How Well Do They Work?

Let us first state that some of our problems may be due to inaccurate input data. It is fairly difficult to get accurate traffic data without a considerable expenditure of man hours. In many cases, traffic predictions were used instead of actural vehicle counts.

The 117/144 methodology was close for heavily traveled freeways with at-grade sections. Two of our districts reported the predicted level to be about 2 dBA above the measured. Some said actual versus predicted was off by a maximum of 4 to 5 dBA in most freeway cases. The accuracy of this method reportedly diminishes as we get away from the heavy volume and at-grade sections. It is considered poor for stop-and-go traffic.

The TSC nomograph has received very little validation. Where it was used, it was considered good for high volumes and poor for low. It was reported unrealistic past 1000 ft (304.80 m).

The TSC computer program was put up on our computer but its input deck proved too much for those who tried to use it and the work was redone using the 117/144 methodology.

Method California 701-A was reported to work very well under all conditions. A methodology developed by Wyle for the San Diego Comprehensive Planning Organization is available, but as yet, not used. The revised design guide recently supplied by BB&N is up on our computer but we have not yet had a chance to put it through its paces.

What Causes the Problems?

The primary problem with low-volume roads probably is within the L_{10} parameter itself. The distribution of vehicles must be known to a greater degree than it is now to handle the low-volume case.

The 4.5 dB per doubling of distance is suspect. This assumes that excess attenuations are a function of distance doubling. Some strong arguments could probably be made against that assumption.

Vehicles in different parts of California probably have different emission levels.

The existing models are so interwoven that it is difficult, to the point of being impractical, to check the components of the models.

Conclusion

We are fairly sure that L_{eq} based parameters will be used in the future. This type of parameter is necessary to handle multimodal transportation studies.

California has had good success with peak levels. We find that they are very useful in describing low-volume conditions. We also use them for validating truck noise emission levels and barrier attenuations. We find them easy to work with and easy to explain to the layman. If we are required to report the variance of noise (L_{np} type thinking) we will probably use the difference between the peaks and the L_{eq} for that purpose.

Although greater rigor should be incorporated in our noise modeling, so should simplicity. We are not at all convinced that these are mutually exclusive goals. What is needed is an accurate foundation in proven theory so that we know, with confidence, the limits on achievable accuracy. We should avoid computational overkill based on questionable basic assumptions.

APPLICATION AND FINDINGS OF TSC NOISE PREDICTION METHODOLOGY

Terry Hatcher and Marvin Patrick Strong,
North Carolina Division of Highways

The North Carolina Division of Highways has found the DOT-TSC-FHWA-72-1 Noise Prediction Program to be a very useful design tool within certain limits. From its orginial program version as issued by the Federal Highway Administration, the program has been adapted to the IBM 370 computer system. Modifications to the input format and output display associated with this adaptation have improved the overall utility of the program affording highway design engineers and technicians a readily comprehensible means to quantitatively assess various traffic noise situations. As a design measure, the methodology is responsive to traffic flow volume changes, roadway geometrics, and topographical variations, and these qualities of the program provide the highway design engineer a sense of appreciation and understanding of specific roadway-receptor relationships.

The methodology is generally exact in its design application requiring a limited number of arbitrary judgments; this moderate degree of exactness further enhances the acceptability of the program as a design tool.

Experience within the North Carolina Division of Highways has shown that the DOT-TSC-FHWA-72-1 program produces considerable inaccuracy when utilized during the preliminary stages of project development. Overpredictions on the order of 10 dBA or more are common and the level of detail available during the planning stage of a project is generally insufficient to warrant the useage of the prediction methodology.

Major problem areas and limitations have been concerned with the consideration of traffic flow and capacity, the inability in certain situations to accurately account for noise attenuation resulting from natural and artificial barriers, and the observance of inconsistencies between measured and predicted noise level data. As the methodology is independent of highway capacity constraints, it assumes that all traffic flow conditions are uninterrupted and it has no measure to account for variations in level of traffic service. The flow condition factor creates inaccuracies in applications pertaining to high-volume urban thoroughfares with no access control, whereas the level of service judgment may generate inaccuracies in design applications for rural highway sections. These specific types of program inaccuracies have been observed in comparisons of predicted versus measured noise level data.

Recent field investigations have been conducted by the North Carolina Division of Highways that suggest that the 87.0 dBA heavy duty spectrum and 3.0 dBA drop-off rate standard to the TSC program generate considerable inaccuracy in noise level predictions. Computer tests were run to compare the accuracy of measured versus predicted data utilizing the 87.0 dBA heavy-duty vehicle spectrum, an 86.0 dBA tractor-trailer vehicle spectrum [50-59 mph (80-95 km/ph) speed interval] as reported in Olson's "Survey of Vehicle Noise". The Journal of the Acoustical Society of America, April 1972, and the 82.0 dBA heavy-duty vehicle spectrum reported by Galloway in NCHRP 117 (see Figure 1). Drop-off rate variables considered during these computer correlation tests were 3.0 dBA and 4.5 dBA.

Four test sites were selected, all of which involved highway sections with 55 mph (88 km/h) speed limits and roadway gradients less than or equal to 2 percent. None of the sites were influenced by interrupted traffic flow, industrial background noise, or other transportation noise. These sites had low ground cover and had little or no hard reflective surfaces within the immediate microphone-roadway survey limits. Figures 2, 3 and 4 depict the traffic flow characteristics observed at these locations. Hourly light-duty-vehicle traffic flows varied from 500 veh/h to 3500 veh/h. Hourly heavy-duty vehicle flows (with the heavy-duty vehicles categorized as 2-axle, 6-tired vehicles and all larger vehicles with 3 or more axles) varied from approximately 70 to 600 veh/h. Tractor-trailer variations as a percentage of all heavy-duty vehicles ranged from 30 to 80 percent.

Tables 1 through 4 give the measured versus predicted L_{10} noise level comparisons utilizing the heavy-duty vehicle spectrum and the drop-off rate variables. Data comparisons were made at receptor locations situated 50, 100, and 200 ft (15.24 m, 30.48 m, and 60.96 m) from the near edge of pavement. Table 5 provides a collective summary of the margin of error for all four study sites.

The individual site data comparisons presented variable results. For the US 1 Raleigh site, the 82.0 spectrum -4.5 dBA drop-off rate produced the most favorable comparison with the measured data. As further investigation for this particular study site, noise level predictions were also made utilizing the 82.0 dBA heavy-duty vehicle spectrum and a 6.0 dBA point source drop-off rate. These variables produced even more favorable correlation with the measured L_{10} data and in general the predictive accuracy improved with increased distance from the roadway. It is interesting to note that the traffic flow conditions at this particular test site were hourly automobile flows less than 1000 veh/h, heavy-duty vehicle flows less than 100 veh/h and tractor-trailer populations comprising 50 percent or less of the total class of heavy-duty vehicles. L10 data correlation for the I-95 Benson site was excellent with the 82.0 dBA heavy-duty vehicle spectrum and the 4.5 dBA drop-off rate. The average margins of error for the L_{10} data comparisons at this particular site were less than 0.1 dBA underprediction at the 50-ft (15.24-m) receptor location, 0.8 dBA overprediction at the 100-ft (30.48-m) receptor location, and 0.8 dBA overprediction at the 200-ft (60.96-m) receptor location. The data results at the I-85 Burlington site and the I-85 Charlotte site were similar in that the 86.0 dBA heavy-duty-vehicle spectrum and 4.5 dBA drop-off rate produced results within approximately 1 dBA of the measured L_{10} values at the 50-ft (15.24-m) receptor location for each site. Accuracy diminished with increased distance from the roadway, which may be attributable to either minor topographical variations or more absorptive ground cover conditions.

Figure 1. Heavy-duty vehicle spectra.

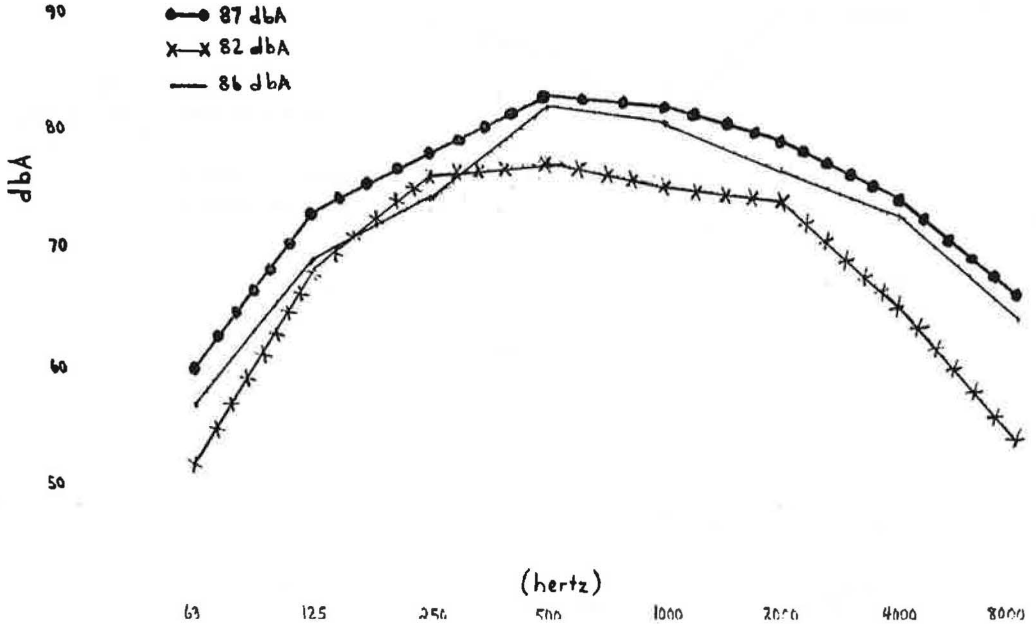

Figure 2. Hourly light-duty vehicles.

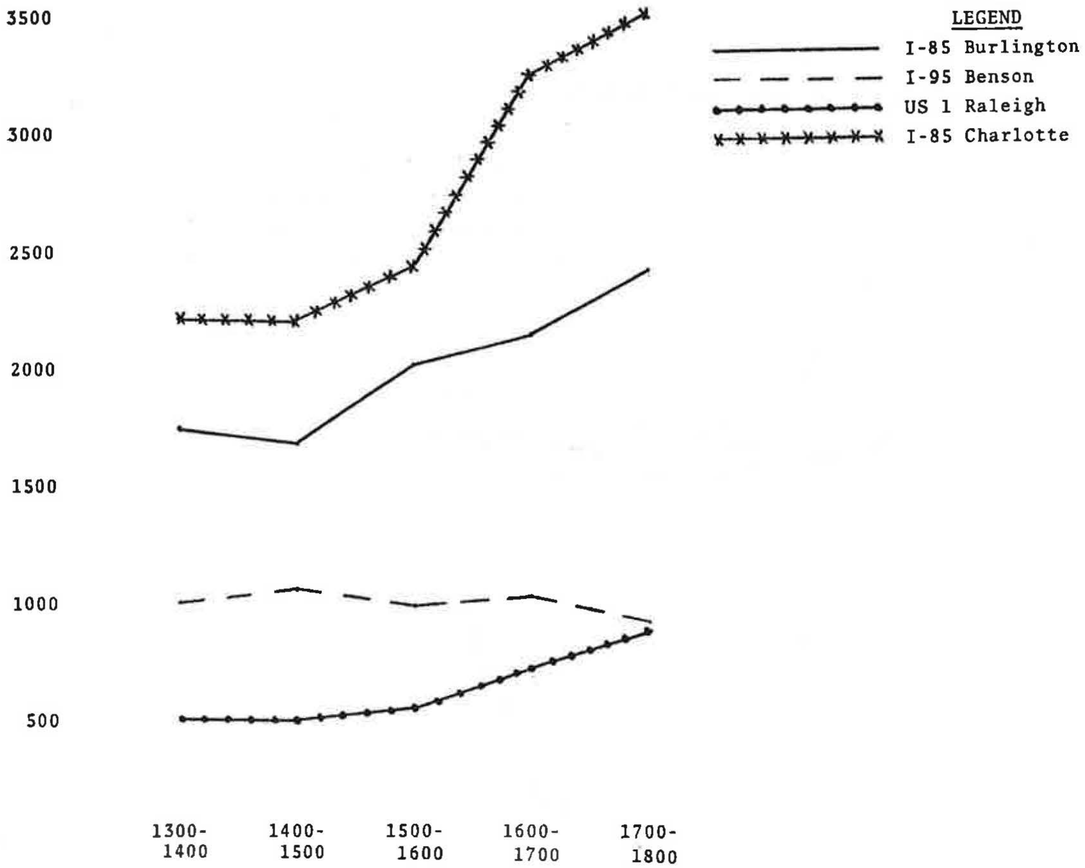

Figure 3. Hourly heavy-duty vehicles.

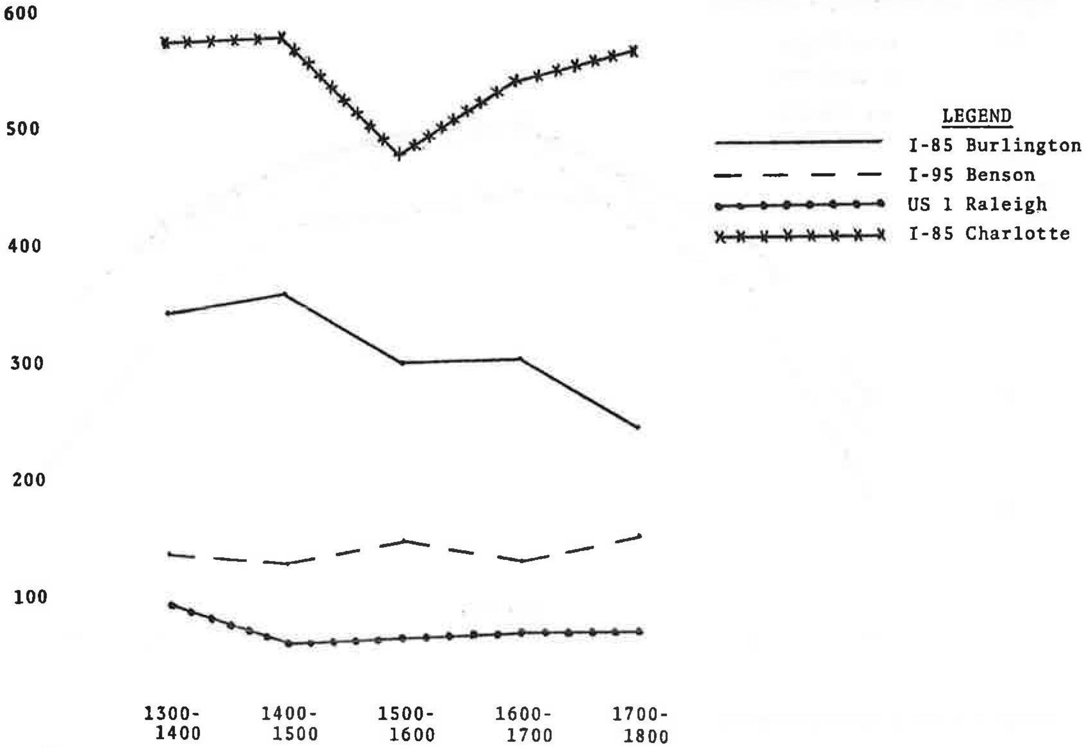

Figure 4. Percent TTST by hour (percent of HDV).

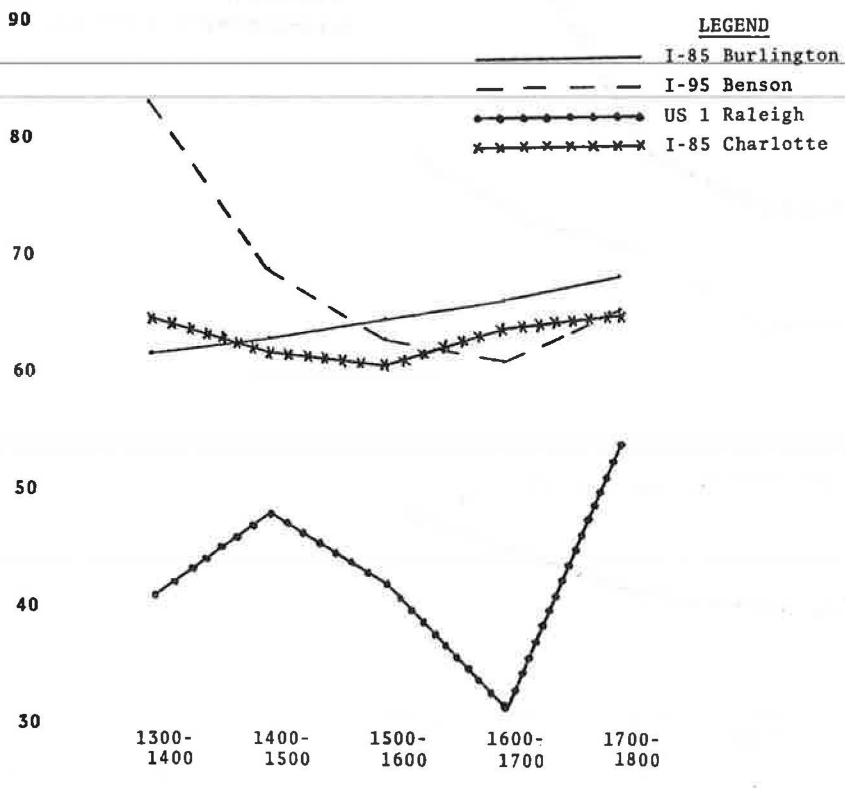

Table 1.

Comparative Traffic Noise Survey
US 1, Raleigh, Wake County
August 11, 1975

Time Period	Measured L10 (dbA)	Predicted L10 87.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 87.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 4.5 dbA(6.0dbA) dropoff (dbA)
Receptor Location - 50 Feet From Edge of Pavement							
1300-1400	71.0	78.7	78.3	77.2	76.8	74.4	74.0 (73.5)
1400-1500	70.5	77.1	76.6	75.7	75.2	73.2	72.7 (72.3)
1500-1600	71.0	77.3	76.8	75.9	75.5	73.5	73.0 (72.6)
1600-1700	70.5	77.7	77.2	76.4	75.9	74.1	73.6 (73.2)
1700-1800	71.0	77.8	77.4	76.6	76.1	74.4	74.0 (73.6)
Receptor Location - 100 Feet From Edge of Pavement							
1300-1400	66.5	75.8	73.8	74.3	72.4	71.6	69.6 (67.6)
1400-1500	65.0	74.1	72.1	72.7	70.7	70.3	68.3 (66.3)
1500-1600	65.0	74.4	72.4	73.0	71.0	70.6	68.6 (66.7)
1600-1700	65.0	74.8	72.8	73.5	71.5	71.2	69.3 (67.3)
1700-1800	66.0	74.9	72.9	73.7	71.7	71.6	69.7 (67.8)
Receptor Location - 200 Feet From Edge of Pavement							
1300-1400	60.5	72.7	69.0	71.2	67.5	68.4	64.8 (61.1)
1400-1500	60.5	70.9	67.2	69.6	65.9	67.1	63.5 (59.8)
1500-1600	60.5	71.2	67.5	69.8	66.1	67.5	63.8 (60.1)
1600-1700	60.5	71.6	67.9	70.3	66.6	68.1	64.5 (60.8)
1700-1800	61.5	71.7	68.0	70.5	66.9	68.5	64.9 (61.3)

Note: 1 ft = 0.3048 m.

Table 2.

Comparative Traffic Noise Survey
I 95, Benson, Johnston County
August 14, 1975

Time Period	Measured L10 (dbA)	Predicted L10 87.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 87.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 4.5 dbA dropoff (dbA)
Receptor Location - 50 Feet From Edge of Pavement							
1300-1400	74.5	79.3	78.2	77.8	76.8	75.2	74.2
1400-1500	73.5	78.8	77.7	77.8	76.3	75.3	73.8
1500-1600	74.5	79.2	78.1	77.8	76.7	75.1	74.0
1600-1700	74.0	79.2	78.2	77.8	76.8	75.2	74.2
1700-1800	74.0	79.3	78.2	77.9	76.8	75.2	74.1
Receptor Location - 100 Feet From Edge of Pavement							
1300-1400	70.5	76.8	74.5	75.4	73.0	72.8	70.5
1400-1500	68.5	76.5	74.0	75.3	72.6	72.9	70.2
1500-1600	70.0	76.9	74.5	75.5	73.0	72.9	70.5
1600-1700	69.0	76.7	74.4	75.3	73.0	72.8	70.5
1700-1800	70.0	77.0	74.6	75.5	73.1	72.9	70.5
Receptor Location - 200 Feet From Edge of Pavement							
1300-1400	67.0	74.0	70.1	72.6	68.7	70.1	66.3
1400-1500	64.0	73.7	69.8	72.5	68.4	70.1	66.1
1500-1600	65.0	74.2	70.2	72.8	68.8	70.2	66.3
1600-1700	65.0	73.9	70.0	72.5	68.6	70.0	66.2
1700-1800	66.0	74.3	70.3	72.8	68.9	70.2	66.3

Note: 1 ft = 0.3048 m.

Table 3.

Comparative Traffic Noise Survey
I 85, Burlington, Alamance County
August 13, 1975

Time Period	Measured L10 (dbA)	Predicted L10 87.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 87.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 4.5 dbA dropoff (dbA)
Receptor Location - 50 Feet From Edge of Pavement							
1300-1400	79.5	83.0	82.0	81.5	80.4	78.5	77.5
1400-1500	79.5	83.1	82.1	81.6	80.6	78.6	77.6
1500-1600	79.5	82.6	81.6	81.1	80.2	78.4	77.4
1600-1700	79.0	82.5	81.4	81.1	80.0	78.3	77.3
1700-1800	79.0	81.7	80.6	80.3	79.3	77.9	76.9
Receptor Location - 100 Feet From Edge of Pavement							
1300-1400	75.0	80.7	78.3	79.2	76.9	76.3	74.0
1400-1500	75.0	80.9	78.5	79.4	77.0	76.4	74.1
1500-1600	75.0	80.3	78.0	78.8	76.5	76.1	73.9
1600-1700	74.5	80.2	77.8	78.8	76.4	76.1	73.8
1700-1800	75.0	79.4	77.0	78.1	75.7	75.7	73.4
Receptor Location - 200 Feet From Edge of Pavement							
1300-1400	68.5	78.1	74.2	76.6	72.8	73.8	70.0
1400-1500	68.0	78.3	74.4	76.8	72.9	73.9	70.1
1500-1600	68.5	77.6	73.8	76.2	72.4	73.5	69.8
1600-1700	68.5	77.6	73.7	76.2	72.4	73.6	69.8
1700-1800	69.0	76.8	72.9	75.5	71.6	73.2	69.4

Note: 1 ft = 0.3048 m.

Table 4.

Comparative Traffic Noise Survey
I 85, Charlotte, Mecklenburg County
August 28, 1975

Time Period	Measured L10 (dbA)	Predicted L10 87.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 87.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 86.0 HDV Spectrum 4.5 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 3.0 dbA dropoff (dbA)	Predicted L10 82.0 HDV Spectrum 4.5 dbA dropoff (dbA)
Receptor Location - 50 Feet From Edge of Pavement							
1300-1400	82.5	85.4	84.5	83.8	82.9	80.6	79.7
1400-1500	82.5	85.4	84.5	83.8	82.9	80.7	79.8
1500-1600	81.5	84.7	83.8	83.2	82.3	80.1	79.3
1600-1700	82.0	85.3	84.4	83.8	82.9	80.8	79.9
1700-1800	82.0	85.2	84.2	83.7	82.7	80.8	79.8
Receptor Location - 100 Feet From Edge of Pavement							
1300-1400	78.5	83.1	80.9	81.6	79.4	78.5	76.3
1400-1500	78.0	83.2	81.0	81.6	79.4	78.5	76.3
1500-1600	78.0	82.4	80.2	80.9	78.7	78.0	75.8
1600-1700	78.0	83.1	80.9	81.6	79.4	78.7	76.6
1700-1800	78.0	83.1	80.8	81.6	79.3	78.7	76.6
Receptor Location - 200 Feet From Edge of Pavement							
1300-1400	74.0	80.5	76.8	79.0	75.3	75.9	72.3
1400-1500	73.5	80.6	76.9	79.0	75.3	76.0	72.3
1500-1600	73.5	79.8	76.1	78.3	74.6	75.4	71.8
1600-1700	74.0	80.5	76.8	79.0	75.3	76.2	72.6
1700-1800	74.5	80.6	76.8	79.1	75.4	76.3	72.7

Note: 1 ft = 0.3048 m.

Table 5.

VARIABLE PARAMETERS (HDV SPECTRUM-DROPOFF RATE-OBSERVER DISTANCE TO EDGE OF PAVEMENT)	MARGIN OF ERROR (MEAN OF THE DIFFERENCE ± SAMPLE STANDARD DEVIATION) L10 DESCRIPTOR
87.0 DBA - 3.0 DBA - 50 FEET	4.6 DBA ± 1.5 DBA
87.0 DBA - 3.0 DBA - 100 FEET	6.7 DBA ± 3.4 DBA
87.0 DBA - 3.0 DBA - 200 FEET	8.8 DBA ± 1.8 DBA
86.0 DBA - 4.5 DBA - 50 FEET	3.1 DBA ± 1.6 DBA
86.0 DBA - 4.5 DBA - 100 FEET	3.0 DBA ± 2.5 DBA
86.0 DBA - 4.5 DBA - 200 FEET	3.7 DBA ± 1.8 DBA
82.0 DBA - 4.5 DBA - 50 FEET	-0.2 DBA ± 2.1 DBA
82.0 DBA - 4.5 DBA - 100 FEET	0.9 DBA ± 2.0 DBA
82.0 DBA - 4.5 DBA - 200 FEET	1.1 DBA ± 2.0 DBA

Note: 1 ft = 0.3048 m.

The general summary for all study sites as given in Table 5 clearly indicates that the comparative results were poor with the 87.0 dBA heavy-duty-vehicle spectrum and 3.0 dBA drop-off rate. The margin of error for this particular pair of variables is shown to be 8.8 dBA ± 1.8 dBA at 200 ft (60.96 m) from the roadway, and this degree of overprediction is clearly unacceptable. The 82.0 dBA heavy-duty-vehicle spectrum and 4.5 dBA drop-off rate produced the best overall correlation between measured and predicted data. All of the test data clearly support the use of a 4.5 dBA per doubling of distance drop-off rate for better predictive accuracy with the TSC Program. The test data do not, however, overwhelmingly support the 82.0 dBA heavy-duty-vehicle emission level over the 86.0 dBA emission level. The test data do infer that slightly higher individual truck emission levels may occur on some interstate highways and major urban freeways. This inference may be correct in that the percentage of 5 or more axle tractor trailers to the total number of heavy trucks will be higher on these types of highway facilities and this particular subclass of trucks will be transporting the greatest payload with the net result of producing louder overall noise levels.

The North Carolina Division of Highways has not had the opportunity to perform noise abatement barrier evaluations with the TSC Program involving pre-existent traffic noise conditions. Nevertheless, the North Carolina Division of Highways has utilized the TSC Program to evaluate noise barriers for probable future traffic noise conditions. Until program modifications were recently issued to eliminate a path length difference error associated with sound wave diffraction, much uncertainty existed concerning the noise reduction effectiveness of both natural and artificial barriers. It is anticipated that this program modification will prove beneficial in making more accurate assessments of future noise abatement considerations.

The Federal Highway Administration is encouraged to bring to prompt completion its investigations pertaining to noise emission levels from heavy duty vehicles as well as drop-off rate determinations. Issuances from these findings will provide program modifications that should improve the accuracy of the TSC Program. Recent findings concerning tire-pavement surface noise level relationships should also be investigated to determine the feasibility of utilizing pavement surface correction factors either generally or on specific types of highway evaluations. The Federal Highway Alministration is also encouraged to perform additional studies to authenticate the claim that the optimum Level of Service 'C' traffic condition generates higher traffic noise levels than less desirable traffic flow conditions.

MINNESOTA'S EXPERIENCE WITH TRAFFIC NOISE PREDICTION

Ronald M. Canner, Jr., Minnesota Department of Highways

Introduction

The Minnesota Highway Department is grategul to those who had the foresight to initiate traffic noise research and develop a noise prediction model under the National Cooperative Highway Research Program (NCHRP). Reports 78 and 117 (3 and 4) could not have been timed better to meet our needs. We would have little hope of completing our interstate freeway program in Minnesota without a way to predict noise and mitigate noise from proposed urban freeways.

We are also grateful to the Federal Highway Administration (FHWA) who assisted us in our first noise barrier design and participated in its construction as an experimental project. FHWA also arranged for the National Highway Institute training class on Fundamentals and Abatement of Highway Traffic Noise and the Noise Measurement Equipment Demonstration, which were helpful to us.

Implementing NCHRP 117

As we became familiar with the format of the NCHRP 117 model, we found that it could be streamlined for use by our highway engineers and technicians. We consolidated charts and tables and developed a one-page work sheet (now revised several times). We later developed tables for the commonly used parts of the charts eliminating the need for repeated visual interpolation.

One of the most useful changes we made in the manual prediction charts was in the shielding chart, a change that eliminated trial and error from the barrier design process. To do this we adapted Maekawa's chart in the 117 report using a simple trigonometric approximation (which yields an error of one to two decibels when the source or receiver is less than one unit of barrier height from the barrier). The revisions in