPA normalization factors (Table 1) go in the right direction. However, the analysis herein shows that several modifications, clarifications, additions and deletions should be made to this table.

The normalization factors in Table 4 are recommended as necessary and appropriate. This table contains a series of two-state factors for which normalization values are given. In addition, 'credit' can be taken for a strong, effective public relations program that responds to all the major attitudinal factors that modify noise annoyance. The normalization factors can be grouped into several categories and it is shown that attitudinal factors are very important to understanding and quantifying noise annoyance. One primary factor is expectation (and *not* expecting). In addition, annoyance judgments are modified by a primary group of four other attitudinal factors (fear, misfeasance, complaint handling, and nonacoustical contributions). With the exception of the weekend time-period adjustment that finds its history in some European laws and regulations, all of the adjustments in Table 4 are based on scientific data and/or the normalization factors originally published in EPA documents in 1974 and in earlier Air Force documents from the 50s and 60s.

Few recognize that a clear understanding of the psychosocial variables is vastly more important than, for example, the difference between a Type I and Type II sound level meter. If, as the evidence suggests, psychosocial variables control more of the variance in community response than acoustic variables, then the active and proper inclusion of normalization factors and procedures represents one of the most important dimensions to environmental noise assessment and analysis.

References

1. EPA (1973), "Public Health and Welfare Criteria for Noise," U.S. Environmental Protection Agency, Office of Noise Abatement and Control (ONAC), Rpt. EPA550/9-73-002, Washington, D.C.
2. ANSI (1996), American National Standards Institute (ANSI) Quantities and Procedures for Description and Measurement of Environmental Sound – Part 4: Noise Assessment and Prediction of Long-term Community Response, Standards Secretariat, Acoustical Society of America, New York, NY.
3. Schultz, T. J. (1978), "Synthesis of Social Surveys on Noise Annoyance," *J. Acoust. Soc. Am.* 64(2), 377-405.
4. EPA (1971), "Effects of Noise on People," US Environmental Protection Agency, Office of Noise Abatement and Control (ONAC), Rpt. NTID300.7, Washington, D.C.
5. EPA (1974). "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U.S. Environmental Protection Agency, Office of Noise Abatement and Control (ONAC), Rpt. EPA550/9-74-004, Washington, D.C.
6. Luz, G. A., Raspet, R., and Schomer, P. D. (1983), "An Analysis of Community Complaints to Noise," *J. Acoust. Soc. Am.* 73(4), 1229-1235.
7. Mabry, J. E., and Carey, R. B. (1980), "An Analysis of Community Complaints to Air Force Aircraft Noise," Air Force Aero-medical Research Laboratory, Rpt. AFAMRL-TR-80-88, Wright-Patterson AFB, OH.
8. USAF, (1977), Community Noise Exposure Resulting from Aircraft Operations: Volume 2. Acoustic Data on Military Aircraft: Air Force Bomber/Cargo Aircraft, Aerospace Medical Research Laboratory, Wright Patterson AFB, Ohio, November 1977.
9. Fidell, S, Barber, D. S., and Schultz, T. J. (1991), "Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise," *J. Acoust. Soc. Am.* 49(1), 221-233.
10. Bowsher, J. M., Robinson, D. R., and Robinson, D. W. (1966), "A Further Experiment on Judging the Noisiness of Aircraft in Flight," Acustica, 17(5), 245-267, S. Hirzel Verlag, Stuttgart, Germany.
11. Schomer, P. D., and Wagener, L. R., Benson, L. J., Buchta, E., Hirsch, K. W., and Krahé, D. (1994), "Human and Community Response to Military Sounds: Results for Field-Laboratory Tests of Small Arms, Tracked-Vehicles, and Blast Sounds," *Noise Cont. Eng. J.*, 42(2), 71-84.
12. Schomer, P. D., and Wagener, L. R. (1995), "Human and Community Response to Military Sounds – Part 2: Results for Field-Laboratory Tests of Small Arms, 25-mm Cannons, Helicopters, and Blast Sounds," *Noise Cont. Eng. J.*, 43(1), 1-13.
13. Fields, J. M. (1993), "Effect of Personal and Situational Variables on Noise Annoyance in Residential Areas," *J. Acoust. Soc. Am.* 93(5), 2753-2763.
14. Bronzaft, A. L., Ahern, K. D., McGinn, R., O'Connor, J., and Savino, B. (1998), "Aircraft Noise: A Potential Health Hazard," *Environment and Behavior*, 30(1), 101-113.
15. Stewart, C. M., Russell, W. A., Jr., and Luz, G. A. (1999), "Can Population Be Used to Determine Ambient Noise Levels?," Paper given at 137th Meeting of the Acoustical Society of America, Berlin, Germany, 15-19 March 1999.
16. Fields, J. M. (1998), "Reactions to Environmental Noise in an Ambient Noise Context in Residential Areas," *J. Acoust. Soc. Am.* 104(4), 2245-2260.
17. Gjestland, T., and Oftedal, G. (1980), "Assessment of Noise Annoyance: The Introduction of a Threshold Level in LEQ Calculations," *J. Sound and Vibration*, 69(4), 603-610.
18. Schulte-Fortkamp, B., and Nitsch, W., "On Soundscape and Their Meaning Regarding Noise Annoyance Measurements," In: Cuschieri et. al., Eds, Fort Lauderdale, FL, Vol 3:1387-1392.
19. Willits, F. K., Bealer, R. C., and Timbers, V. L. (1990), "Popular Images of 'Rurality': Data from a Pennsylvania Survey," *Rural Sociology*, 55(4), 559-578, Winter 1990.
20. Bishop, D. E., Mills, J. F., and Beckmann, J. M. (1976), Sound Exposure Level Versus Distance Curves for Civil Aircraft, Report 2759 R, Project 11150, Bolt, Beranek and Newman, Inc., February 1976.
21. Green, J. (1997), 1997 CPEO Military List Archive, 17 Dec. 1997, subject: Westover AFB Noise Case, www.cpeo.org/lists/military/1997/msg00449.html.
22. Staples, S. L., Cornelius, R. R., and Gibbs, M. S. (1999), "Noise Disturbance From a Developing Airport: Perceived Risk or General Annoyance," *Environment and Behavior*, 31(5), 692-710.
23. ISO (1998). Acoustics–Description and Measurement of Environmental Noise–Part 2: Acquisition of Data Pertinent to Land Use–Amendment 1, International Organization for Standardization (ISO), Geneva, Switzerland.
24. Illinois (1987). State of Illinois Rules and Regulations, Title 35: Environmental Protection, Subtitle H: Noise, Section 900.101: Definitions, Chapter I: Pollution Control Board.
25. ANSI (1993). American National Standards Institute (ANSI) Quantities and Procedures for Description and Measurement of Environmental Sound – Part 3: Short-term Measurements of Environmental Sound, Standards Secretariat, Acoustical Society of America, New York, NY.
26. Blazier, Warren (1981), "Revised Noise Criteria for Application in the Acoustical Design and Rating of HVAC systems," *Noise Control*

Eng. J., 16(2), 64-73 (March-April 1981).
27. ANSI (1995), American National Standards Institute (ANSI) Criteria for Evaluating Room Noise, Standards Secretariat, Acoustical Society of America, New York, NY.
28. Schomer, P. D., and Sias, J. W. (1998), "On Spectral Weightings to Assess Human Response, Indoors, to Blast Noise and Sonic Booms," *Noise Cont. Eng. J.*, 46(x), 57-71.
29. Sutherland, L. C., (1978), "Indoor Noise Environments Due to Outdoor Noise Sources," *Noise Cont. Eng. J.*, 11(3), 124-137.
30. Brown, D. and Sutherland, L. C. (1992), "Evaluation of Outdoor-to-Indoor Response to Minimized Sonic Booms," NASA, Contract Rpt. NAS1-19060, Douglas Aircraft Co., National Aeronautics and Space Administration, Langley Research Center, VA.
31. Schomer, P. D., (2000), "Loudness-Level Weighting for Environmental Noise Assessment," *Acta-Acustica*, 86(1).
32. Tokita, Y., Shimizu, K., and Okuda, M. (1980), "Proposal on the Low-Frequency Noise Meter," Proceedings of the Conference on Low-Frequency Noise and Hearing, 7-8 May 1980, Aalborg, Denmark, Henrik Møller and Per Rubak, editors.
33. Alverson, S. R., (1998), "Low-Frequency Noise From Aircraft Ground Operations," Presented at the U.C. Berkeley Noise Symposium, Harris Miller Miller & Hanson, Inc., 25 February 1998.
34. Schomer, P. D., and Averbuch, A. (1989), "Indoor Human Response to Blast Sounds that Generate Rattles," *J. Acoust. Soc. Am*. 86(2), 665-673.
35. Schomer, P. D., and Neathammer, R. D. (1987), "The Role of Helicopter Noise-Induced Vibration and Rattle in Human Response," *J. Acoust. Soc. Am*. 81(4), 966-976.
36. Sato, T. (1994), "Path Analyses of the Effect of Vibration on Road Traffic and Railway Noise Annoyance. In: Kuwano, S. Ed. Proceedings Inter Noise 94, Yokohama, Japan, Vol. 2, 923-928.
37. Paulsen, R. and Kastka, J. (1995), "Effects of Combined Noise and Vibration on Annoyance," *J. Sound and Vibration*, 181, 295-314.
38. Ohrstrom, E. (1997), "Effects of Exposure to Railway Noise: A Comparison Between Areas With and Without Vibration," *J. Sound and Vibration*, 205, 555-560.
39. Lercher, P., Brauchle, G., and Widmann, U. (1999), "The Interaction of Landscape and Soundscape in the Alpine Area of the Tyrol: An Annoyance Perspective," In: Cuschieri et. al., Eds, Fort Lauderdale, FL, Vol 2:1347-1350.
40. Hubbard, H. H. (1982), "Noise Induced House Vibration and Human Perception," *Noise Cont. Eng. J.* 19(2), 49-55.
41. Harris, A. S. (1988). "Use of Seasonal DNL for Airport Noise Compatibility Planning," *J. Acoust. Soc. Am*., 83 Sup. 1, pS33.
42. Colorado (1997), District Court, Adams County Colorado, Case No. 97 DV 0498, Division C, Thomas H. James and Jerilyn J. James Plaintiffs, v. City and County of Denver, a body politic and body corporate of the State of Colorado, Defendant.
43. Griffiths, I. D., and Raw, G. J. (1989), "Adaptation to Changes in Traffic Noise Exposure," *J. of Sound and Vibration*, 132(2), 331-336.
44. Muldoon, J. P., and Miller, R. L. (1989), "Low Levels of Aircraft Noise from Expanded East Coast Plan Operations," inter-noise 89, 665-670, Newport Beach, CA.
45. Wyle Laboratories (1995), Aircraft Noise Study for Marine Corps Air Station Miramar, CA, Research Report WR 94-25, Arlington, VA.
46. Wyle Laboratories (2000), Helicopter Noise Measurements on Offshore Routes for MCAS Miramar, Research Report WR 99-35, Arlington, VA.
47. Everett, D. (1999), "Letters to the Editor on the Issue of Helicopter noise from Miramar Marine Base in San Diego, California," *The San Diego Union-Tribune*, Opinion, September 9, 1999, B-15.
48. Perry, T. (1999), "Marines to Shift Helicopter Flight Path," *Los Angeles Times*, Wednesday, February 24, 1999, p. A18.
49. Huard, R. (1999), "Mayors of Four Cities in Flight Path of Helicopters from Miramar Marines Base in San Diego, California Meet to Discuss Ways to Reduce Noise," *The San Diego Union-Tribune*, September 9, 1999, Local Pages B-3:7,8; B-1:1; B-3.2.
50. Fidell, S., and Howe, R. (1998), Use of Airport Noise Complaint Files to Improve Understanding of Community Response to Aircraft Noise, NASA/CR-1998-207650, NASA Langley Research Center, Hampton, VA, April 1998.

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