ANALYSIS OF APPROVED AND RECENTLY DEVELOPED PREDICTION METHODS

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The necessity to accurately predict noise levels emanating from existing and proposed highways has become more apparent in the last few years, with the enactment of such legislation as the National Environmental Policy Act of 1969 and the Federal Aid Highway Acts of 1970 and 1973, along with the promulgation of noise standards from the United States Department of Transportation Federal Highway Administration (FHWA). In the past 5 years, many models have been developed expressly to meet the prediction needs. Among the more important models are the Transportation Systems Center computer program, the National Cooperative Highway Research Program (NCHRP) 78/117/144 report series, the NCHRP 3-7/3 Revised Design Guide (RDG) and the Ontario Highway Noise Prediction Method.

The New York State Department of Transportation (NYSDOT) made the decision to use NCHRP 117/144 in its highway noise prediction work and has been in the process of continually refining that model. The NYSDOT computer program HUSH is based on the so-called "Michigan model" computerized version of NCHRP 117/144, which was distributed by FHWA. Although HUSH represents significant improvements over both NCHRP 117/144 and the "Michigan model," it is still basically a freeway model and thus subject to limitations in many of the practical situations that highway designers face, especially in urban and suburban conditions.

In light of these limitations, the NYSDOT is continuously searching for new and improved methods to more accurately predict noise levels for all situations. Therefore it has undertaken a study aimed at evaluating 2 new prediction methods and comparing them with actual field measurements, and with results obtained using HUSH. The 2 new methods being evaluated are the NCHRP 3-7/3 Revised Design Guide and the Ontario method.

Briefly, the Revised Design Guide is a physical model designed for freely flowing traffic manifested in both a nomograph and computer program. For purposes of this study, the NYSDOT extracted the emission and propagation equations from the computer program and wrote simple programs for use with a programmable hand calculator and with the computer system used by the New York State Department of Environmental Conservation (DEC) Bureau of Noise Control. The equation used was

$$L_h = L_{og}\frac{V}{DS} + SL + 3.2 - 5\,L_{og}\frac{rn}{50} + 10\,L_{og}\frac{\theta}{180}\text{ dBA}$$

where

SL (heavy trucks) = 86 dBA;
SL (medium trucks) = 28 + 30 $L_{og}S$ dBA;
SL (autos) = 18 + 30 $L_{og}S$ dBA;
L_h = hourly equivalent sound level, or L_{eq};
V = hourly volume;
D = normal distance to the line source, in ft (m);
S = average speed of vehicle class, in mph (km/h);
rn = distance from the observer to the closest element point in ft (m); and
θ = finite element subtended angle, in deg.

Conversions from L_h to L_{10}, the level exceeded 10 percent of the time, were made by using the following table, as taken from Chapter 3 of the November 1974 version of the RDG:

Class	Parameter A = VD/S	$L_{10} - L_h$
I	16,000 and above	1
II	3,000 to 16,000	2
III	200 to 3,000	3
IV	50 to 200	1
V	25 to 50	-2
VI	10 to 25	-5
VII	less than 10	-

The Ontario method is a regression line model, in the form of nomographs, based on 133 noise measurements taken at 120 locations near rural and urban freeways, highways, and residential streets in Canada. The nomograph for L_{10} uses

$$L_{10} = 52.7 + 11.2\ L_{og}\ (Vc + 3V_t) - 14.8\ L_{og}\ D + 0.21S$$

where

V_c = hourly car volume;
V_t = hourly truck volume;
D = distance to the edge of pavement, in ft (m); and
S = average vehicular speed, in mph (km/h).

This equation was also programmed into the New York DEC computer system. The Ontario method, as well as HUSH, provides no mechanism to obtain the equivalent sound level, L_{eq}.

Measurement Procedures

Up to this point in the study, some 60 measurements of traffic noise have been made. It is hoped that by the time the study has run its course, enough measurements will have been made so that statistical significance can be achieved for many combinations of vehicle volume, speed, and observer-receiver distances.

Three levels of sophistication have been used in data collection. The first is the "check-off"method as detailed in the FHWA course "Fundamentals and Abatement of Highway Traffic Noise." This method simply requires a technician to read a sound level meter at 10-sec intervals, enough times to develop 95 percent confidence that the L_{10} is within ±3 dBA. For purposes of the NYSDOT study, these confidence limits were achieved for ±2 dBA. However, this method does not give an accurate, reliable measure of the L_{eq} and, therefore, has not proven satisfactory for studying the RDG.

The second level of sophistication used in measurement is audio recording and playback through a graphic level recorder—statistical distribution analyzer system. However, this method has proven cumbersome when attempting to obtain the needed resolution of the data for purposes of the study.

The third level in measurement procedure sophistication has proven to be the most satisfactory. This method involves audio tape recording and playback through a real time analyzer. This allows for an accurate determination of the L_{10} and L_{eq} levels.

All measurements made thus far in the study have been performed by the NYSDOT Noise Measurement Unit. This group consists of 5 full-time, certified noise measurement technicians, usually working in teams of 2 or 3. During each measurement, precise counts of auto, medium truck, and heavy truck volumes are made.

Preliminary Results

Results for comparison purposes were obtained by inputting the actual traffic and geometric parameters into the 3 models (HUSH, RDG, and Ontario), and comparing the outprints to the field measurements. Below is a table showing the number of sites, means of the differences between predicted and measured values, and the standard deviation of the mean for various categories: md = mean of the differences, sd = standard deviation, ns = number of sites included, and EPD = edge of pavement distance.

Category	HUSH (L_{10})	Ontario (L_{10})	RDG (L_{10})	RDG (L_{eq})
All Sites	md=+3.3,sd=2.7 ns=61	md=-0.6,sd=3.1 ns=61	md=+0.5,sd=2.9 ns=61	md=+2.6,sd=2.7 ns=33
Low Volume Site	md=+3.1,sd=2.2 ns=14	md=-0.8,sd=4.0 ns=14	md=+1.2,sd=2.3 ns=14	md=+3.2,sd=1.0 ns=8
Medium Volume Site	md=+3.4,sd=2.7 ns=34	md=-0.7,sd=2.7 ns=34	md=+0.3,sd=2.9 ns=34	md=+2.2,sd=2.6 ns=20
High Volume Site	md=+3.6,sd=2.2 ns=13	md=+0.7,sd=2.3 ns=13	md=+1.1,sd=2.4 ns=13	md=+2.4,sd=2.4 ns=5.
EPD 50 feet	md=+2.3,sd=2.5 ns=25	md=-0.8,sd=3.5 ns=25	md=-0.2,sd=2.9 ns=25	md=+1.7,sd=2.7 ns=12

Category	HUSH (L_{10})	Ontario (L_{10})	RDG (L_{10})	RDG (L_{eq})
EPD 100 feet	md=+3.8,sd=2.2 ns=17	md=+0.1,sd=2.2 ns=17	md=+0.8,sd=1.6 ns=17	md=+1.3,sd=2.9 ns=9
EPD 200,400 feet	md=+4.6,sd=2.6 ns=15	md=-0.9,sd=3.7 ns=15	md=+2.1,sd=2.7 ns=15	md=+2.6,sd=2.9 ns=12

Note: 1ft = 0.3048 m.

For purposes of this study, a low-volume site is defined as having less than 600 veh/h, a medium volume site has 600 to 1800 veh/h, and a high volume site has more than 1800 veh/h.

It is clear from the data that HUSH, or NCHRP 117/144, overpredicts by 3 to 4 dBA for most situations. This agrees with conclusions that many other researchers have made. It is interesting to note that even at low volumes and close distances, HUSH does not do too badly. However, as distances increase, the overprediction gets larger, possibly indicating the influence of excess attenuation of the ground and atmosphere. For all the methods evaluated, HUSH generally displays the lowest standard deviations, thus indicating consistency in its overprediction.

From the data given in the table, the Ontario method appears to be the most accurate in terms of mean of the difference. There is a slight underprediction for low and medium volumes, and a slight overprediction for high volumes, but actually the differences are negligible. However, the standard deviations are somewhat larger than for HUSH, particularly at low volumes. More data will be gathered for low volume situations in order to more adequately examine what is happening.

The Revised Design Guide predicts very accurately and with low standard deviations for all situations for the L_{10} descriptor. As distances increase the RDG L_{10} starts overpredicting, although not as badly as HUSH. Again, this overprediction is probably due to ground and atmospheric attenuation. The measurement team noted significant intuitive differences in noise levels at the larger distances, depending on the type of ground cover between the receiver and the road.

For the 33 measurements taken by audio tape recording, it was possible to accurately determine the equivalent sound level L_{eq}; thereby providing a data base for a preliminary evaluation of the RDG L_{eq}. For all 33 sites, the RDG has an overprediction for L_{eq} of 2.6 dBA, and has a slightly higher overprediction, 3.2 dBA, for the light, low-volume sites. Since the RDG first obtains L_{eq} and then adds a conversion for L_{10}, it appears that there may be compensating errors in the L_{eq} and the (L_{10}-L_{eq}) parameters, because the RDG L_{10} is significantly more accurate than the RDG L_{eq}. However, no firm conclusions can be reliably drawn because there are too few measurements available at this point, particularly for low volumes.

An interesting trend in the data is developing with regard to the (L_{10}-L_{eq}) parameter. For the 33 measurements where an accurate L_{eq} has been determined, 31 have shown (L_{10}-L_{eq}) to be equal to 3 ±1 dBA. The other 2 measurements were atypical; that is, they were taken at the same location, and each time the number of heavy trucks exceeded the number of automobiles, and both were of extremely low volumes. Once, the (L_{10}-L_{eq}) parameter was 0, and the other time, -2.

These results indicate that the simple relationship for (L_{10}-L_{eq}) = 3 may apply for most practical situations. Also, there appears to be a range in volume below which the (L_{10}-L_{eq}) relationship complicates, or the L_{10} descriptor becomes unstable. In any event, there is a definite need to obtain more tape recorded data at the low volumes.

Conclusions

The preliminary results of this study clearly indicate that progress is being made in highway noise prediction. HUSH, which includes several revisions over NCHRP 117/144, is outperformed by the 2 newer models. The Ontario method is closer to the target on the average, but tends to have a larger spread on individual predictions. This may be explained by the fact that it is basically a regression line model and cannot therefore account for physical inconsistencies as well as a theoretically derived model can. However, the Ontario method shows the value of empirical data in model building.

The results from the Revised Design Guide are encouraging in that they show an improvement in physical modeling over HUSH. However the (L_{10}-L_{eq}) parameter, both in the model and in actual conditions, needs more empirical testing and input before confidence can be gained, especially for low vehicular volumes.