

Guide on Evaluation and Abatement of Traffic Noise 1993



***Prepared by the
AASHTO Highway Subcommittee on Design
Task Force for Environmental Design***

***Published by the American Association of State
Highway and Transportation Officials***

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FOREWORD

Increasing concern for the impact of highway projects on the environment led to the formation in December 1971 of the Task Force for Environmental Design as a subgroup within the Operating Subcommittee on Roadway Design.

The Task Force was organized to provide a focal point and working group with environmental design expertise in order to give direction and develop and promote design guides, policies, and standards in the subject area.

The first undertaking of the Task Force was the consolidation and dissemination of research information relating to traffic noise and the development of guidelines for the abatement of traffic-generated noise through highway design procedures and techniques. The *Guide on Evaluation and Attenuation of Traffic Noise* resulted from this undertaking, being published first in 1974 and again in 1985.

The state of the art in traffic noise reduction continues to change, and the current version of this guide represents the best information available to the Task Force at this time. The efforts of the Task Force members and their assisting staffs are gratefully acknowledged.

1.0 INTRODUCTION

1.1 The Problem—Traffic-Generated Noise

Noise is a problem of continuing public concern. Noise levels can be reduced only at a price. Because the motor vehicle is so crucial in our everyday living, it receives considerable attention from all elements of society. Peoples' reaction to traffic-generated noise is complex. It involves a combination of physiological and psychological factors that vary from person to person. Through the joint efforts of government and private concerns, appropriate responsibilities can be shared to obtain an effective and rational approach to noise control and abatement. State Highway Agencies should cooperate with local governments and citizens' groups to provide input for development of compatible land use planning techniques. In addition to land use planning, control of noise from the source, that is tire, engine, and exhaust noise, can aid in obtaining a quieter highway environment. Legislation and the design and manufacture of quieter vehicles are important components of this aspect of reducing highway traffic noise. Finally, highway design techniques for noise abatement should be used to the extent practicable.

The purpose of this guide is to familiarize the designer with the complex problem of highway traffic noise. The highway designers must do more than merely collect and evaluate noise data. They must also evaluate probable noise levels and the effectiveness of reducing highway traffic noise through location and design features and arrive at a cost-effective solution to the problem.

In considering and evaluating the impact of traffic-generated noise, the highway designer must realize that noise reduction measures may conflict with other social and environmental objectives. Such possibilities should be carefully evaluated in the noise analysis.

A review of the nature of the noise problem follows this introduction. Attacking the traffic noise problem with its interrelated aspects is presented as a systems approach—a sharing of responsibility for noise reduction. The guide provides some insight into the problems faced by highway planners and designers and presents remedial measures for noise reduction. Proce-

dures are outlined to aid in conducting noise studies. When noise studies indicate abatement measures may be reasonable and feasible, design features are presented to aid in obtaining cost-effective abatement.

2.0 NATURE OF NOISE

2.1 General Characteristics

Noise may be defined as unwanted sound. Sound is the sensation produced in the hearing organs when waves are created in the surrounding air by a vibrational disturbance. Each small region of the vibrated disturbance (from a point source) results in a compressional wave which radiates spherically outward from the source. The wave is analogous to the expansion of a balloon; as the balloon expands and its radius becomes greater, its surface area increases. Similarly, as the sound wave front moves away from its source and the surface area of the front increases, the acoustic energy in the wave decreases in proportion to the square of the distance from the source. Sound from a line source is made up of the sounds from each of the point sources. Energy losses occur due to friction. But simply stated, the intensity of the sound wave decreases as the distance from the source increases.

If an obstacle or barrier, such as a wall, is placed in the path of a wave front, a portion of the sound will be reflected by the obstacle, another portion may be absorbed by it, and yet another portion may be transmitted through it. In addition, a portion of the wave front that clears the top and ends of the obstacle will be bent or diffracted resulting in a "shadow" zone (Figure 1). The abating effect of a barrier is therefore dependent upon its dimensions and on the properties of the construction materials.

A dense, compact material with considerable mass will allow virtually no sound to pass through. This is a desirable quality for abating structures. A dense, smooth surface will reflect more sound than a porous, compressive substance. A porous, compressible material will absorb rather than reflect a portion of the sound striking it. However, it will allow a substantial portion of the sound to pass through the barrier unless it is backed by a dense, tight material.

The amount of noise finding its way into the shadow zone by diffraction is dependent on the frequency of the noise source, curvature of the wave front, and angle of incidence. The effect on an observer is dependent on the observer's distance beyond the barrier and on the barrier height and length.

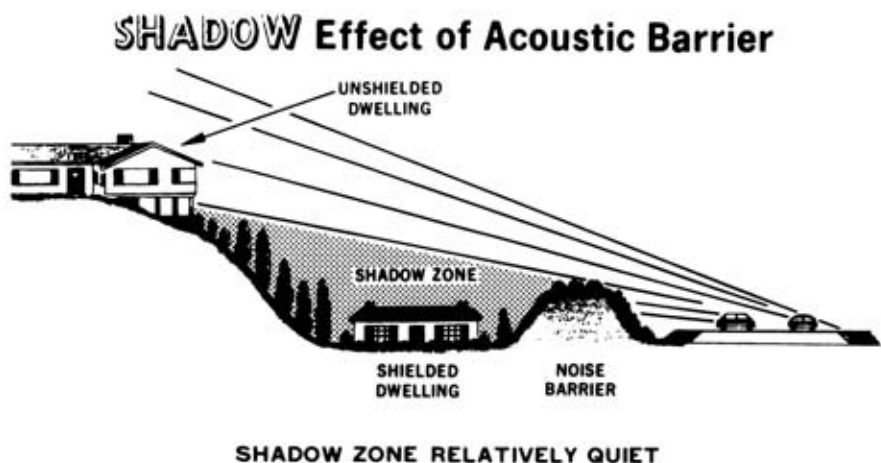


Figure 1

2.2 Measures of Sound Intensity

Each sound wave generates a pressure variation which is measured in units termed "microbars," a pressure of one dyne per square centimeter or approximately one-millionth of the normal atmospheric pressure. It is inconvenient to express sound levels in terms of microbars, since the range of numbers is astronomical. For convenience, sound pressure levels are described in terms of decibels (dB). This term is borrowed from electrical communications engineering, and it represents a relative quantity.

COMMON OUTDOOR NOISE LEVELS	NOISE LEVEL (dBA)	COMMON INDOOR NOISE LEVELS
	- - 110	Rock Band
Jet flyover at 350 m	- -	
	- - 100	Inside Subway Train (N.Y.)
Gas Lawn Mower at 1 m	- -	
Diesel Truck at 15 m	- - 90	Food Blender at 1 m
	- -	
Noisy Urban Daytime	- - 80	Garbage Disposal at 1 m
	- -	Shouting at 1 m
Gas Lawn Mower at 30 m	- - 70	Vacuum Cleaner at 3 m
Commercial Area	- -	Normal Speech at 1 m
	- - 60	
	- -	Large Business Office
Quiet Urban Daytime	- - 50	Dishwasher Next Room
	- -	
Quiet Urban Nighttime	- - 40	Small Theater, Large
Quiet Suburb Nighttime	- -	Conference Room (Background)
	- - 30	Library
Quiet Rural Nighttime	- -	Bedroom at Night
	- - 20	Concert Hall (background)
	- -	Broadcast Recording Studio
	- - 10	
	- -	Threshold of Hearing
	- - 0	

Figure 2: Common Indoor and Outdoor Noise Levels

By definition, dB are logarithmic functions of the pressure. To be more precise, the sound pressure level in dB is 20 times the logarithm of the ratio of the root-mean-square sound pressure in microbars to some ref-

erence pressure, usually 0.0002 microbars. The logarithmic function is used because the range of sound pressures is too great to be accommodated on a linear scale.

$$\text{Sound Pressure Level (dB)} = 10 \log_{10} (P/P_0)^2 = 20 \log_{10}(P/P_0)$$

P = root mean square sound pressure (N/M^2)

P_0 = reference sound pressure; $2 \times 10^{-5} \text{ N/M}^2$

Using dB instead of pressure units, the sound pressure levels of all likely sounds are covered on a scale of 0 to about 140 (Figure 2). The reference for sound pressure measurements is 0 dB, which corresponds to 0.0002 microbars. This represents the weakest sound that can be heard in an extremely quiet place by a person with very good hearing. A sound level of 100 dB corresponds to pressure of 20 microbars, or 100,000 times the pressure 0 dB. The range of sound pressure levels most frequently encountered in evaluating traffic-generated noise on highways is 50 to 95 dB.

2.3 Frequency and Loudness

Sound pressure level alone cannot be taken as an indication of loudness. The frequency of a sound wave is the number of times it repeats itself in each second (i.e., the rapidity with which the pressure fluctuations occur). Frequency is expressed in hertz (Hz). One hertz is one cycle per second. The audible range of frequency is from 20 to 20,000 Hz, but the ear is much more sensitive to sounds with frequencies near 1,000 Hz than to those near the range extremes. In order for a sound at 100 Hz to seem as loud as a sound at 1,000 Hz, the pressure level would have to be about 20 dB greater at the lower frequency. Most traffic noise has frequencies in the 100 to 4,000 Hz range, with engine noises occurring within the lower frequencies (100-250 Hz) and tire whine and wind turbulence occurring toward the upper limit of the range.

Very few sounds are pure tones (i.e., consisting of a single frequency). To measure sound precisely, it would be necessary to measure pressure levels for each of the multitude of frequencies which make up the sound. It usually is not convenient to measure a sound level in this manner. A simplified procedure consists of dividing the audible range of frequencies into 9 octave bands, obtaining pressure levels for each band, and then combining the results into a single value. By weighting the sound pressure level for

each octave band, an aggregate value can be obtained which approximates the response of the human ear to the sound pressure of the composite frequency. The A-weighted network most closely represents the range of human hearing and its response to traffic noise. The resulting sound level is represented by dBA.

2.4 Fluctuations in Traffic Noise

In assessing noise levels, the peak variation over a period of time is an important consideration. Occasional loud noises may be accepted with little complaint, but repeated high levels are usually a major problem in noise-sensitive areas. Moreover, it is far more costly to provide protection against the occasional loud noise than to protect against frequently recurring low-level noises. For providing noise protective measures where they will do the most good for the lowest expenditure, one should consider the maximum duration of exposure of the greater sound levels.

One factor which annoys and disturbs human activity is the magnitude of the loudest noise events which occur. Another factor is the repetitiveness of these loud noise events. For example, a few repetitions of a loud noise each day will not be particularly bothersome and will not warrant much attention. Several repetitions per hour could be quite objectionable. A third factor is the sustained or continuous nature of the noise.

An equivalent sound level descriptor (L_{eq}), which is based on the average acoustic intensity over time, has gained wide acceptance as a good representation of these three factors. The equivalent sound level, L_{eq} , represents the sound level which, if held constant over a specified period of time, would contain the same total acoustic energy as the actual fluctuating sound level during the same time period. It is defined as:

$$L_{eq} = 10 \log_{10} \left[\frac{1}{T} \sum_{t=1}^N 10^{(L_t/10)} \right]$$

where L_t is the sound level measured in dBA, T is total time, and t is the increment of time.

Because L_{eq} represents the average acoustic energy of the time pattern, it is a more versatile descriptor than the percentile descriptors, such as