

# EVALUATION AND MODIFICATION OF TRAFFIC NOISE PREDICTION PROCEDURE FOR KENTUCKY HIGHWAYS

Kenneth R. Agent and Charles V. Zegeer,  
Bureau of Highways, Kentucky Department of Transportation

Approximately 270 recordings of noise levels were obtained at 39 highway sites and compared with the predictions of noise levels based on the procedure given in a National Cooperative Highway Research Program report on highway noise. The measured noise levels were computed in terms of the A-weighted  $L_{10}$  value (level exceeded 10 percent of time) and then compared with the predicted noise levels. A significant discrepancy was found between predicted and measured noise levels. Generally, the predicted values exceeded the measured values. Average error per location was 4.8 dBA; the maximum error was 13 dBA. A nomograph was devised to correct the predicted value; this nomograph involves observer-roadway distances, truck volumes, and automobile speeds. Application of the correction factors reduced the average error by 60 percent to 1.9 dBA. Based on these findings, the nomograph was approved by the Federal Highway Administration for use in predicting noise levels in Kentucky.

•POLICY and Procedure Memorandum 90-2 of the Federal Highway Administration stated that all highways constructed after July 1, 1972, must conform to specific design noise levels. To predict future noise levels of highways, a noise prediction procedure has been used. The procedure provides for the determination of the  $L_{10}$  noise level (level exceeded 10 percent of the time) based on factors such as observer-roadway distance and shielding. The procedure has not been thoroughly validated, and questions remain about its accuracy. If discrepancies do exist, adjustment factors may need to be applied to more accurately forecast noise levels.

## PROCEDURES

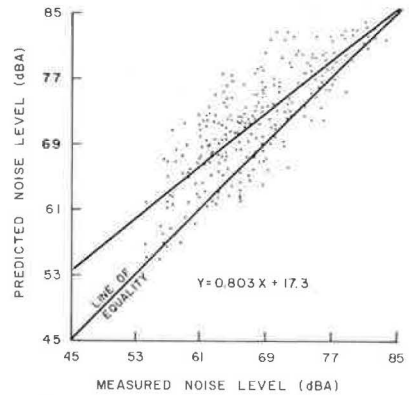
To evaluate the currently used noise prediction procedure required that field noise recordings be obtained and compared with noise levels estimated from the prediction model. All recordings were taken at locations with zero grade so that the observer was level with the roadway and there was no shielding to reduce the number of variables that might affect accuracy of the prediction. Figure 1 shows a typical recording site. It was considered essential that gradient, vertical elevation, shielding, element, and interrupted adjustments be evaluated separately from the basic situation—that is, a straight, level section of roadway on unobstructed terrain. The only exceptions to these criteria were some locations in downtown areas, chosen because of high-volume, low-speed traffic, where it was necessary to use the interrupted adjustment because of the high number of traffic signals. Therefore, the only data required to predict noise level were the distance from observer to roadway, surface type, and car and truck volumes and speeds. Predicted noise levels were determined by using the procedure given in a National Cooperative Highway Research Program report (1). The procedure is now being used by the Kentucky Bureau of Highways (2).

Noise recordings were made by using a Bruel and Kjaer precision sound-level meter and strip-chart recorder. Noise recordings (each 10 min long) were made at 39 locations by using the A-weighting network in the meter. A total of 270 recordings were obtained. Use of the strip-chart recorder offered certain advantages: The observer

Figure 1. Typical recording setup.



Figure 2. Predicted versus measured noise levels.



could note effects of any unrelated influences such as wind and airplanes, could adjust or disregard the section of the measurement affected and could continually check for agreement between the meter indication and the recorded measurement. From the 10-min recordings, noise levels at intervals slightly greater than 1 sec were determined in the laboratory by using a digital data reduction system. The output was punched onto computer cards through direct coupling with a card punch unit. The  $L_{10}$  noise level, the standard for federal limitations on allowable traffic noise, was computed with a simple computer program. The measured  $L_{10}$  noise level was then compared with the predicted level.

## FINDINGS

The primary objective of this study was to determine whether a significant discrepancy exists between predicted and measured noise levels. Figure 2 shows that the prediction procedure tends to yield higher values. The average error per location was 4.8 dBA, the maximum error was 13 dBA, and the differences were significant at the 0.01 level (probability = 99 percent) (3).

To determine the reason for this discrepancy, we prepared several computer plots (Figure 3). Differences between predicted (uncorrected) and measured noise levels were plotted against several variables that affect noise level, and an optimal linear fit was determined. The variables considered were

1. Observer-roadway distance,
2. Total volume,
3. Car volume,
4. Truck volume,
5. Ratio of car volume to truck volume,
6. Car speed,
7. Truck speed, and
8. Percentage of trucks.

In Figure 3, the plot of observer-roadway distance shows that for short distances the prediction procedure usually yielded higher values than measured values. As the distance increased, the error decreased until the predicted values were below measured values at greater distances.

A nomograph was used to correct the predicted noise levels. A combination of variables should be considered when the corrections are made. For example, an observer-roadway distance of 50 ft (15 m) yields a predicted value that is too high at locations with low truck volumes. The nomograph should permit a reduction of values

Figure 3. Prediction procedure error as function of several variables.

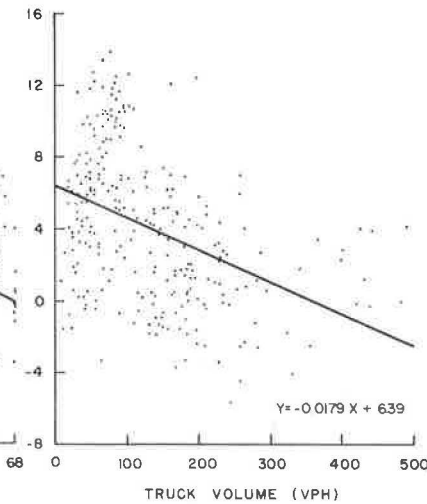
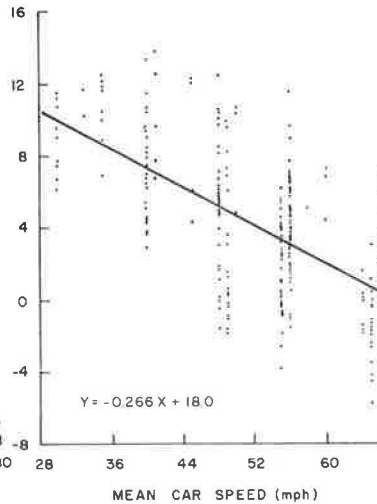
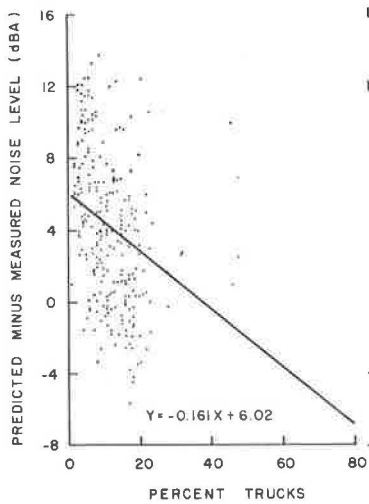
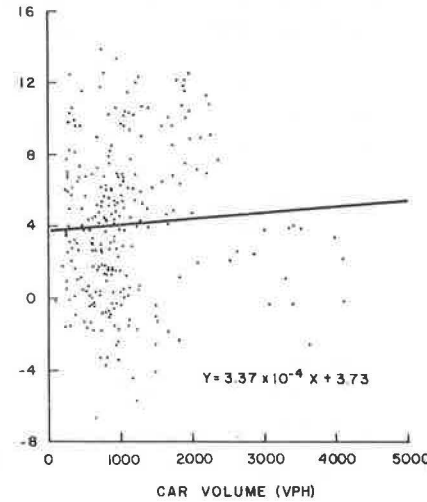
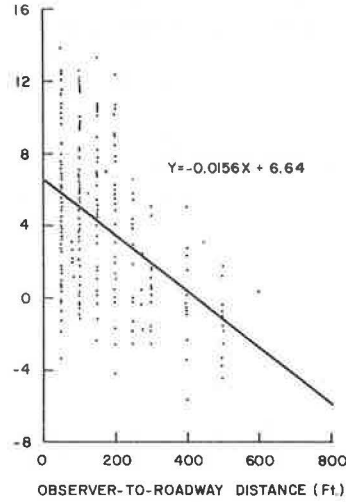
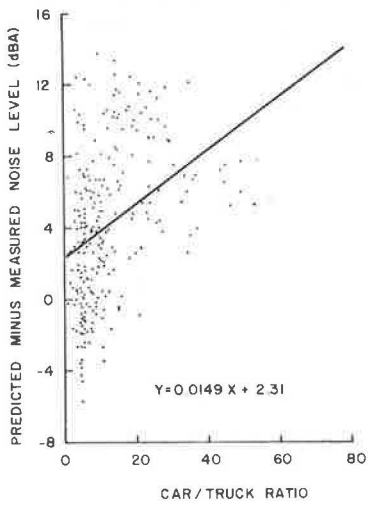
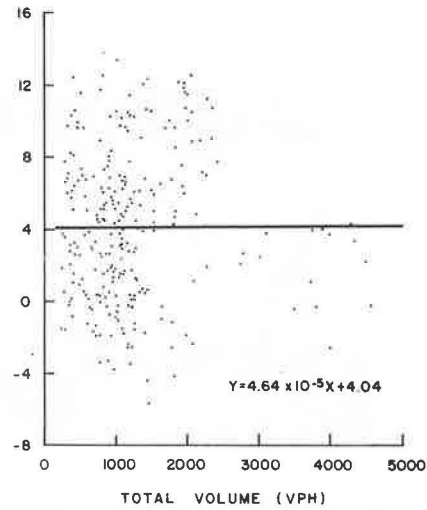
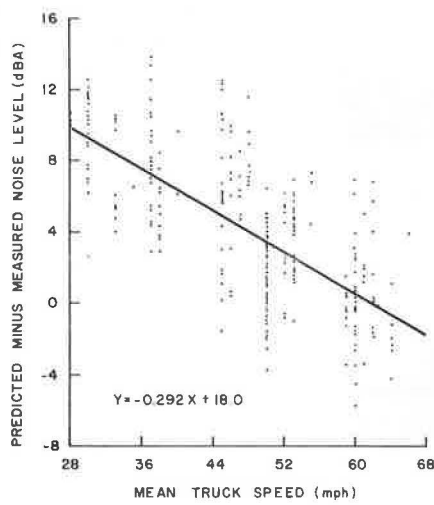
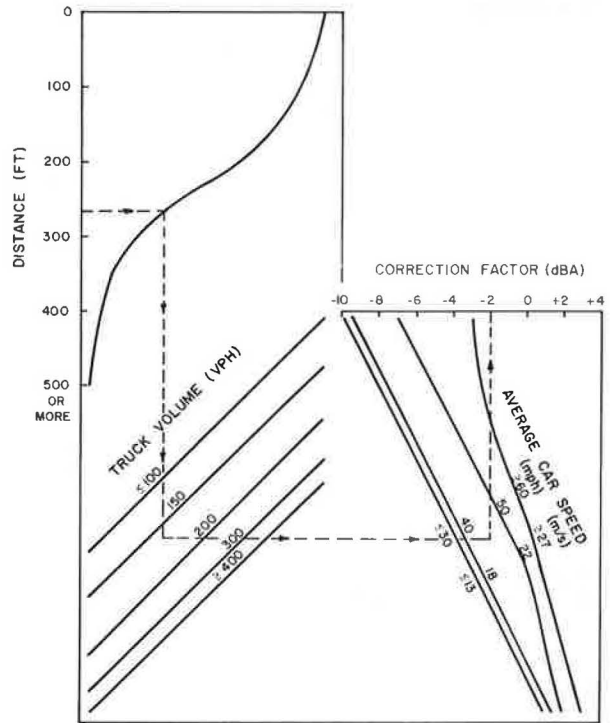


Figure 4. Prediction correction factor nomograph.



at that distance for locations with low truck volumes, but no correction should be made for locations with high truck volumes. A small value should be added for very high volumes. Similar corrections should be made for other variables.

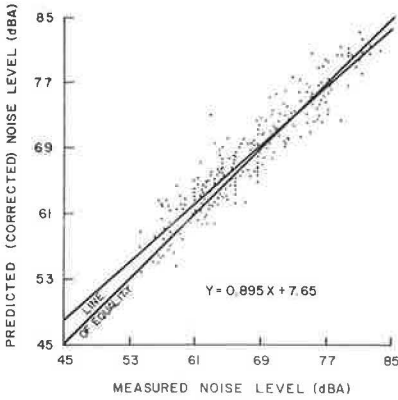
Variables that showed a definite relationship to the prediction procedure error were selected (Figure 3). These variables were then used in various combinations for preparation of trial nomographs. The nomograph that yielded the greatest overall reduction in error is shown in Figure 4. Observer-roadway distance, truck volume, and car speed must be known to determine correction factors from the nomograph.

The following example illustrates use of the nomograph shown in Figure 4. A level, straight, four-lane roadway with a normal surface has a truck volume of 150 vehicles per hour (vph), a car volume of 500 vph, an average truck speed of 40 mph (64 km/h), and a mean car speed of 50 mph (80 km/h). Noise readings are taken at 200 ft (61 m), and there are no barriers or traffic interruptions, such as traffic signals.

The prediction procedure yields a final  $L_{10}$  value of 70.8 dBA. To determine the correction from the nomograph, find the distance of 200 ft (61 m) on the scale in the upper left corner of the nomograph. Draw a horizontal line until it intersects the curved truck volume. Then draw a vertical line downward to the lines that represent truck volume of 150 (interpolation is necessary in many cases), a horizontal line is then drawn to the lines representing mean car speed. Where the horizontal line intersects the line for car speed of 50 mph (80 km/h) (interpolation is again necessary in many cases), draw a vertical line until it intersects the scale that provides the correction factor. Read the correction factor of -3.2 dBA, and add it (algebraically) to the 70.8 dBA obtained from the prediction procedure. Thus, the corrected value is 67.6 dBA.

Correction factors were obtained for each of the 270 recordings to determine the predicted (corrected) noise levels. Results are shown in Figure 5. The optimal linear fit of the points lies very close to the 45-deg line, which represents the line where predicted noise levels equal measured noise levels. Plots were also made of variables involved versus error in corrected noise levels (Figure 6). As may be seen, the optimal

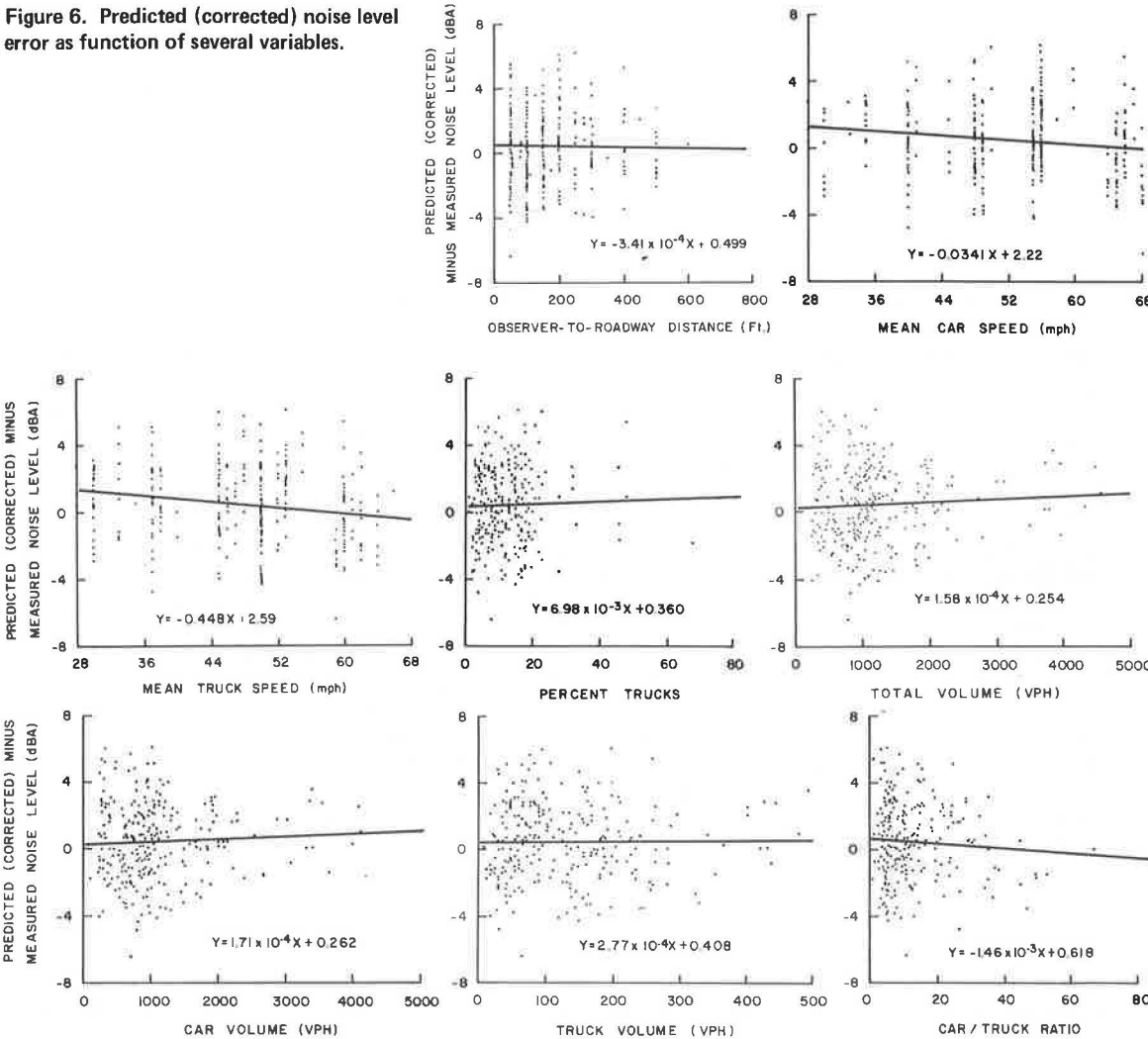
**Figure 5. Predicted (corrected) versus measured noise levels.**



**Table 1. Distribution of errors.**

Difference Between Predicted and Measured Noise Levels (dBA)	Locations Before Correction		Locations After Correction	
	No.	Percentage Exceeding Noise Level	No.	Percentage Exceeding Noise Level
0 to 0,9	38	100,00	78	100,00
1 to 1,9	41	85,93	67	71,11
2 to 2,9	22	70,74	74	46,30
3 to 3,9	25	62,59	26	18,89
4 to 4,9	26	53,33	15	9,26
5 to 5,9	21	43,70	7	3,70
6 to 6,9	29	35,93	3	1,11
7 to 7,9	14	25,18	0	0
8 to 8,9	9	20,00	0	0
9 to 9,9	13	16,67	0	0
10 to 10,9	17	11,85	0	0
11 to 11,9	8	5,56	0	0
12 to 12,9	5	2,59	0	0
13 to 13,9	2	0,74	0	0

**Figure 6. Predicted (corrected) noise level error as function of several variables.**



linear fit line lies very close to zero error for all variables.

The average error per location, after corrections were applied, was 1.9 dBA. This represents a 60 percent reduction in error from the uncorrected predictions. This error reduction is significant at the 0.01 level. After correction, the residual error between measured and corrected values was found not to be statistically significant at the 0.1 level, but significant at the 0.2 level. This remaining error might have been due to factors such as imperfections in data collection. The meter for measuring noise level was calibrated each day before recordings were made, and the strip-chart recorder was continually compared with the sound-level meter to ensure accurate readings, but some degree of error might be expected. Variable pavement types can cause variations in sound levels, and the adjustment for pavement type is probably inadequate since it simply provides for an adjustment of +5 dBA for rough pavements or -5 dBA for smooth pavements. In addition, types of cars and trucks that pass during recording periods vary. For example, the prediction procedure cannot provide for the percentage of tractor-trailers that pass. For a particular location and a given truck volume, the noise level will increase markedly as the percentage of tractor-trailers increases. The prediction procedure also does not account for differences in noise levels of a particular type of vehicle. Therefore, if an abnormal number of quiet or loud vehicles pass while the recording is being made, the measured noise level will differ from the predicted noise level.

Table 1 gives the distribution of differences between predicted and measured noise levels before and after corrections were applied. The number of locations with large errors was greatly reduced when the predicted noise level was corrected.

A statistical test was performed to evaluate the variability that remained after corrections were applied. Results indicated that error variability before correction was significantly larger than error variability after correction to the 0.01 level of significance.

## CONCLUSIONS

1. A significant discrepancy was found between predicted and measured noise levels; the average error was 4.8 dBA.

2. A nomograph developed for the correction of predicted noise levels resulted in a significant reduction in errors. Significant corrections were necessary for (a) short observer-roadway distance and low truck volume (correction = 3 to 10 dBA, depending on average car speed), (b) short observer-roadway distance and low mean car speed (correction = 5 to 10 dBA, depending on truck volume), and (c) short observer-roadway distance, low truck volume, and low mean speed of the car (correction  $\approx$  10 dBA).

3. Although errors were substantially reduced, remaining errors (average of 1.9 dBA) indicate that further study of other variables should be made. In particular, more accurate adjustments are necessary for various pavement types. Variations of noise levels emitted from different vehicles cause error between predicted and measured noise levels, and further adjustments may be forthcoming.

## IMPLEMENTATION

Approval to use the nomograph in Kentucky's noise prediction procedures was received from the Federal Highway Administration effective October 10, 1974. The nomograph has been incorporated into the computer noise prediction model and is now in use.

## REFERENCES

1. C. G. Gordon, W. J. Galloway, B. A. Kugler, and D. L. Nelson. Highway Noise—A Design Guide for Highway Engineers. NCHRP Rept. 117, 1971.
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3. Experimental Statistics. National Bureau of Standards, Handbook 91, Aug. 1, 1963.