Role of Plant Materials in Traffic Noise Control

DAVID I. COOK

The primary objective of this series of studies was to determine the extent to which plant materials are capable of reducing intrusive noise, mainly that from traffic. Tape-recorded sound and live sound were used for noise sources. Measurements were made by direct instrument reading and by magnetic-tape recording. Distances in the range of 5-122 m (16-400 ft) were used. Several kinds of trees and shrubs alone and combined with solid barriers were studied. More than 20 000 individual readings were taken in the three series of experiments; the minimum was 4 and the maximum was 12 readings at each position. Each experimental point shown on the graphs represents averages of eight or more readings. Although varying atmospheric conditions pose difficulties in the measurement of outdoor sound, the reduction of sound is less affected by the insertion of barriers than the individual day-to-day measurements are; under similar atmospheric conditions, measurements were repeatable within 1 or 2 dB. Readings much beyond 91 m (300 ft) from the noise source were subject to large atmospheric-induced fluctuations of sound level and are considered less reliable than are closer readings. Results indicate that plant materials can be used effectively to reduce intrusive noise under certain conditions. They are not a panacea, however, and considerable knowledge based on experience is needed for proper application. Perhaps the best use, in the majority of cases, is a combination of trees and some form of solid barrier. Three series of experiments, which span an eight-year period, serve as the basis for this paper.

Land adjacent to a busy thoroughfare is, in a sense, wasted land, or at best of limited use. It is the purpose of this paper to show how plant materials may be used to reclaim a portion of this land by reducing intrusive traffic noise to an acceptable value.

Although opinions vary widely on the ability of plant materials to reduce traffic noise, a viewpoint is offered that is based on experimental results as opposed to opinions that often appear to come from incomplete theories, conjecture, and folklore.

RURAL HIGHWAY NOISE

The need to control noise along rural highways is attributed to a desire for quieter roadside developments, which include motels, recreational facilities, and rest areas. Purely theoretical studies made in an effort to reduce highway noise are extremely difficult due to the nature of the noise source and the many variables encountered. It seems practically impossible to model or describe mathematically the noise emitted by a moving vehicle, which is actually noise from multiple sources that creates complicated gradients by its motion. Statistical analysis of experimental data is therefore most likely to yield accurate results that can be expressed numerically for design purposes.

Truck noise is most frequently mentioned as the most objectionable type of highway noise and, although some progress has been made in reducing emission levels from exhaust, intake, and engine accessories, noise generated by the interaction between tires and road remains high, and the chances for substantial reduction appear rather slim. Because of the frequency of complaints, most of the studies conducted in rural areas have concerned truck noise.

During an eight-year period, Cook and Van Haverbeke made three separate experimental studies by using tape-recorded noise and noise from moving vehicles as the sources. Conclusions from both types of studies are similar, but numerical results from actual moving vehicles are considered more reliable. Expanded discussions, which include detailed results of the studies, may be found in publications by Cook and Van Haverbeke (1-3).

TREE-BELT STUDIES

The original tree-belt studies were made by using taped noise projected toward wide belts of tall dense trees and measured on the opposite side. Control measurements were made under similar atmospheric conditions over a relatively soft surface devoid of large trees and shrubs to determine how much of the noise reduction (insertion loss or relative attenuation) was attributable to the belt. Fourteen tree belts of varying widths, heights, and tree species located within 161 km (100 miles) northwest of Lincoln, Nebraska, were selected for the study. Many had been planted during the Dust Bowl days in the late 1930s and early 1940s under the Prairie States Forestry Project directed by the U.S. Forest Service. A typical belt of trees is illustrated in Figure 1.

Figure 2 shows the sound level measured behind the trees at various distances from the noise source. The lower curves show the relative attenuation that may be expected when the surfaces that have trees are compared with the treeless surfaces.

An approximate 68-dB(A) level is observed 76 m (250 ft) from the noise source when measured behind the belt and the same level when measured 137 m (450 ft) behind the treeless surface. Thus a gain of 61 m (200 ft) of usable space is realized by the addition of the belt. The 68-dB(A) level had been suggested by Briton and Bloom (in a 1968 study that involved personal interviews) as an approximate dividing line between objectionable and unobjectionable noise (4).

Although wide belts of tall dense trees appear to offer substantial reductions in noise levels--typically in the range of 5-8 dB--and accompanying space saving of 61 m (200 ft), the time required to develop a tree structure of the necessary magnitude is often prohibitive. Therefore, another plan was conceived that offered partial immediate noise control and gradual improvement over a period of several years.

Solid barriers in the form of earth dikes (landforms or berms) have been used with varying degrees of success, and it was thought that a combination of landforms and plant materials might serve the intended purpose. Accordingly, an earth dike of vary-

Figure 1. Typical prairie-state shelter belt [in-row spacing, 2 m (7 ft)].

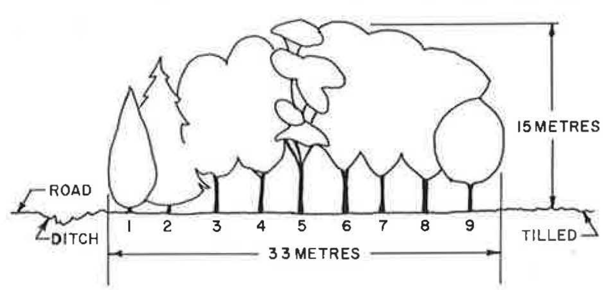


Figure 2. Sound level and attenuation versus distance for a tree belt.

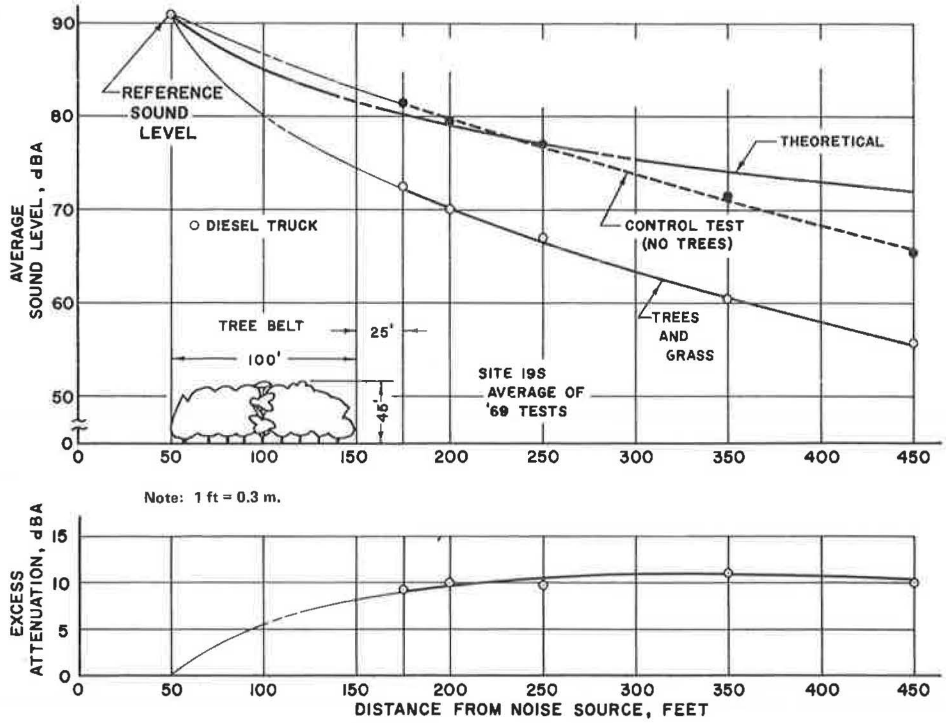
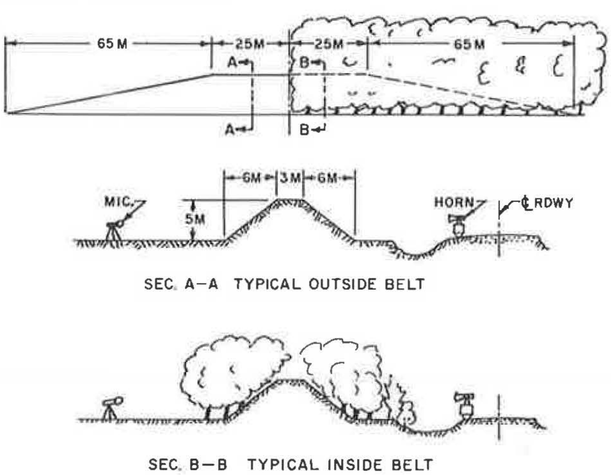


Figure 3. Hastings landform.



ing heights (Figure 3) was constructed on forest service property adjacent to US-6 near Hastings, Nebraska.

One-half of the dike was placed within a tree belt, whereas the other half was outside the belt but covered with short grasses. Tape-recorded truck noise was projected from the highway shoulder toward the screen, and the levels were measured on the opposite side as well as over an open field for comparison. This combination of belt and landform requires a frontage of approximately 46 m (150 ft), which includes the shoulder and the ditch. The trees are sufficiently far from the shoulder so as not to be a hazard to stray vehicles.

Figure 4 shows the noise levels behind the screen at varying distances from the noise source. One can observe that the noise level behind the screen is less than 60 dB(A) for all positions, a level generally considered quite satisfactory for daytime environments (4). The full-height barrier is needed to produce the desired result, since this height shields the exhaust stack of the truck from view. A site thus protected could be several hundred meters closer to the highway than an unprotected site.

LIVE-NOISE TESTS

This test series was run at the same site as that used for the tape-recorded series, but trucks that were actually moving along the highway were used as the noise source. Successive readings of the noise were made from each truck as it passed along the highway from the area of trees only to the area of the tree-covered landform to the area of the bare landform and finally to the area of open field, which served as the control surface.

Although not shown, the noise levels measured for all three surface treatments (except for the open field) were well below the maximum 68 dB(A) recommended for daytime out-of-door environments. Figure 5 illustrates the test results.

If the relative effects of the several types of surface cover are noted, a rapid decrease of attenuation is observed with distance for the bare landform and a slight improvement with distance for the trees alone. There is fairly uniform attenuation with distance for the combination--a desirable characteristic for highway rest areas or other roadside developments.

This test series, in my opinion, yields the most reliable results of any observed because actual vehicles of the type desired were the source of the noise and because experimental variables of atmospheric changes with time were practically eliminated by the method employed.

SUBURBAN TRAFFIC NOISE

For the average homeowner, suburban traffic noise is likely to be the most disturbing type, for it seems to be ever present. Careful advance planning for quiet communities is most desirable, but often it has come too late or has been influenced by economic factors and the noise problem remains. A third research study was conducted by using 10 residential

Figure 4. Sound level and attenuation versus distance for a tree-covered landform.

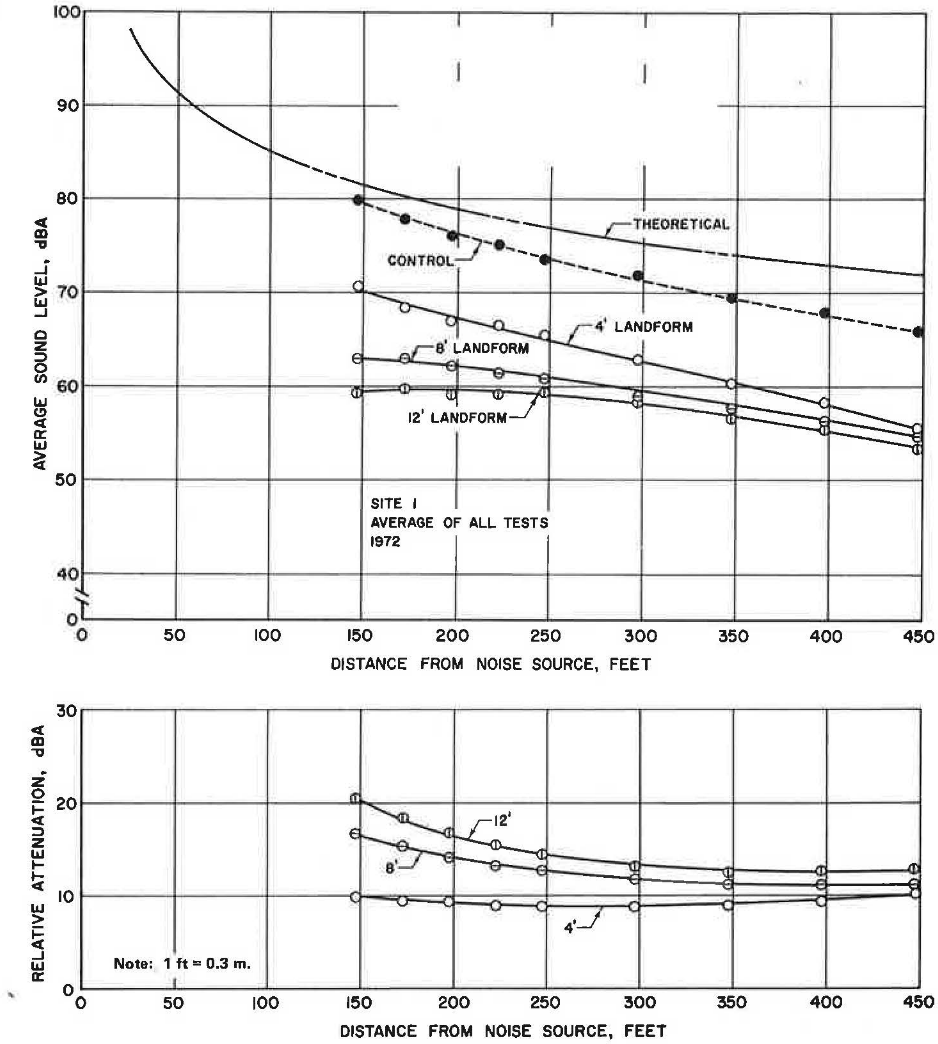
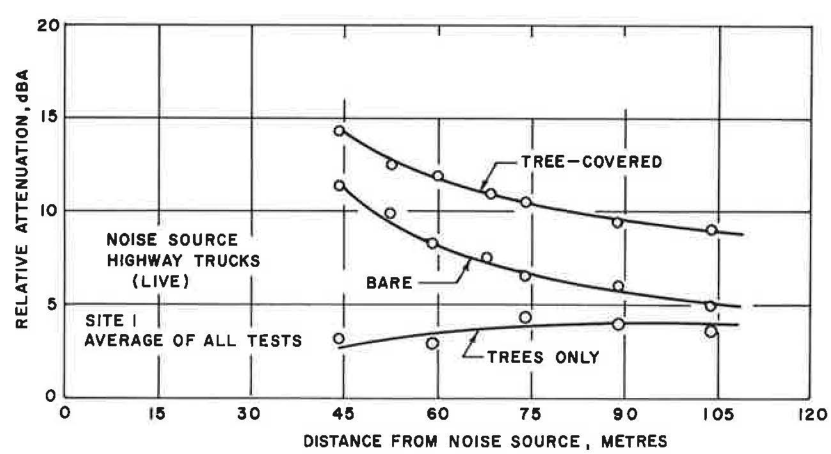


Figure 5. Sound-level attenuation of trees and landforms.



properties located along a busy arterial street as test sites. Three sites are shown in Figures 6, 7, and 8 as well as the experimental curves, which show the test results. Actual moving vehicles that attained speeds of 48-56 km/h (30-35 mph) were used in these tests. Only passenger vehicle noise was observed, since other vehicles were infrequent and nonuniform in emission levels.

The surface cover of site 105 (Figure 6) consisted exclusively of plant materials in a dense configuration. The noise level in the protected backyard area was found to be acceptable for daytime use. I consider this to be a good example of how plant materials alone may solve a traffic noise problem if it is not severe. Very little space is needed for the noise screen, and the pines make an excellent backdrop for other ornamental plants within the yard.

Figure 6. Sound level and attenuation versus distance for screen of plant materials.

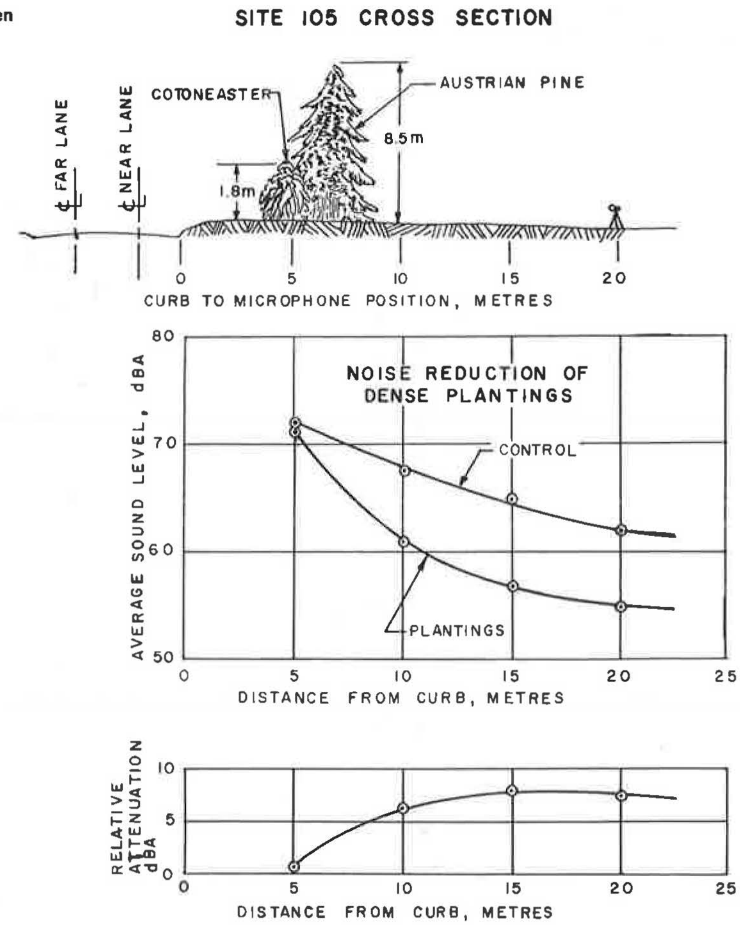
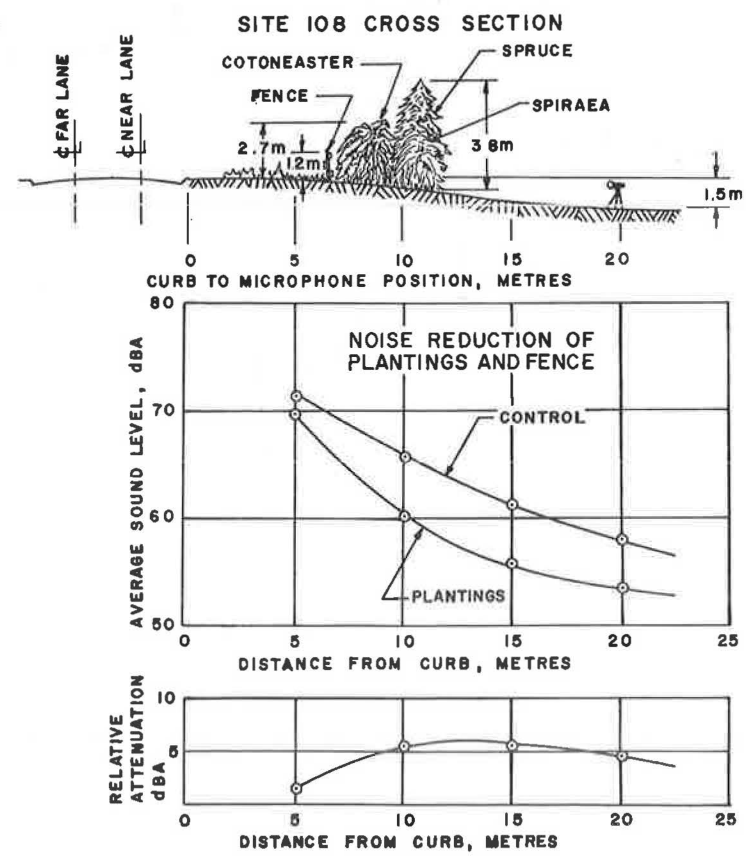


Figure 7. Sound level and attenuation versus distance for combination of wood fence and plant materials.



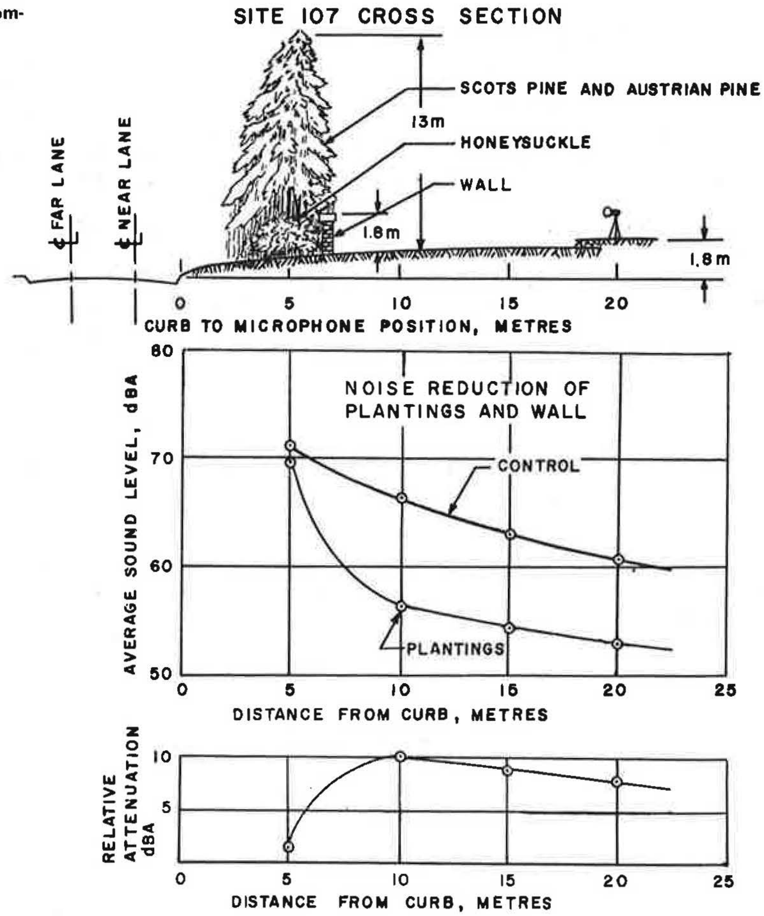


Figure 8. Sound level and attenuation versus distance for combination of brick wall and plant materials.

The screening of site 108 (Figure 7) consisted of clump plantings of trees and shrubs behind a woven-board fence. The amount of noise reduction realized at this site was somewhat less than it was at site 105, in spite of the semisolid fence. The lesser benefit may be attributed to open areas between the plantings and to the surface configuration caused by the elevated roadway at this point. On other occasions noise levels higher than expected have been observed adjacent to elevated highways and it has been concluded that elevated highways are to be avoided when noise in the immediate area is likely to be a problem.

The screening of site 107 (Figure 8) consisted of tall Scotch and Austrian pines, some smaller shrubs, and a solid brick wall about 1.8 m (6 ft) high. Results were exceptionally good--the best of all sites tested--and this may be attributed to the large tree mass, the solid wall (which hid the vehicles from view), and a slightly depressed roadway at this point. A noise problem from passing vehicles would be nonexistent within the entire backyard area.

SPECIAL CONSIDERATIONS

In this experimental study, certain facts that relate to the use of plant materials to reduce traffic noise became apparent. The noise source itself was subject to considerable variation in intensity and spectral characteristics. The nature of the propagation corresponded roughly to that of a point source; there was considerable variation, however.

Wind and temperature gradients as affected by tree barriers played a significant role in the propagation.

Experiments with thin belts, which would correspond to wintertime conditions, indicate that trees that have less foliage and underbrush have less ability to reduce traffic noise. For this reason I recommend evergreen varieties where year-round protection is desired. Within the limited scope of the investigations, no attempt was made to separate each of the several variables that affect propagation of traffic noise, but the abilities and limitations of plant materials to reduce the intrusion have, it seems, been fairly well established by this series of studies. Also, the most effective use of trees and shrubs and their combination with solid barriers may now be predicted with reasonable confidence.

CONCLUSIONS AND RECOMMENDATIONS

Although plant materials will not eliminate or greatly reduce all traffic-noise disturbances, there are many instances in which they may be used to advantage. The following recommendations are offered:

1. For a severe noise problem, such as that caused by large trucks that pass through a residential neighborhood in which there is adequate frontage available, earth berms planted with trees and shrubs in a dense configuration are recommended.
2. For the most-severe noise problem, such as that caused by high-speed truck traffic that passes through a residential neighborhood in which there is very little frontage available, a solid wall on top of an earth berm is recommended. Plant materials

may be placed adjacent to the wall to soften the appearance, but such placement will likely cause little additional noise reduction beyond that produced by the wall itself unless several rows of tall trees in dense planting configurations can be used. Some noise reduction in the form of less reflected noise from the wall back toward the roadway and beyond may be realized with minimal plantings, however.

3. For moderate noise problems, such as those caused by automobile traffic and occasional trucks, two or three rows of dense plantings of tall trees and dense shrubs may provide sufficient protection. When more screening is desired, a low earth berm can be added. This combination is recommended.

Plant materials should be considered as an alternative or supplement to walls or berms in a noise-reduction program. Not only do they provide noise reduction on their own, but they appear to act in such a manner as to complement the reduction caused by the solid-type screen and are more pleasing in appearance.

Any effective noise screen is worthwhile to consider in land use planning. Often only minimal space is required, and the protected area is made available for a wider variety of uses.

ACKNOWLEDGMENT

The Forest Service, U.S. Department of Agriculture, provided support funds and services of D.F. Van Haverbeke, research forester, for the three studies on which this paper is based. The study was administered through the Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

The University of Nebraska College of Engineering and Technology provided equipment and other support services as needed.

REFERENCES

1. D.I. Cook and D.F. Van Haverbeke. Trees and Shrubs for Noise Abatement. College of Agriculture, Univ. of Nebraska, Lincoln, Experiment Station Bull. RB 246, 1971.
2. D.I. Cook and D.F. Van Haverbeke. Tree-Covered Landforms for Noise Control. College of Agriculture, Univ. of Nebraska, Lincoln, Experiment Station Bull. RB 263, 1974.
3. D.I. Cook and D.F. Van Haverbeke. Suburban Noise Control with Plant Materials and Solid Barriers. College of Engineering, Univ. of Nebraksa, Lincoln, Engineering Res. Bull. EM 100, 1977.
4. J.H. Briton, Jr., and J.N. Bloom. Effect of Highway Landscape Development on Nearby Property. Franklin Institute Research Laboratories, Philadelphia, PA, Tech. Rept., 1968.

Publication of this paper sponsored by Committee on Transportation-Related Noise.

Noise Abatement and Public Policy Decisions: A Case Study—I-440 in Nashville

ANDREW N. BARRASS AND LOUIS F. COHN

Many state departments of transportation have become increasingly aware that early involvement of the public is essential for an effective highway noise-abatement program. Several states have developed formats for public meetings and other methods that assess citizen opinions prior to initiation of an abatement program. The Tennessee Department of Transportation has developed a thorough public-meeting and public-involvement procedure that is used before final design phases. This procedure was developed as an outgrowth of the I-440 community workshops. The I-440 community or neighborhood meeting is discussed in this paper and the Tennessee approach to noise-abatement information meetings is presented. In addition, other states' experiences are summarized and compared with the I-440 project. Other states' methods of public involvement or information meetings are explored, as well as their position on negative feedback from these various methods.

Since the adoption of federal design noise levels by the Federal Highway Administration (FHWA), many states have become increasingly aware of the necessity of involving the public in the noise-abatement decision-making process (1). Early involvement of citizens in noise-abatement measures by such states as California, Minnesota, and Pennsylvania has led to a consensus that such early involvement is essential for an effective highway noise-abatement program. Data have shown that when new highway construction occurs near otherwise-quiet neighborhoods, citizen apprehension toward both the highway and the potential noise impacts is lessened when public meetings are undertaken as a part of the project development (2,3).

Many states have developed formats for public meetings or information meetings, slide presentations, or costly multimedia programs for the purpose of presenting information about highway noise generation and potential noise-abatement measures. Minnesota, for example, has developed a thorough and concise slide-and-tape presentation that discusses the history of traffic noise, the development of highway noise problems, and noise-abatement procedures (4). Other city or state agencies and FHWA have produced similar information packages about transportation noise impacts for public meetings or predesign hearings.

The Environmental Planning Division of the Tennessee Department of Transportation (TDOT) has considered numerous possible formats and presentations that deal with the concepts of highway noise and noise abatement. Among these are (a) informal public meetings, (b) discussion-group interaction, (c) slide-tape presentations, and (d) questionnaires.

The method eventually adopted by TDOT is based on community information meetings, which were developed for and conducted as a part of a public-involvement strategy for redesign of a highly controversial Interstate project in metropolitan Nashville. The