Essential Ingredients of a Noise Model

Because of the many needs that noise models serve, their essential ingredients are very demanding. Most models, especially the basic ones, must be versatile and comprehensive. They must be able to account for traffic characteristics (volume, speed, and truck traffic), topography (vegetation, barriers, height, and distance), and roadway characteristics (configuration and grades). In special situations, meteorological conditions and pavement characteristics may be necessary variables.

The models must be easy to use. Because of the large number of highway projects involved, and the large number of potential locations of impact, the models must be relatively simple and not too time consuming to exercise. In order to serve the wide range (very large to very small) of highway agencies that use the models, they must include both manual and computer options.

The most important criterion for the noise model is accuracy. Since most of our noise abatement decisions are based on predictions, it is imperative that they be used with confidence. They must have the confidence of the highway agencies that use them, the public that will be affected by them, and the courts that may someday be called on to arbitrate disputes.

Noise prediction models are the keystone to dealing with highway traffic noise impacts. It is imperative that we have the very best models we can get.

RECENT DOT STUDY EVALUATING NCHRP 117 AND TSC HIGHWAY NOISE PREDICTION METHODS

James Steinberg, Transportation Systems Center

Let me begin this discussion by giving you an overview of where the Transportation Systems Center fits into the highway noise prediction program. This is not intended to be one of the formal organization, but rather an indication of how information flows and of how we communicate with other groups involved in highway noise prediction. As shown in Figure 1, there are two divisions within TSC that give technical support to the Office of Noise Abatement within DOT. The Mechanical Engineering Division has the people, equipment, and expertise for recording and analyzing highway noise measurements, while the Information Sciences Division is more involved in the prediction of highway noise values using various computer models. Our responsibilities in this area include the implementing of various prediction models, debugging of these models to some extent, maintenance, upgrading, and distribution of the TSC model, and the comparison and analysis of the various models for validation purposes.

Since most of you are quite familiar with the TSC and 117 models, I will not go into the models themselves to any great extent. Figure 2 gives the basic equations for each model, shows that the 117 model is fundamentally an empirical one, while the TSC model is based on theoretical considerations. As far as use of the models is concerned, the TSC model, using roadway and barrier endpoints and receiver locations expressed in a Cartesian coordinate system, greatly reduces the structuring of the input case and does not require that the user calculate the various subtended angles. The running of subsequent cases with changes to only individual parameters is more straightforward with the TSC model. Both models were intended to be used in free-flowing traffic situations and do not behave well (or at all) in urban or interrupted traffic flow situations.

TSC has recently undertaken a study of the TSC and Michigan 117 models (and BBN's revised design guide in the near future) for the purposes of comparison of the models and validation against field measurements. Figure 3 illustrates the primary functions involved in the study. Hourly noise measurements, traffic counts and mix, site geometry, and single-truck spectrum measurements are being taken at 3 locations [50 ft (15,24 m), 100 ft (30.48 m), and 200 ft (60.96 m) from the roadway] for several sites in each of four states. Included in each state is a site where measurements are taken for 24 consecutive hours. At TSC, the noise measurement data are handled by the Mechanical Engineering Division where they analyze it to determine the L_{10}, L_{50}, and L_{eq} levels at each location for each hourly interval of measurement. The traffic flow and site geometry is formatted by the Information Sciences Division for input to the noise prediction models. The models are then used to predict the L_{10}, L_{50}, and L_{eq} levels for each hour. The field measurement and prediction models results are then combined and input to a program that produces 9 graphs. Each graph shows the TSC, 117, and field data versus time for one receiver [50 ft (15.24 m), 100 ft (30.48 m), and 200 ft (60.96 m)] and one measurement type (L_{10}, L_{50}, or L_{eq}). A sample of one of these graphs is shown in Figure 4.

Figure 1.

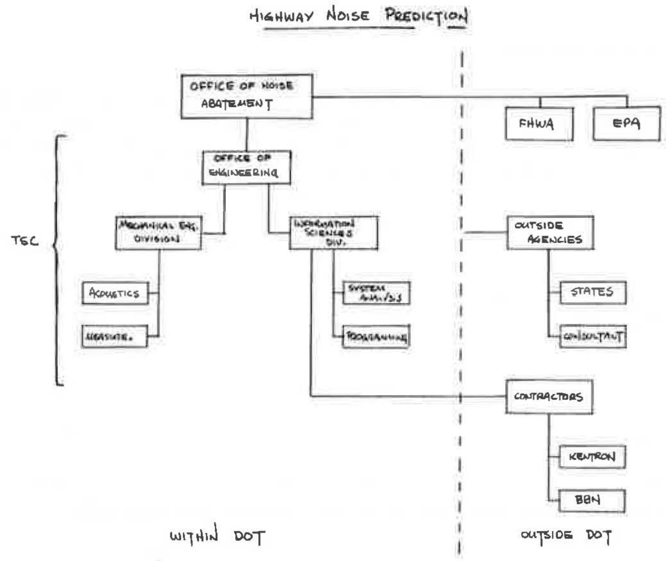


Figure 2.

BASIC EQUATIONS FOR EACH MODEL

	TSC	MICHIGAN 117
L_{50}	$L_e - \sigma_L^2/8.7$	$10\log\rho - 15D + 30\log S + 10\log\left[\tanh(1.19\times10^{-3}\rho D)\right] + 31$
L_{10}	$L_{50} + 1.28\sigma_L$	$L_{50} + 10\log\left[\frac{\cosh(1.19\times10^{-3}\rho D)}{\cosh(1.19\times10^{-3}\rho D) - 0.951}\right]$
L_{90}	$L_{50} - 1.28\sigma_L$	NOT USED
L_e	$10\log I$	$L_{50} + 0.07(L_{10} - L_{50})^2$
L_{np}	$L_e + 2.56\sigma_L$	$L_e + 2(L_{10} - L_{50})$
TNI	$L_{50} + 8.76\sigma_L + 30$	$L_{10} + 6(L_{10} - L_{50}) - 30$

WHERE: L_e = SOUND ENERGY MEAN LEVEL
σ_L = STANDARD DEVIATION OF SOUND PRESSURE
I = MEAN SOUND INTENSITY
ρ = MEAN VEHICLE CONCENTRATION (VEH PER HOUR/VELOCITY)
D = RECEIVER DISTANCE
S = VEHICLE SPEED

Figure 3.

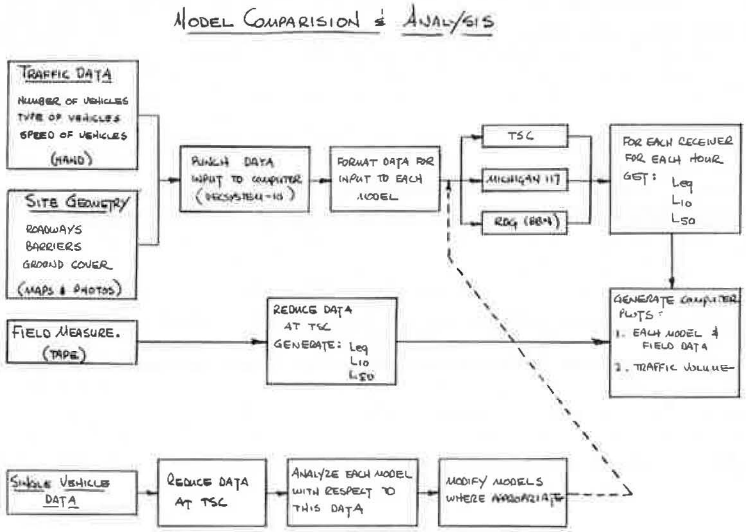


Figure 4.

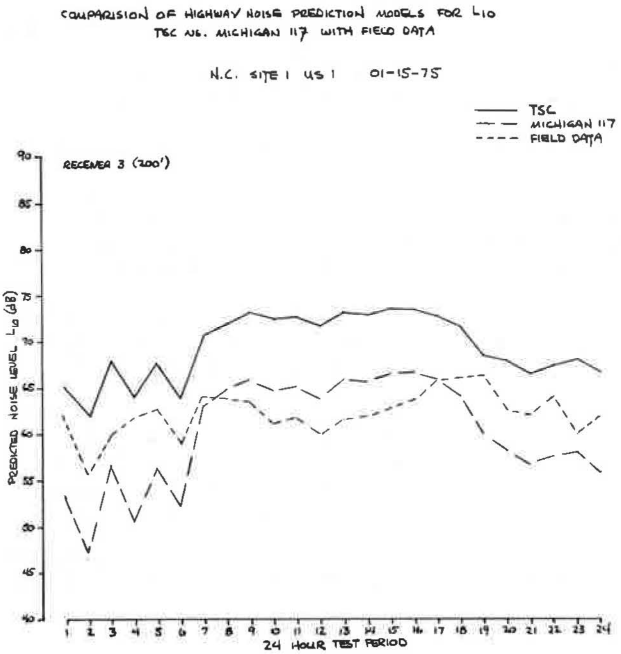
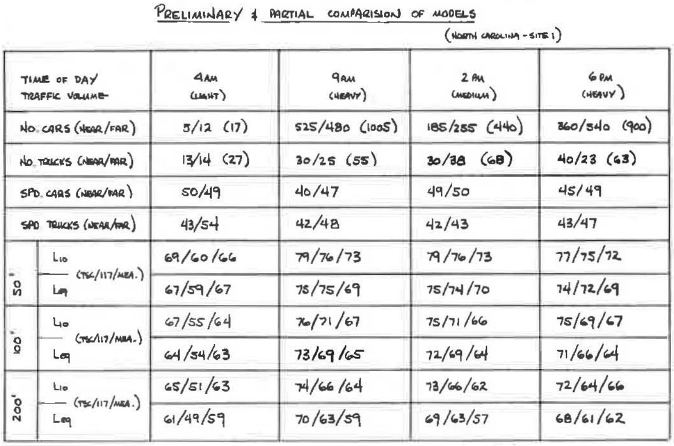


Figure 5.



PRELIMINARY & PARTIAL COMPARISION OF MODELS
(NORTH CAROLINA - SITE 1)

TIME OF DAY TRAFFIC VOLUME		4AM (LIGHT)	9AM (HEAVY)	2 PM (MEDIUM)	6 PM (HEAVY)
NO. CARS (NEAR/FAR)		5/12 (17)	525/480 (1005)	185/255 (440)	360/540 (900)
NO. TRUCKS (NEAR/FAR)		13/14 (27)	30/25 (55)	30/38 (68)	40/23 (63)
SPD. CARS (NEAR/FAR)		50/49	40/47	49/50	45/49
SPD. TRUCKS (NEAR/FAR)		43/54	42/48	42/43	43/47
50'	L10 (TSC/117/MEA.)	69/60/66	79/76/73	79/76/73	77/75/72
	Leq	67/59/67	75/75/69	75/74/70	74/72/69
100'	L10 (TSC/117/MEA.)	67/55/64	76/71/67	75/71/66	75/69/67
	Leq	64/54/63	73/69/65	72/69/64	71/66/64
200'	L10 (TSC/117/MEA.)	65/51/63	74/66/64	73/66/62	72/64/66
	Leq	61/49/59	70/63/59	69/63/57	68/61/62

Figure 5 summarizes some of the results for the 24-hour site in North Carolina for selected traffic densities.

These preliminary results show that the values from the TSC model are much higher than the field data (6 to 10 dB), while the Michigan 117 model results are not quite as high, they still remain above the field data. It is also interesting to note how the two models follow each other fairly well, although separated by several dB. Both models exhibit erratic behavior at low traffic volumes.

As I have mentioned, these are only preliminary results from a first pass at the data. We are still in the process of ensuring that the procedures used to structure the input for the models from the raw data are valid and that the noise measurements were not affected by conditions that are not considered by the models (wind, humidity, etc.). These results seem to be holding for the two states processed to date (North Carolina and Florida). We are anticipating additional data from Washington and Colorado.

Coincident with this straightforward processing of the data, we are undertaking an analysis of the field measurements to determine the noise decrease with doubling of distance and the relationship between L_{eq} and V/DS for events where one vehicle type predominates.

Each state is also providing single-vehicle data that will allow us to generate the 50-ft (15.24-m) spectrum for each vehicle class and to then compare these spectra against those used in the models. If appropriate, the spectra of the models will be modified and all of the cases rerun with the modified models to determine the effects of the new spectra, and hopefully, bring the results into closer agreement with the field measurements.

One final word, since the workshop, we have received and implemented the revised design guide on TSC's Decsystem-10. The initial results using this model are encouraging.

EXPERIMENTAL DATA SUPPORTING THE NCHRP 3-7/3 REVISED DESIGN GUIDE FOR HIGHWAY NOISE PREDICTION AND CONTROL

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Introduction

The revised design guide for highway noise prediction and control, developed as a result of research conducted under NCHRP Project 3-7/3 contains many changes and modifications to the procedure presented in NCHRP Reports 117/144 designed to improve the accuracy and to extend the range of applicability under which the prediction may be used. These changes and modifications resulted from the experience gained through the use of 117/144 and the TSC models by highway departments and from further research conducted under the NCHRP 3-7/3 program. (The TSC model, developed by the Transportation Systems Center is one of two highway noise prediction procedures approved by the FHWA; the other is the NCHRP 117/144 procedure.)

The objective of this presentation is to bring forth field noise data in support of the revised design guide model. Since the revised design guide was only recently completed and since only a very limited amount of field data is available for a valid comparison, this analysis can be judged as preliminary at best. However, the data presented may be viewed as a first order test of the model in the sense that it provides an estimate of the prediction accuracy under a variety of highway conditions.

Before we explore the main topic of this presentation, a few words of comment about the acquisition and analysis of the field noise data are in order. The assumption that any field data regardless of how they were acquired and how well the site parameters are known can be fairly compared to a prediction procedure is false. More often than not such practice has led to incorrect and misleading conclusions as to the accuracy of the model being tested.

The validation of a prediction procedure like the one being offered here requires more than a cursory examination of a field test site. First of all, we must strive to acquire acoustic data that are valid for the type of descriptor (i.e., L_{10}, L_{50}, or L_{eq}) being used in the prediction procedure. It also must be remembered that a prediction procedure of this type, by its very nature, implies that the calculated noise levels are "typical" for the given traffic conditions considered. That is, the prediction procedure will and should predict the noise levels that will be experienced at the given location if this same condition is measured repeatedly.