National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

DIGEST 69 - APRIL 1975

These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed and prior to publication of the project report in the regular NCHRP series, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may obtain, on a loan basis, an uncorrected draft copy of the agency's report by request to: NCHRP Program Director, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418

Establishment of Standards for Highway Noise Levels

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 3-7, "Establishment of Standards for Highway Noise Levels," by B. Andrew Kugler, Senior Consultant, Bolt, Beranek and Newman, Canoga Park, California.

THE PROBLEM AND ITS SOLUTION

Those engaged in urban highway planning and design each year have found themselves in greater need for background data on which to resolve questions relating to highway noise levels and their effect on adjacent land uses. Consequently, the NCHRP sponsors have supported 10 years of research into the problems associated with highway noise. During this time, four separate and successive projects have been initiated with Bolt, Beranek and Newman. Three reports have been published to date on the first three phases, as follows:

NCHRP Report 78, "Highway Noise - Measurement, Simulation, and Mixed Reactions"
NCHRP Report 117, "Highway Noise - A Design Guide for Highway Engineers"
NCHRP Report 144, "Highway Noise - A Field Evaluation of Traffic Noise Reduction Measures "

The last phase of the research has been recently concluded with the submission of a six-volume final report. For this closing phase, the following five project objectives were established:

1. Document and summarize existing noise level information on the characteristics of motor vehicle noise sources, including trucks, buses, and automobiles.
2. Summarize the present state of the art in noise control for motor

vehicle sources and show expected trends in source control with existing technology.

3. Improve the prediction techniques for traffic noise propagation in urban areas and document the acoustic and nonacoustic aspects of traffic noise reduction measures, through both highway design and land-use planning.
4. Evaluate the economic trade-off considerations of relieving the highway noise problem through control at the source rather than exclusively through noise control by highway design.
5. Develop recommendations for improved highway noise level design criteria based on greater knowledge of the effects of time-varying noise in terms of annoyance, speech interference, and sleep interference.

Work on these objectives led to the preparation of six reports entitled: (1) "Design Guide for Highway Noise Prediction and Control;" (2) "Description and Control of Motor Vehicle Noise Sources;" (3) "Highway Noise Propagation and Traffic Noise Models;" (4) "Community Measures to Reduce Impact of Highway Noise;" (5) "Economic Evaluation of Highway Noise Reduction Strategies;" and (6) "Time-Varying Highway Noise Criteria."

It is anticipated that Volume 1 will be published as one report, Volumes 2 through 5 will be published as a second report, and Volume 6 will not be published. In the interim, loan copies of each volume or the entire set can be provided upon request to the Program Director, National Cooperative Highway Research Program, 2101 Constitution Avenue, N.W., Washington, DC 20418.

In addition to the reports, two computer programs are available--the first for prediction of highway noise levels, and the second for graphically plotting the output from the first. Volume One of the final report contains the computer users' manual, as well as both program listings and a sample problem. Card deck or tape copies of the program materials may also be arranged by contacting the Program Director of NCHRP.

Lastly, an illustrative motion picture film (19 minutes, color) entitled "Quiet Highway Design" has been prepared as one task in this project phase. Prints may be obtained on a short-term loan basis upon request to NCHRP, or may be purchased by arrangement with Bolt, Beranek and Newman.

FINDINGS

It is not possible to list all the project findings in the brevity desired here. What follows, therefore, is a digest of the summary of findings presented as Appendix A of Volume 1 of the final report.

Volume 1, "Design Guide for Highway Noise Prediction and Control"

Most of the material in Volume One pertains to either the development or the presentation of new design guide procedures replacing those presented in NCHRP Report 117. As procedures, they are more relevantly discussed under the heading of "Applications." The research reports in Volumes 2 through 6 more typically present findings--findings which for the most part constituted the basis for the modified design guide procedures and which, therefore, have already been applied.

Volume 2, "Description and Control of Motor Vehicle Noise Sources"

The noise of single motor vehicles can be described precisely by models. Furthermore, the abatement potential of total vehicle noise can also be determined, and vehicle costs associated with source noise reduction can be estimated.

The findings in Volume 2 indicate the following in terms of the Society of Automotive Engineers (SAE) acceleration pass-by 50-ft maximum A-weighted sound levels in decibels:

1. Reduction of diesel truck noise below the 80-dBA level scheduled by California for 1978 appears possible with an additional initial cost to the operator of from $400 to $700.

2. Achievement of a 75-dBA truck to meet the scheduled Chicago ordinance 1980 levels and the Environmental Protection Agency (EPA) best-possible-current-technology target will increase the initial cost into the $1,400 to $2,200 range. (The technical feasibility of a 72-dBA truck has been demonstrated.)

3. Additional initial costs of a 70-dBA truck to meet the California scheduled 1988 level is going to be extremely expensive in terms of initial operator costs using the best possible current technology.

4. California (1978), Chicago (1980), and proposed EPA limits of 75 dBA for automobiles are achievable at moderate initial costs (in the range of $100).

5. Achievement of the 70 dBA scheduled by California for 1988 is going to be very expensive (costs cannot be estimated) and may be attainable only with major configuration changes and, perhaps, engine performance degradation.

6. Reduction of motorcycle noise to 80 dBA (California, 1980) appears to require significant and undetermined modifications.

Volume 3, "Highway Noise Propagation and Traffic Noise Models"

This volume covers six individual studies that provide basic information needed to formulate a model for the prediction of highway traffic noise levels. The first study concerns the rate at which traffic noise diminishes with distance from the highway. The results of carefully planned field surveys indicate that the propagation loss for traffic noise over clear and flat terrain varies, depending on the ground cover (for example, from a 3-dB decrease per doubling of distance across a freshly plowed field to a 4.5-dB decrease per doubling of distance across parkland).

The second study assesses a previously recommended procedure for the prediction of noise attenuations due to roadside barriers, elevated roadways, and depressed roadways. By use of data collected during a prior study, good agreement was found between predicted and measured noise reductions. Basic cost data for various types of highway noise reducing constructions are also presented.

The third study concerns the directivity pattern of the noise radiated by passing vehicles in the plane normal to their axis of motion. The results indicate that vehicle noise in general, and truck noise in particular, can be assumed with only minor errors to be omnidirectional (equally intense in all directions) over angles from 0 to 45° in the plane normal to the vehicle motion.

The fourth study deals with the peak drive-by noise levels and emission levels of trucks in various categories and in various regions of the country. Extensive surveys in six states revealed that truck drive-by noise levels correlate with both the number of axles and speed, although the speed dependence is weak below 50 mph. After correcting for number of axles and speed, the average drive-by noise levels of heavy trucks fall in a range of ± 2 dBA from state to state. When averaged over all sites in the survey, the emission levels for trucks are about 82 dBA for medium trucks and about 90 dBA for heavy trucks.

The fifth study relates to a survey of users of the NCHRP Report 117 noise prediction procedures. Responses from 38 state highway agencies indicate that the procedures of Report 117 were considered overly complicated by most users, and did not cover all needs of the highway design engineer.

The final study reports on other noise prediction methods in use in the United States. The results of all six studies, combined with data from studies reported in the other volumes, were used in formulating the model presented in Volume 1.

Volume 4, "Community Measures to Reduce Impact of Highway Noise"

This volume covers studies of techniques for reducing highway noise impacts on neighboring communities by actions taken beyond the right-of-way. Three general categories of action are considered: (a) suppression of noise impact through proper land use and zoning, (b) reduction of the interior noise in community structures through additional sound treatment, and (c) reduction of the exterior noise in limited community areas through the use of sound barriers.

Land-use strategies were based on restricting the use of land bordering on the right-of-way to: (a) clear buffer zones; (b) structures that are normally unoccupied, such as warehouses and storage facilities; (c) structures that house activities normally involving high self-generated noise levels, such as shopping centers and manufacturing facilities; and (d) properly sound-treated high-rise structures that might provide some additional noise reduction to the remainder of the community through shielding. The study indicates that applying such land-use strategies to existing communities would generally be economically impractical due to the high costs associated with the acquisition of land. However, the techniques have merit for applications to future communities where the required zoning regulations could be imposed before the land is developed.

The building sound treatment study involves a complete assessment of the noise reduction that might be achieved inside community structures through modifications to current buildings, as well as through changes in the design of future buildings. Structure types considered include single- and multi-family dwellings, low- and high-rise hotels and commercial buildings, and various community service buildings such as schools, churches, auditoriums, and hospitals. The modifications to existing structures and changes in planned structures required to achieve 5, 10, and 15 dBA of noise reduction are detailed, with complete architectural descriptions and the associated capital costs. The results suggest that up to 15 dBA of interior noise reduction is possible for all types of community structures through proper sound insulating constructions. The required costs vary widely with the type of structure and its regional location, but are generally within reason.

Sound barriers within the community are considered for special applications, such as providing noise protection for a school playground. The findings are that properly designed barriers can provide up to 15 dBA of exterior noise reduction in limited outside areas. Although they can be relatively expensive, barriers provide the only reasonable techniques for achieving substantial noise reductions in open areas of existing communities by actions taken beyond the right-of-way.

Volume 5, "Economic Evaluation of Highway Noise Reduction Strategies"

The economic aspects of various techniques for suppressing the impact of highway traffic noise on neighboring communities are reported here. Noise reduction techniques in three general categories are considered: (a) reducing the source noise by quieting vehicles, (b) reducing the transmitted noise by appropriate highway construction, and (c) reducing the received noise by proper community land use and building construction.

For the case of vehicle noise reduction measures, the quieting of only heavy trucks is more cost-effective than the quieting of all vehicles. However, the quieting of all vehicles obviously provides a greater noise reduction potential. For the case of highway noise reduction measures, the building of roadside barriers is far more cost-effective than the construction of various elevated and depressed roadway configurations. Furthermore, barriers provide as much noise reduction potential as any other highway construction measure. For the case of community measures, the most cost-effective techniques are probably those related to land-use strategies; for example, zoning the land bordering on the right-of-way for activities least sensitive to intruding noise (storage facilities, warehouses, manufacturing facilities, etc.). Appropriate sound treatment of community structures can yield substantial interior noise reduction, but the cost per dBA is relatively high.

Volume 5 suggests the following broad conclusions: (1) quieting of at least the heavy-truck portion of the vehicle population appears to be the most attractive strategy for achieving up to about 5 dBA of highway traffic noise reduction in the community; (2) building of roadside barriers is the next most attractive strategy, and can provide up to an additional 13 dBA or so of noise reduction; (3) land-use strategies provide very attractive methods for reducing the impact of noise by moving sensitive activities away from the highway; (4) the reduction of interior noise in community structures by proper building treatment is a relatively unattractive alternative when compared to other options.

Volume 6, "Time-Varying Highway Noise Criteria"

This volume treats the impact of time-varying traffic noise levels on the neighboring community. It was found that noise levels specified by other criteria for effects of noise on people probably afford a good first approximation to noise levels that may be appropriate for minimizing sleep interference.

Results also showed that the equivalent noise level (L_{eq}) of time-varying traffic noise is adequate for assessing speech interference and annoyance ratings. For a constant L_{eq}, an increase in the variability of traffic noise increases the comprehension of contextual material and decreases annoyance. Low-level traffic noise was judged more annoying with speech present than with speech absent.

APPLICATIONS

Volume 1 of the final report is essentially a design tool; it presents new design guide procedures in a form that permits their direct implementation. Its purpose is to provide the highway engineer or designer with the procedures for predicting, evaluating, and minimizing traffic-generated noise. Two predictive methods are presented.

The first of these, the short method, is described in Chapter Five. It relies on the use of two nomographs to estimate the L_{10} levels at any observer location associated with a new highway design or improvement. When properly used, the short method will allow the highway designer to identify potential problem areas. It is also useful to save analysis time by indicating what locations require no further study. The short method is valuable in preliminary investigations (for example, where a number of different alignments may be compared without detailed design features having been established for any one configuration).

The second method is called the complete method. Its objective is two-fold: (a) to predict accurately the noise levels generated by a specific highway design; (b) to evaluate all sensitive areas where noise exceeds the standards of FHWA PPM 90-2 and determine for them which roadway sections are responsible. The method, which uses a computer program, is described in Chapter 6 of Volume 1. Outputs from the program may be produced in two forms--as tabulations where all the basic numerical quantities of interest are displayed, and as graphic displays on a scaled map of the L_{10} levels at all selected observer positions. The program identifies the highway elements responsible for conditions where the noise criteria are exceeded and the relative magnitude of noise reduction required.

Armed with this information, the user may proceed to modify highway designs so as to achieve noise reduction compatible with the design goals. Chapter 7 describes how a variety of roadway shielding noise control measures may be applied, and sample problems are provided for both the nomograph and computer solutions.

In addition to presenting the design guide procedures, Volume 1 provides procedures for two other types of studies. Appendix C, "Procedures and Techniques for the Measurement of Existing Background Noise Levels," describes noise measuring equipment and its use, and data collection and analysis procedures (including sampling techniques) for measuring and analyzing community noise. Appendix D, "Evaluating the Impact on the Public Health and Welfare of a Change in Environmental Noise Exposure," describes measures that can be used in evaluating environmental noise, and a general method for quantifying noise impacts on the community.

Volume 5, "Economic Evaluation of Highway Noise Reduction Strategies," also provides a useful highway applications tool. It offers methodology for making cost-effectiveness comparisons of different strategies for achieving noise reduction through such highway-related measures as barriers.

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