Enhancement of Highway Noise Modeling Through Computer Graphics

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Predictive modeling of highway noise has evolved dramatically in recent years. Current state-of-the-art models require extensive use of three-dimensional (X, Y,Z) coordinate data to represent roadways, barriers, and receivers. Introduction of incorrect data is all too common when such models are used because of the need to transfer information from maps to coding forms to computer files. To overcome these problems, the Vanderbilt University Transportation Research Group has developed an interactive computer graphics program, VUPLOT, designed to plot coordinate data in plan (X,Y) or profile (X,Z) view. One subroutine of VUPLOT permits the plotting of STAMINA-type input files or the selective plotting of roadways, barrier, or receiver files. Another subroutine overwrites roadway segment noise level contributions to the overall L_{eq} value at a particular receiver on a plan view plot of the prediction scenario. This paper discusses in detail the interactive use of VUPLOT and its subroutines.

Within the past 10 years, advances in software development have paralleled the significant growth in the sophistication of highway noise-prediction models (1). Opportunities for the noise analyst manifest themselves in the refinement, level of detail, efficiency, and overall accuracy achievable through such computer programs as STAMINA 1.0 (2) and STAMINA 2.0 (3). The advances also created problems for the analyst, primarily related to data management. Because of the complexity of the models, thousands of separate pieces of input data may be required to represent a given highway configuration. With such large numbers of input data values, two separate but equally significant problems inevitably come about: input errors and analyst disorientation.

Three opportunities exist for the accidental introduction of errors into an input file:

1. When reading coordinates from plans,
2. When coding coordinates onto forms, and
3. When typing data into the computer.

In using either of the STAMINA versions, input errors can be troublesome because, for fatal errors, error messages are unable to pinpoint bad coordinates. This can result in a kind of hit or miss, time-consuming debugging process. For nonfatal errors, use of either version of STAMINA can prove disastrous because execution will proceed and erroneous noise levels will be generated.

While attempting to maintain control of extensive data bases, it is not uncommon for the analyst to lose the ability to visualize or conceptualize input and output. Figuratively speaking, the analyst may become awash in a sea of numbers. Once the orientation of the numbers is lost, judgmental errors are possible.

Various members of the Vanderbilt University Transportation Research Group (VUTRG) have had extensive experience in using the STAMINA models on complicated highway projects and have often fallen victim to both of the problems discussed above. In its efforts to eliminate both problems and in its desire to significantly advance the state of the art in highway noise modeling, VUTRG has developed an interactive computer graphics package for plotting STAMINA and STAMINA-type input and output data in several forms. The package is the Vanderbilt University Plotting Package, called VUPLOT.

VUPLOT

VUPLOT is an independent FORTRAN computer program that allows the user to access two main graphics subroutines, SCHEME and LEVEL. SCHEME plots coordinate input data for STAMINA in plan (X,Y) or profile (X,Z) view, by using either a standard, complete STAMINA input file or a file that contains only a list of roadways, barriers, or receivers. LEVEL plots a plan view (X,Y) of selected roadways showing noise level contributions by individual segment at a selected receiver.

On execution of VUPLOT, the computer writes

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STAMINA PLOTTING ROUTINES

YOU MAY:
    GENERATE A SCHEMATIC PLOT        (ENTER -1)
    GENERATE A NOISE LEVEL PLOT      (ENTER 1)
    END PLOTTING PROCEDURE           (ENTER 0)

TYPE OF PLOT:
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To activate the SCHEME subroutine, the appropriate response is -1. The computer responds with

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YOU MAY PLOT SELECTIVELY (PLOTTING ITEMS OF YOUR
CHOICE) OR FROM A SPECIFIC DATA FILE.

DO YOU WISH TO PLOT FROM A SPECIFIC FILE? (YES):
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Should the analyst desire to plot a STAMINA input file, he or she simply hits carriage return to default to yes. This type of plot is often used when the analyst wishes (a) to examine the plan or profile orientation; (b) to examine interrelations among roadways, barriers, and receivers; or (c) to prepare a graphical illustration of the prediction scenario.

In the plotting of the specific file (i.e., defaulting the above question) the computer next writes,

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PLEASE ENTER THE NAME OF THIS FILE:
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The response to this would be something like RUN2B.DAT, where RUN2 may indicate the second in a sequential set of prediction scenarios and B may indicate the second modification of RUN2. The DAT simply reminds the analyst that the file is an input data file.

After the analyst enters the file name, the computer asks,

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TO WHICH FILE SHOULD THIS DATA BE OUTPUT?
(PLOT.PLT):
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Default to this question sends the output data to the general plotting file named PLOT.PLT. Reexecution of VUPLOT later will cause PLOT.PLT to be written over, so if the analyst desires to save a plot, he or she should create a new output file, such as RUN2B.PLT. In either case, the data in this output file are in such a format as to be suitable for use with the CALCOMP plotting system used by Vanderbilt.

Next, the computer writes,

ENTER SCALE: 1 INCH = FEET (250):

The default is 250 ft equals 1 in. Scale is only important when the analyst desires to obtain a hard copy printout of the plot. The computer then asks,

DO YOU WISH TO VARY THE HEADING SIZE WITH THE PLOTTING SCALE? (NO):

Default to this question causes the heading characters (e.g., titles and numbers) to be 0.3 in high, both on the cathode ray tube (CRT) screen and in the hard copy. For purposes of report preparation, it may be advantageous to alter this dimension.

The next command from the computer requires that the analyst select either plan or profile plotting,

ENTER AXES TO BE PLOTTED, SEPARATED BY A COMMA (X,Y):

Default to this command will result in a plot of the plan view of the scenario. The only other response acceptable to the computer is X,Z, which results in a profile or elevation plot. For a profile plot (X,Z) one additional question must be addressed,

BY WHAT FACTOR DO YOU WISH TO EXPAND THE VERTICAL AXIS SCALE IN TERMS OF THE HORIZONTAL AXIS SCALE? (10):

The analyst will ordinarily default to this question so that the vertical axis will be expanded tenfold with respect to the horizontal axis. Otherwise, it would be difficult to perceive subtle changes in elevation. One situation where the analyst will want to use no expansion for the vertical axis is when he or she seeks a profile plot of the top of a barrier. This could be accomplished by deleting all but one roadway and the barrier in question and expanding the plotting scale to 50 ft equals 1 in or 100 ft equals 1 in. Representation of the barrier's top geometrics will then be excellent.

When plotting either plan or profile, the next question asked by the computer is,

DO YOU WISH TO USE MULTICOLOR PLOTTING? (YES):

A default to yes on this question will cause the hard copy plots to show the roadways in black, the barriers in green, and the receivers in red. Headings will still be in black. Multicolored plots are especially useful in complex scenarios that include large numbers of roadways, barriers, and receivers.

By using the coordinate data entered via the input file, along with the plotting scale in feet per inch entered in response to a previous question, the computer will calculate internally the width of the vertical axis and print

THE VERTICAL AXIS IS XX. INCHES LONG

where XX is the length as determined by the computer. This information is helpful in two cases. First, when the plot is viewed on the CRT screen, the maximum height of the vertical axis is 7 in, so it may be necessary to increase the scale before executing the program that actually draws the plot on the screen (TEKPLT). Second, the drum plotter used to generate hard copy plots can print on either 15- or 36-in paper. Knowledge of the maximum vertical dimension will help the analyst to select the appropriate paper width.

The final three questions in the SCHEME subroutine of VUPLOT pertain to labeling:

DO YOU WISH TO LABEL THE ROADWAYS? (YES):
DO YOU WISH TO LABEL THE BARRIERS? (YES):
DO YOU WISH TO LABEL THE RECEIVERS? (YES):

A default on these questions will cause the programs to print the names of the roadways, barriers, and receivers, as given in the comment section of the STAMINA input data.

At this point the plot has been created and stored in the output file (i.e., PLOT.PLT or RUN2B.PLT). In order to view the plot on the CRT screen or obtain a printed copy, the analyst must engage the program TEKPLT or PLOT, respectively.

Selective Plotting for SCHEME

A most important feature of VUPLOT is its ability to eliminate coding errors prior to STAMINA execution. This is accomplished by using a data storage file system that contains open-ended files for roadways, barriers, and receivers. On the Vanderbilt system these are named RDWYS.DAT, BARS.DAT, and REC.DAT, respectively. RDWYS.DAT may contain an unlimited number of roadways, complete with traffic data and speeds, suitable for STAMINA use. Similarly, BARS.DAT and REC.DAT may contain an unlimited number of barriers and receivers ready for STAMINA. When the analyst is prepared to make noise predictions, he or she simply copies the appropriate roadways, barriers, and receivers from RDWYS.DAT, BARS.DAT, and REC.DAT into a new file, inserts the other information required by STAMINA, and executes.

Use of the selective plotting feature of VUPLOT will allow the analyst to visually inspect the coordinates and identify miscoded points easily. After specifying SCHEME (TYPE OF PLOT: -1), VUPLOT states and then asks,

YOU MAY PLOT SELECTIVELY (PLOTTING ITEMS OF YOUR CHOICE) OR FROM A SPECIFIC DATA FILE.

DO YOU WISH TO PLOT FROM A SPECIFIC FILE? (YES):

To initiate selective plotting, this question is answered, no. The computer will then ask,

DO YOU WISH TO PLOT ANY ROADWAYS? (YES):

Unless the interest is only in barriers and receivers, default is usually the response to this question. The computer then asks,

HOW MANY ROADWAYS DO YOU WISH TO PLOT? (DEFAULT PLOTS ALL EXISTING ROADWAYS):

Since the roadways file RDWYS.DAT will likely contain a large number of roadways, the answer to this question will be an integer between one and the total number of roadways in the file. For example, to plot the first five roadways in the RDWYS.DAT file, the following dialogue would take place

HOW MANY ROADWAYS DO YOU WISH TO PLOT? (DEFAULT PLOTS ALL EXISTING ROADWAYS): 5

ENTER A DESIRED ROADWAY NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 1

ENTER A DESIRED ROADWAY NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 2

ENTER A DESIRED ROADWAY NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 3

ENTER A DESIRED ROADWAY NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 4

ENTER A DESIRED ROADWAY NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 5

Similar interaction then takes place for data in the barrier and receiver files (BARS.DAT and REC.DAT). For example, to include the fifth barrier in BARS.DAT and the third, eighth, and twelfth receivers in REC.DAT the dialogue would be

DO YOU WISH TO PLOT ANY BARRIERS? (YES):

HOW MANY BARRIERS DO YOU WISH TO PLOT? (DEFAULT PLOTS ALL EXISTING BARRIERS): 1

ENTER A DESIRED BARRIER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 5

DO YOU WISH TO PLOT ANY RECEIVERS? (YES):

HOW MANY RECEIVERS DO YOU WISH TO PLOT? (DEFAULT PLOTS ALL EXISTING RECEIVERS): 3

ENTER A DESIRED RECEIVER NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 3

ENTER A DESIRED RECEIVER NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 8

ENTER A DESIRED RECEIVER NUMBER (NUMBERS MUST BE ENTERED SEQUENTIALLY!): 12

Following this interaction, the same questions pertaining to output file name, scale, heading size, plan or profile axes, color, and labeling discussed earlier for SCHEME, are asked and answered.

Once the subroutine SCHEME has been used, the output file created, and the labeling decided on, the command

TYPE OF PLOT:

is again put forth. In order to initiate the subroutine LEVEL, the response to this command is 1. LEVEL allows the analyst to examine the contribution of individual roadway segments to the overall L_{eq} value at specific, individual receivers. This type of plot is valuable late in the design phase where barrier-top elevations are being finalized in an optimization procedure. This concept was originally developed by VUTRG in an earlier study (4), when such plots were hand drawn.

LEVEL Plotting

On initiating the subroutine LEVEL, the computer asks,

WHICH INPUT DATA FILE IS TO BE USED?:

The analyst responds with the name of the STAMINA input file he or she wishes to examine. For example: RUN2B.DAT. The computer then responds with

WHICH OUTPUT DATA FILE IS TO BE USED?

Because the program must correlate predicted segment noise levels with output plots, the answer to this question must match that of the previous question. That is, the output file specified must be the plot file created by the STAMINA input. For example, if the STAMINA file was RUN2B.DAT, the output file to be used in the plot must be RUN2B.PLT. This is because LEVEL writes over STAMINA-produced noise level segment data onto a plot of that STAMINA data.

After specification of the appropriate data file, the computer asks,

TO WHICH FILE SHOULD PLOTTING OUTPUT BE SENT? (PLOT.PLT):

As with the SCHEME subroutine, defaulting to this question will cause the output to be sent to the general plotting file named PLOT.PLT. Should the analyst desire to save the plot for later use, he or she should create a new output file. For example, an appropriate output file name for data generated from RUN2B.DAT and RUN2B.PLT would be LRUN2B.PLT, signifying a LEVEL plot of the data in those files.

The next three questions in the dialogue are identical to those discussed in the SCHEME subroutine. These are as follows:

DO YOU WISH TO USE MULTICOLOR PLOTTING? (YES):

ENTER SCALE: 1 INCH = FEET (250):

DO YOU WISH TO VARY THE SIZE OF THE HEADING WITH THE CHOSEN SCALE? (NO):

Since LEVEL plots segment noise level values at only one receiver, the computer asks,

ENTER RECEIVER NUMBER FOR WHICH LEVELS ARE DESIRED (1):

Defaulting to this question results in the calculation of levels for the first receiver in the STAMINA input list. Should the analyst desire levels for any other receiver, he or she simply inputs its number (sequence) from the STAMINA input list of receivers.

One problem with writing noise level values directly onto graphical plots is the likelihood of writing over numbers on those of adjacent segments and roadways. To solve this problem, the program allows the analyst to specify only those roadways for which he or she has an interest. For example, if only interested in roadways 4 and 5 from a STAMINA input file, the dialogue would appear as

HOW MANY ROADWAYS DO YOU WISH TO PLOT? (ALL): 2

NOTE: ROADWAYS ARE REFERENCED SEQUENTIALLY AS THEY APPEAR IN THE DATA FILE

ENTER DESIRED ROADWAY NUMBER: 4

ENTER DESIRED ROADWAY NUMBER: 5

Should the analyst desire to include all the roadways in the STAMINA input, he or she simply defaults to this question. Regardless of whether all of the roadways are plotted in the input file, the total L_{eq} value for all roadways is shown in the heading.

At this point, the output plotting file has been constructed and the execution of the LEVEL subroutine is completed. The command,

TYPE OF PLOT:

is once again given. To disengage VUPLOT, the analyst simply defaults.

Drawing Plots with VUPLOT

The Vanderbilt DEC1099 system works via file storage, retrieval, and editing. Since the output from both subroutines of VUPLOT (SCHEME and LEVEL) is in the form of files stored in the system, it is necessary to use separate programs designed to physically construct the plots. Two such programs are available. The first, TEKPLT, is for use with a remote

Figure 1. Plan view of example plot from VUPLOT subroutine scheme.

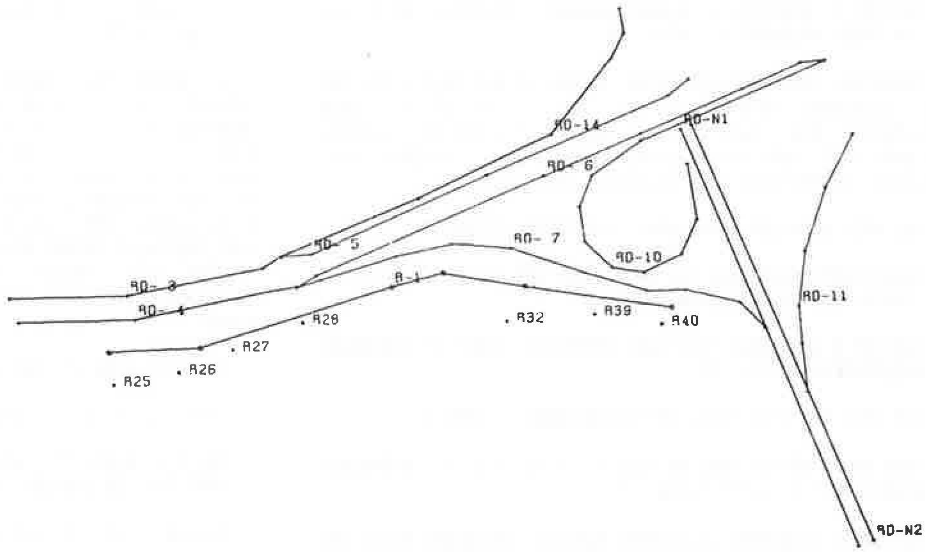


Figure 2. Profile view of example plot from VUPLOT subroutine scheme.

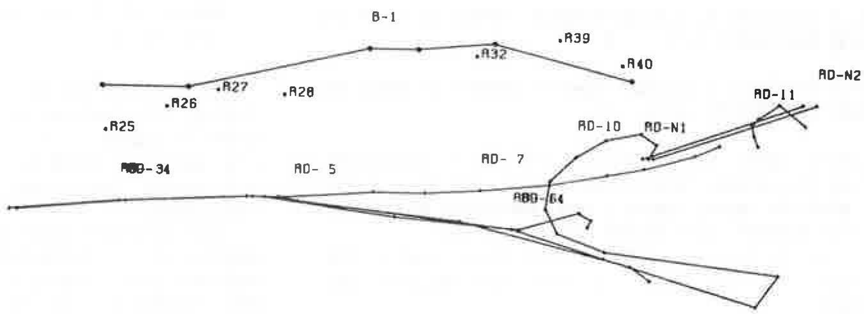
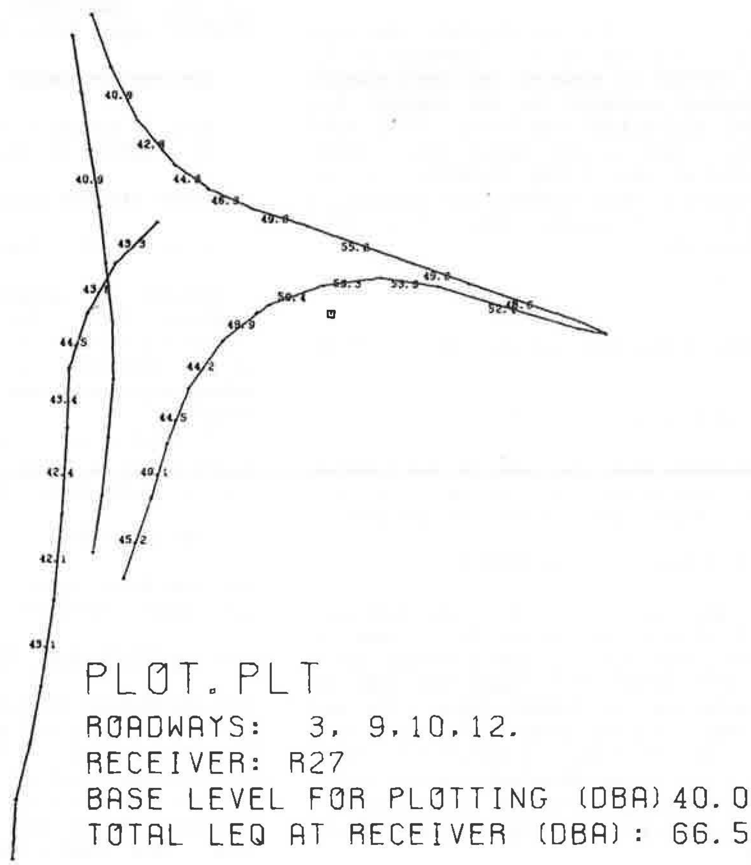


Figure 3. Plan view of example plot from VUPLOT subroutine LEVEL.



CRT terminal. The second, PLOT, is for use with a CALCOMP-type hard-copy plotter. Because these programs are system specific and because their use is quite simple, they will not be discussed here.

Figure 1 shows an example of a plan (X,Y) view plot of a STAMINA input file named EX4.DAT. Figure 2 shows the profile plot (X,Z) for the same file. Figure 3 shows a levels plot (in plan X,Y) for a receiver in the STAMINA input file.

SUMMARY

Use of coordinate-based computer models for highway noise prediction has become widespread in recent years, with resulting increases in accuracy and design flexibility as well as in error potential. For such programs as STAMINA 1.0 and STAMINA 2.0, these errors can manifest themselves as resulting from reading coordinates from plans, from coding coordinates onto forms, and from typing data into computer files. Another problem associated with such models is analyst disorientation, where a preponderance of numbers may cause the analyst to lose his or her ability to visualize the physical meaning of the input and output.

VUTRG has developed an interactive computer graphics package named VUPLOT that allows the analyst to plot, either on a CRT screen or hard copy, plan or profile representations of roadways, barriers, and receivers. The SCHEME subroutine of VUPLOT allows the analyst to plot a labeled series of roadways, barriers, and receivers from either a standard STAMINA input file or from separate unlimited storage files for roadways, barriers, and receivers. The LEVEL subroutine allows the analyst to overlay segment noise level contributions for a particular receiver, on a plan view plot of selected roadways near that receiver.

REFERENCES

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Highway Construction Noise Modeling

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A model and interactive computer program for predicting highway construction noise levels have been developed and evaluated for the Federal Highway Administration (FHWA), as part of its on-going efforts to provide state-of-the-art tools for highway-noise analysis. The model addresses noise sources as points, lines, or areas and has a built-in data base for 53 different sources. Noise barrier attenuation may also be analyzed. The results of the calculations are the total 8-h equivalent sound levels [L_{eq}(8h)] at noise receptors as well as the individual contributions from each source. Use of the model will not be required by FHWA; however, the model can serve as a useful tool for meeting the requirements of the FHWA noise standards for impacted areas and for evaluating abatement measures. It may also be used during construction as a diagnostic tool for investigating citizen complaints and for designing mitigation strategies, if necessary.

In its efforts to provide the latest tools for analysis of highway noise, the Federal Highway Administration (FHWA) conducted a research project to develop a model and computer program for predicting levels of highway construction noise (1). At the completion of the project, Vanderbilt University was asked to evaluate the model and prepare a user's manual (2) and construction noise-analysis handbook. This paper outlines the highway construction noise model and program. It discusses basic features, data input requirements, program output, and several applications.

BACKGROUND

FHWA has recognized the need to address the impacts of highway construction noise from federal-aid projects for many years. The FHWA noise standards state that the following steps are to be performed when doing a highway noise study (3):

1. Identify receptors that are sensitive to highway construction noise;
2. Determine mitigation measures for those receptors impacted by construction noise, considering the cost and feasibility of such measures; and
3. Incorporate the needed abatement measures into the plans and specifications for the project.

The states were given total flexibility to meet the requirement of this paragraph. No maximum permitted noise levels were included in the noise standards, and the use of specific procedures to determine impact was neither specified nor required. FHWA thought that the level of effort applied for mitigation of construction noise depended on the type of project and its circumstances. Requirement of specific analysis techniques or imposition of maximum permitted noise levels would be an added regulatory incumberance that would often be more extreme than warranted.

However, FHWA recognized its leadership role in providing guidance to state noise analysts. As a result, it embarked on a program to provide state-of-the-art information on construction noise. The first part of this effort was an in-house staff study on highway construction noise measurement, prediction, and mitigation (4). This report presented simplified measurement and prediction tools and sample contract specifications for different categories of construction noise control. The report has served as a useful reference to state noise analysts for the last six years.

FHWA's second effort in the study of highway construction noise was a symposium held in 1977 on