TRAFFIC NOISE AND ITS EFFECT ON PEOPLE

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A descriptive apparatus is formulated to provide a means of relating traffic noise to human response. The basic variables of a sound that are intrinsic to any element of human response (magnitude, frequency distribution, and temporal characteristics) are specified. Maximum noise levels that permit satisfactory speech and listening environments for various types of spaces are given; it was found to be impossible to provide similar levels to prevent sleep interference. It was concluded that specifying criteria for different levels of annoyance is highly dependent on the nature of the intruding noise, the individual, local or regional attitudes, and even the socioeconomic status of the listeners.

•THE basic elements in describing any sound consist of measures of the magnitude of the sound, how its energy is distributed over the audible frequency range, and how its characteristics change with time. The magnitude of a sound is formally described in terms of its intensity, or the amount of energy radiated through a unit area in unit time. This method of description is, unfortunately, of little practical use. The range of intensity involved is easily 20 orders of magnitude in extent, and intensity itself is a vector quantity, difficult to measure.

Fortunately, both of these limitations are eliminated in practice by the use of a logarithmic scale for intensity, and, for most cases of practical concern, the square of sound pressure is proportional to sound intensity. The logarithmic scale is defined in terms of decibels, with intensity or sound pressure being the logarithmic ratio of that value for the particular sound of concern to that of an appropriate reference quantity. Thus, sound pressure level L (the word level being used to denote a measure in decibels) is defined as $L = 20 \log_{10} (p/p_o)$, where p is the root-mean-square value of the sound pressure, and p_o is the reference base of 2 nPa (0.0002 dyne/cm^2), roughly the threshold of hearing for humans. It should be remembered that the value of L will change with distance from a sound source. If this measure of magnitude is used to describe a specific sound source, it must always be accompanied by a measure of distance from the source.

Knowledge of the distribution of sound energy over the frequency range of audibility is of major importance because of the way in which the human hearing mechanism discriminates sound. We are most sensitive to sound in the midfrequency range, where the intelligence in speech is conveyed, and considerably less sensitive at lower and very high frequencies. For many engineering purposes it is often desirable to use sets of electrical filters to segment the sound level into various frequency ranges. The most common filter sets break the audible spectrum into slices an octave or less in frequency in width. An octave-band filter set typically uses eight values to separate the frequency components of a sound over the frequency range of audible interest for many applications.

Rather than have a whole series of sound levels for various frequency bands as the descriptor for a sound, it is often desirable to have a single number measure that conveys a frequency-weighted connotation. A number of frequency-weighting or "equalization" networks have evolved and have been standardized over time. It has been found

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through psychoacoustical evaluations that many sounds, when measured with the network designated "A," are subjectively judged to be approximately equal in noisiness when their "A-weighted" sound pressure levels are of equal magnitude. This finding has had wide application in motor vehicle noise where noise levels are most often measured or specified in sound level A, or less accurately, dBA.

The variation with time of a noise signal is the third important item in noise description. Just as people respond differently to noises having different frequency content, they also respond differently to temporal characteristics. Noises of the same A-level, but of different duration, are judged to have different noisiness values. The rate of change of noise level has been shown in some experiments to be of importance. The transient sound of a door slam or backfire has a startle effect due to the temporal characteristics of the sound.

Fortunately, in most traffic-noise situations we are concerned with two types of temporal characteristics for the sound signals. The first case is the passage of a single vehicle. This usually produces a smoothly varying sound signal, rising from some residual background noise level value to a maximum, then smoothly decaying to the background level as the vehicle has passed. This type of time pattern can easily be described by the maximum level produced and the duration between two points in the time pattern on either side of the maximum, say, 10 dB below it. An alternate description is the integral of level over the time history of the event, producing a numerical value equivalent to that which a steady signal of equal duration would have produced.

The second type of traffic noise signal of major concern is that produced by the noise from many vehicles combined, i.e., traffic noise. In this type of noise, the sound of any one individual vehicle is often indistinguishable from the merged contributions of the others. Of course, noises significantly higher than the average, e.g., individual diesel truck sounds superposed over automobile traffic, will stand out as discrete noise signals. This general type of noise is most easily considered as a random noise signal made up of a large number of individual contributions and is best described by statistical parameters.

If the traffic consists largely of automobiles, with only a few percent diesel trucks, at flow rates of more than a few hundred vehicles per hour, the noise levels have the characteristics of a normal statistical distribution. Thus the distribution can be described by a mean (average) noise level and the variance in the distribution. This noise level distribution comes about due to a normal distribution of individual vehicle source noise levels, a normal distribution in individual vehicle speeds, and the nature of the probability of the number of vehicles passing an observation point in a series of discrete slices of time (a Poisson distribution).

An example of a distribution of individual passenger vehicle noise levels is shown in Figure 1 (1). A predictive model for traffic noise, which is based on average traffic flow densities and speeds, is compared to an observed traffic noise distribution (Fig. 2) (2).

The problem is not so clearly described when the proportion of diesel trucks to passenger vehicles is higher than a few percent. In this case there is a superposition of basically two different normal distributions, one for each vehicle class, with substantially different means and variances for the two distributions. The result, of course, can often be a bimodal distribution of noise levels. An example is shown in Figure 3.

A convenient way to describe the generalized case of traffic-noise level distributions is in terms of the percentile points of a cumulative distribution. The points of interest in the distribution are designated by the levels that are exceeded a given percentage of the time and are written as subscripts to the sound level designator L. Thus the median level, that occurring just one-half of the time, is designated as L_{50}.

Two other values used frequently in describing traffic noise are that point exceeded 90 percent of the time, L_{90}, and that exceeded only 10 percent of the time, L_{10}. The lower value, L_{90}, is often used as a measure of background level and the upper value, L_{10}, as a measure for various "not-to-exceed" noise criteria. Obviously other values can be specified, but the extreme points involve confidence interval problems, sampling

Figure 1. Noise level distribution (normal highway cruise speed).

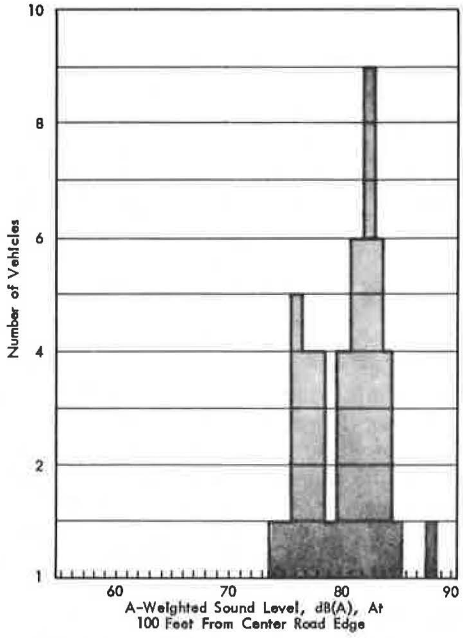


Figure 2. Comparison of prediction model and measured noise levels for passenger automobiles.

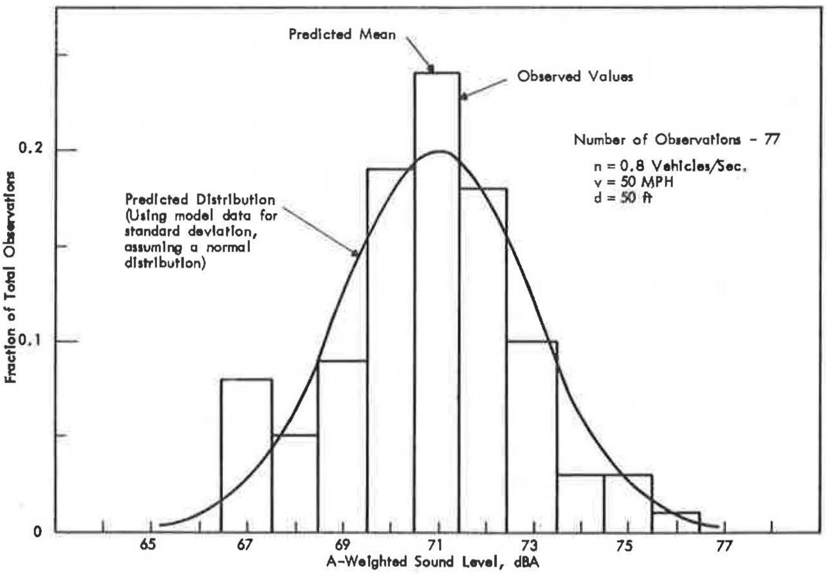


Figure 3. Typical noise distribution level for mixed traffic.

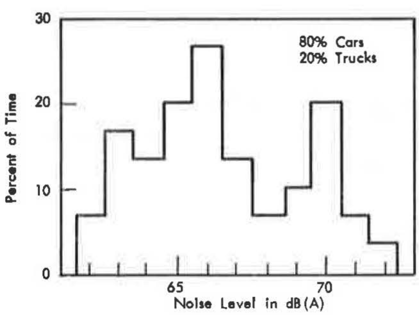
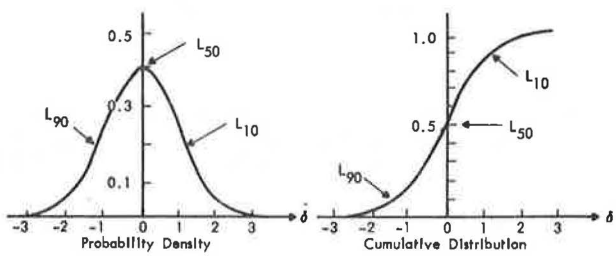


Figure 4. Relation among L_{10}, L_{50}, and L_{90} for normal distribution of sound level.



rates and total duration of sample periods used in measurements, and other statistical problems. It can be noted that, for a normal distribution, the L_{50} value is also the mean, and the L_{90} and L_{10} values are symmetrically disposed about the L_{50} value and are related to the standard deviation, σ, by $L_{10} - L_{90} = 2.56\sigma$. Schematic examples of these points are shown for both cumulative and density distributions in Figure 4.

The purpose of all this descriptive apparatus is to provide means for relating traffic noise to human response. We have already specified the basic variables of a sound that are intrinsic to any element of human response: magnitude, frequency distribution, and temporal characteristics. Let us now briefly consider the kinds of human response that noise engenders.

First, excessively high noise levels can cause temporary or permanent loss of hearing. Fortunately, traffic noise does not generate levels so high that they will cause hearing damage. It is thus more significant here to consider those human responses having to do with discription of specific activities and general annoyance.

The two most commonly discussed activity interference situations are those of speech communication and sleep disturbance. Of these two, disruption of speech communication is by far the better understood. By "speech interference" we also imply interference with listening to television and radio, or the ability to use a telephone satisfactorily. Relatively simple experiments allow criteria to be developed that specify how loud a noise will be before speech intelligibility is degraded. These criteria take into account the distance between people wishing to communicate, the voice power used, e.g., normal voice and raised voice, and the nature of the space in which the communication takes place, e.g., living room, office, schoolroom, factory, or out-of-doors.

Sleep disturbance by noise is much more difficult to quantify. Serious research on this subject has been pursued mostly in the past few years. Major problems are present in even defining what is meant by sleep and what is meant by disturbance of sleep. Even when operational definitions are specified, relatively little is known as to whether, and to what extent, human physiological or psychological functions are affected.

Annoyance from noise, on the other hand, is an aggregate of all the responses, feelings, and interpretations that people put to their relative acceptance of noises. These responses are not only to the physical characteristics of the noise but also to the information conveyed by the noise, that is, its semantic or contextual content. For example, a dripping faucet, a crying baby, the sound of surf or a waterfall, and squealing brakes all have different semantic content. The acceptability or annoyance engendered by a noise is also dependent on whether people expect that noise to be as it is, or what I term its "appropriateness." People expect it to be noisy adjacent to a busy urban street; they do not expect it to be noisy at a mountain retreat.

In summary, it is relatively easy to specify maximum noise levels to permit satisfactory speech and listening environments for various types of spaces where human activity takes place. It is impossible at this time to provide similar criteria for sleep interference. Specifying criteria for different levels of annoyance is highly dependent on the nature of the intruding noise, individual, local or regional attitudes, and even the socioeconomic status of the listeners.

In concluding this brief presentation, one can observe that most studies of annoyance show that, in addition to the other factors, speech and sleep interference become strong components of annoyance when these interferences are triggered by noise. The administrator faced with specification of acceptable noise levels, as he weighs all these factors, will most likely consider speech interference and rather coarse concepts of the related annoyance elements in arriving at this final position.

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