

Research Report
409

**EVALUATION AND MODIFICATION OF THE TRAFFIC
NOISE PREDICTION PROCEDURE
FOR KENTUCKY HIGHWAYS**

by

Kenneth R. Agent
Research Engineer

and

Charles V. Zegeer
Research Engineer

Division of Research
Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

accepted for publication by the
Transportation Research Board

November 1974

**EVALUATION AND MODIFICATION OF THE TRAFFIC
NOISE PREDICTION PROCEDURE FOR KENTUCKY HIGHWAYS**

by

Kenneth R. Agent and Charles V. Zegeer

ABSTRACT

Approximately 270 noise-level recordings were obtained at 39 highway sites and compared with the noise-level predictions obtained by the procedure outlined in NCHRP Report 117. The measured noise levels were computed in terms of the A-weighted L_{10} value (level exceeded 10 percent of time) and then compared to 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-to-roadway distances, truck volumes, and automobile speeds. By applying correction factors, the average error was reduced to 1.9 dBA, a 60-percent reduction in error. Based on these findings, the nomograph was approved by the Federal Highway Administration for use in predicting noise levels in Kentucky.

INTRODUCTION

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

PROCEDURES

To evaluate the presently used noise-prediction procedure, it was necessary to obtain field noise recordings and compare them with noise levels estimated from the prediction model. All recordings were taken at locations with zero grade, with the observer level with the roadway, and with no shielding in order 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 should 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 using the procedure outlined in NCHRP Report 117 (2). This procedure is now being used by the Kentucky Bureau of Highways (3).

Noise recordings were made using a Bruel and Kjaer, precision sound-level meter, Type 2203, and a strip chart recorder, Type 2305. Noise recordings were made (each recording was of 10 minutes duration) at 39 locations using the A-weighting network in the meter. A total of 270 recordings were obtained. Use of the strip-chart recorder offered certain advantages. It enabled the observer to note effects of any unrelated influences such as wind, airplanes, etc. The observer could adjust or disregard the section of the measurement affected. Also, the observer could continually check for agreement between the meter indication and the recorded measurement. From the 10-minute recordings, noise levels at intervals slightly greater than one second were determined in the laboratory utilizing a digital data reduction system, Gerber Model GDDRS-3B. The output was punched onto computer cards through direct coupling with a card punch unit. By means of a simple computer program, the L_{10} noise level was computed.

The L_{10} noise level is the standard for federal limitations on allowable traffic noise. The measured L_{10} noise level was then compared with the predicted level.

FINDINGS

The primary objective of this study was to determine if a significant discrepancy exists between predicted noise levels and measured noise levels. Figure 2 clearly indicates the prediction procedure tends to yield higher values. The average error per location was found to be 4.8 dBA; the maximum error was 13 dBA. The differences were found to be significant at the 0.01 level (probability = 99 percent) (4).

To determine the reason for this discrepancy, several computer plots were prepared (Figure 3); differences between predicted (uncorrected) and measured noise levels were plotted against several variables which affect noise level. An optimal linear fit was determined. Variables considered were:

- observer-to-roadway distance,
- total volume,
- car volume,
- truck volume,
- car volume-truck volume ratio,
- car speed,
- truck speed, and
- percent trucks.

The plots clearly indicate some relationships between several of the variables considered and the prediction procedure error. For example, the plot of observer-to-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 employed to correct noise levels obtained from the prediction procedure. A combination of variables should be considered when making the corrections. For example, an observer-to-roadway distance of 50 feet (15 m) yields a predicted value which is too high at locations having low truck volumes. The nomograph, of necessity, should permit a reduction of values for locations (observer-to-roadway distance of 50 feet (15 m)) having low truck volumes, but no correction should be made for locations having high truck volumes. A small value should be added for very high volumes. Similar corrections should be made for other variables.

Variables which 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 (Figure 4) which yielded the best results (greatest overall reduction in error) involved observer-to-roadway distance, truck volume, and car speed.

To determine correction factors from the nomograph, the following must be known:

1. observer-to-roadway distance (ft),
2. truck volume (vph), and
3. average car speed (mph).

The following example illustrates use of the nomograph in Figure 4. A level, straight, four-lane roadway with a "normal" surface has a truck volume of 150 vph, car volume of 500 vph, average truck speed of 40 mph (18 m/s), and mean car speed of 50 mph (22 m/s). Noise readings are taken at 200 feet (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, first find the distance of 200 feet (61 m) on the scale in the upper left-hand corner of the nomograph. Draw a horizontal line until it intersects the curved, turning line. Then draw a vertical line downward to the lines which represent truck volume. Where the vertical line intersects the point which represents the truck volume of 150 (interpolation will be 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 (22 m/s) (interpolation will again be necessary in many cases), draw a vertical line until it intersects the scale which provides the correction factor. Read the correction factor of -3.2 dBA and add it (algebraically) to the 70.8 dBA which was 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-degree 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 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 and 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 several factors. Imperfections in data collection are possible causes. The noise-level meter was calibrated each day before recordings were made, and the strip-chart recorder was continuously compared to the sound-level meter to insure 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 plus or minus 5 dBA for rough or smooth pavements, respectively. In addition, types of cars and trucks which pass during recording periods vary. For example, the prediction procedure cannot provide for the percentage of tractor-trailer trucks which might pass. For a particular location and a given truck volume, the noise level will increase markedly as the percentage of tractor-trailer trucks 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 passes while the recording is being made, the measured noise level would differ from the predicted noise level.

Table 1 shows 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 which remained after corrections were applied. Results indicated error variability before correction was significantly larger than error variability after correction to the 0.01 level of significance.

CONCLUSIONS

The objective of the study was met and following are conclusions drawn from the analyses:

1. A significant discrepancy was found between predicted noise levels 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-to-roadway distance and low truck volume (correction = 3 to 10 dBA, depending on average car speed),
 - B. short observer-to-roadway distance and low mean car speed (correction = 5 to 10 dBA depending on truck volume), and
 - C. short observer-to-roadway distance, low truck volume, and low mean car speed (correction \approx 10 dBA).
3. Although errors were substantially reduced, remaining errors (an average of 1.9 dBA) indicate 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. *Policy and Procedure Memorandum 90-2*, Federal Highway Administration, April 26, 1972.
2. Gordon, C. G.; Galloway, W. J.; Kugler, B. A.; and Nelson, D. L.; *Highway Noise -- A Design Guide for Highway Engineers*, National Cooperative Highway Research Program Report No. 117, Highway Research Board, 1971.
3. *Procedure for Predicting Traffic Noise Levels*, Design Memorandum No. 1-72, Kentucky Bureau of Highways, January 14, 1972.
4. *Experimental Statistics*, National Bureau of Standards Handbook 91, August 1, 1963.

TABLE 1
DISTRIBUTION OF ERRORS

DIFFERENCE BETWEEN PREDICTED AND MEASURED NOISE LEVELS (dBA)	BEFORE CORRECTION		AFTER CORRECTION	
	NUMBER OF LOCATIONS	PERCENTAGE OF LOCATIONS EXCEEDING A GIVEN NOISE LEVEL	NUMBER OF LOCATIONS	PERCENTAGE OF LOCATIONS EXCEEDING A GIVEN NOISE LEVEL
0 - .9	38	100.00	78	100.00
1 - 1.9	41	85.93	67	71.11
2 - 2.9	22	70.74	74	46.30
3 - 3.9	25	62.59	26	18.89
4 - 4.9	26	53.33	15	9.26
5 - 5.9	21	43.70	7	3.70
6 - 6.9	29	35.93	3	1.11
7 - 7.9	14	25.18	0	0
8 - 8.9	9	20.00	0	0
9 - 9.9	13	16.67	0	0
10 - 10.9	17	11.85	0	0
11 - 11.9	8	5.56	0	0
12 - 12.9	5	2.59	0	0
13 - 13.9	2	0.74	0	0

Figure 1. Typical Recording Site.

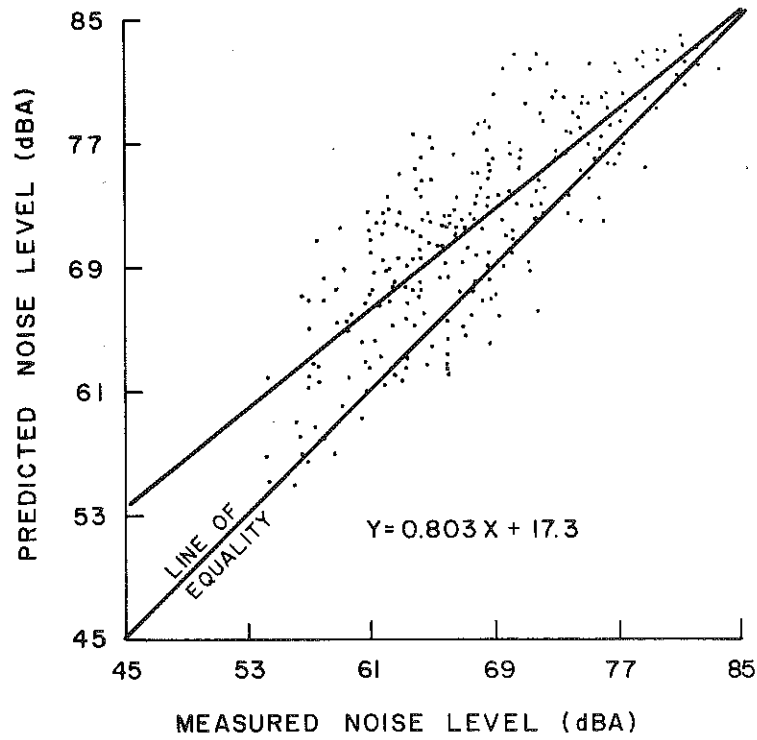
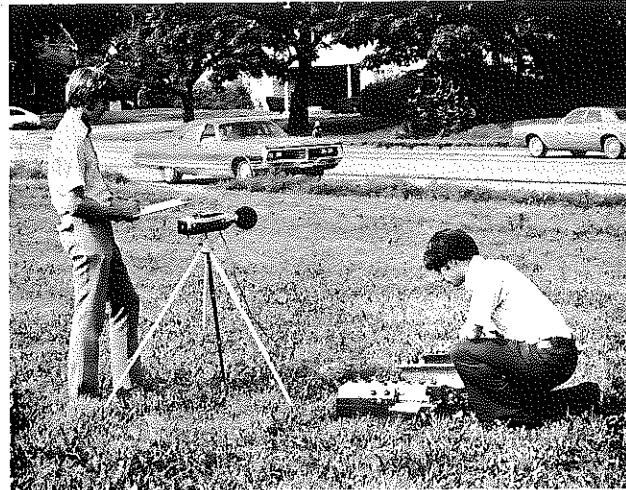


Figure 2. Predicted Noise Levels versus Measured Noise Levels.

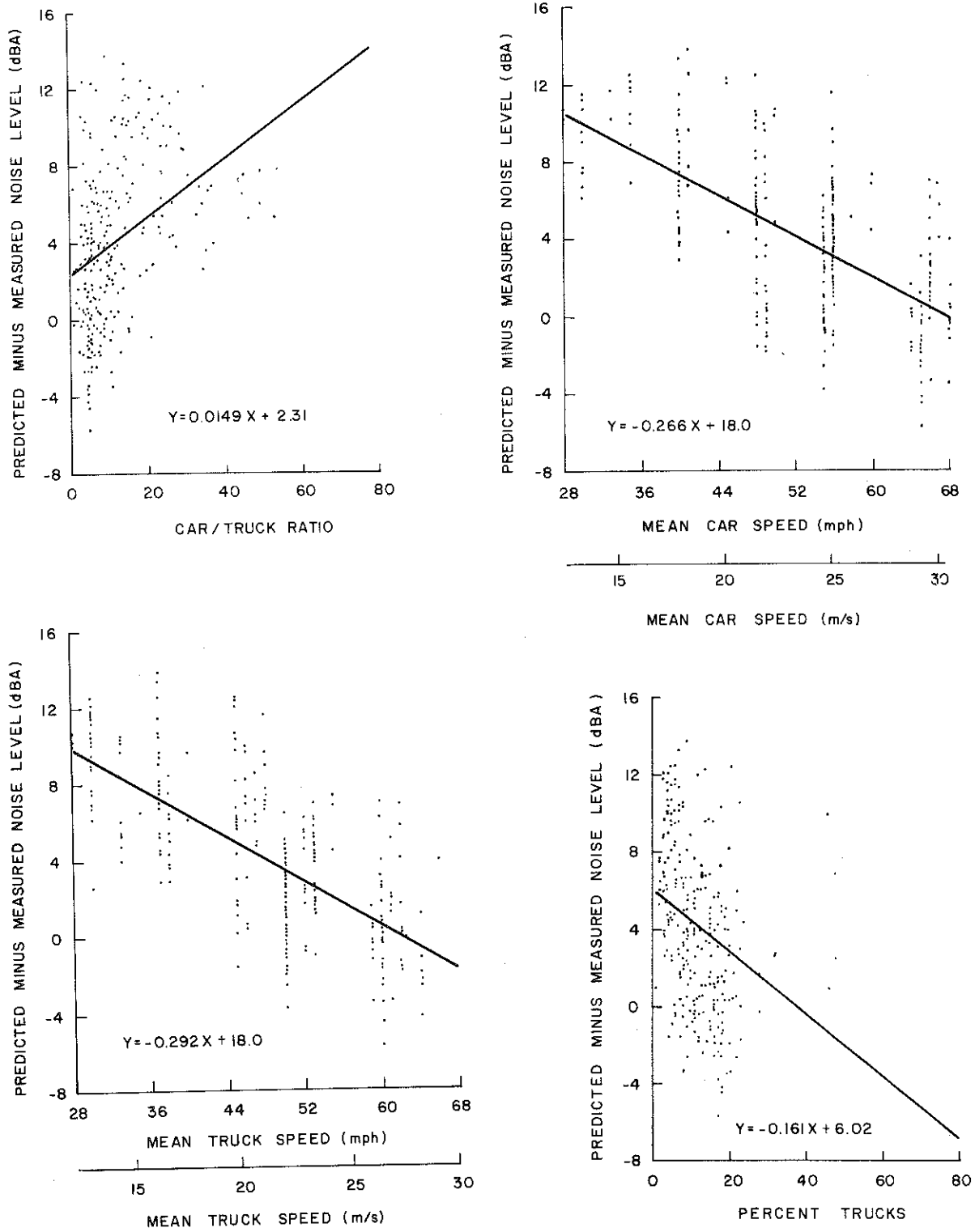


Figure 3. Prediction Procedure Error as a Function of Several Variables.

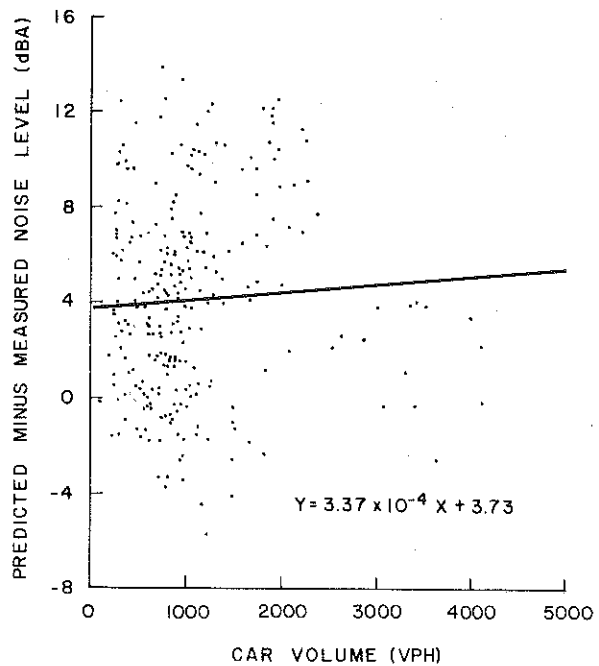
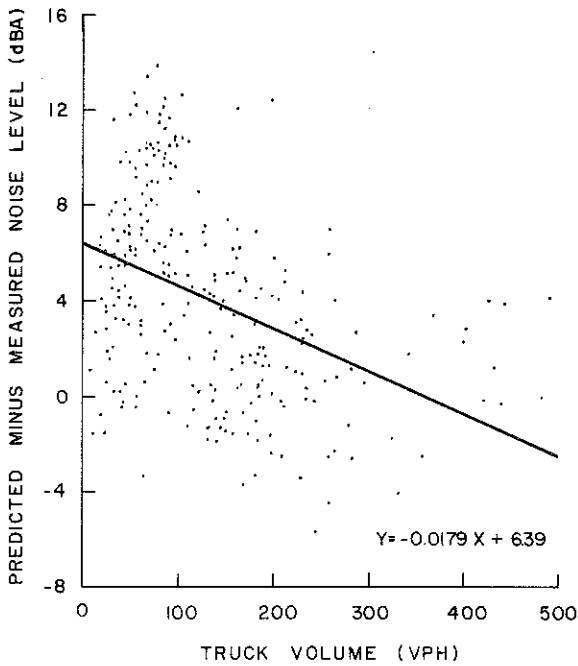
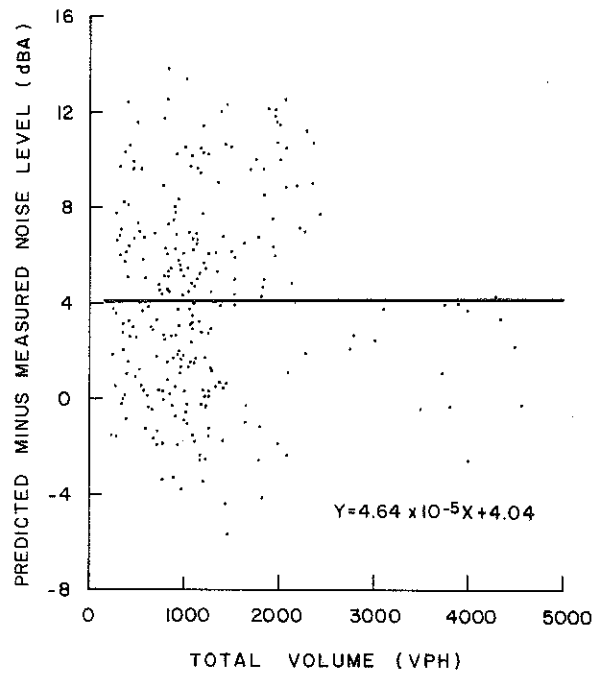
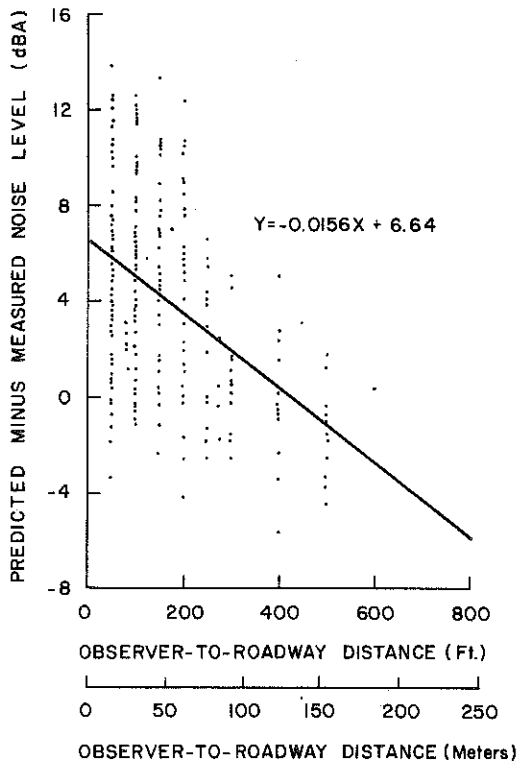


Figure 3. Continued.

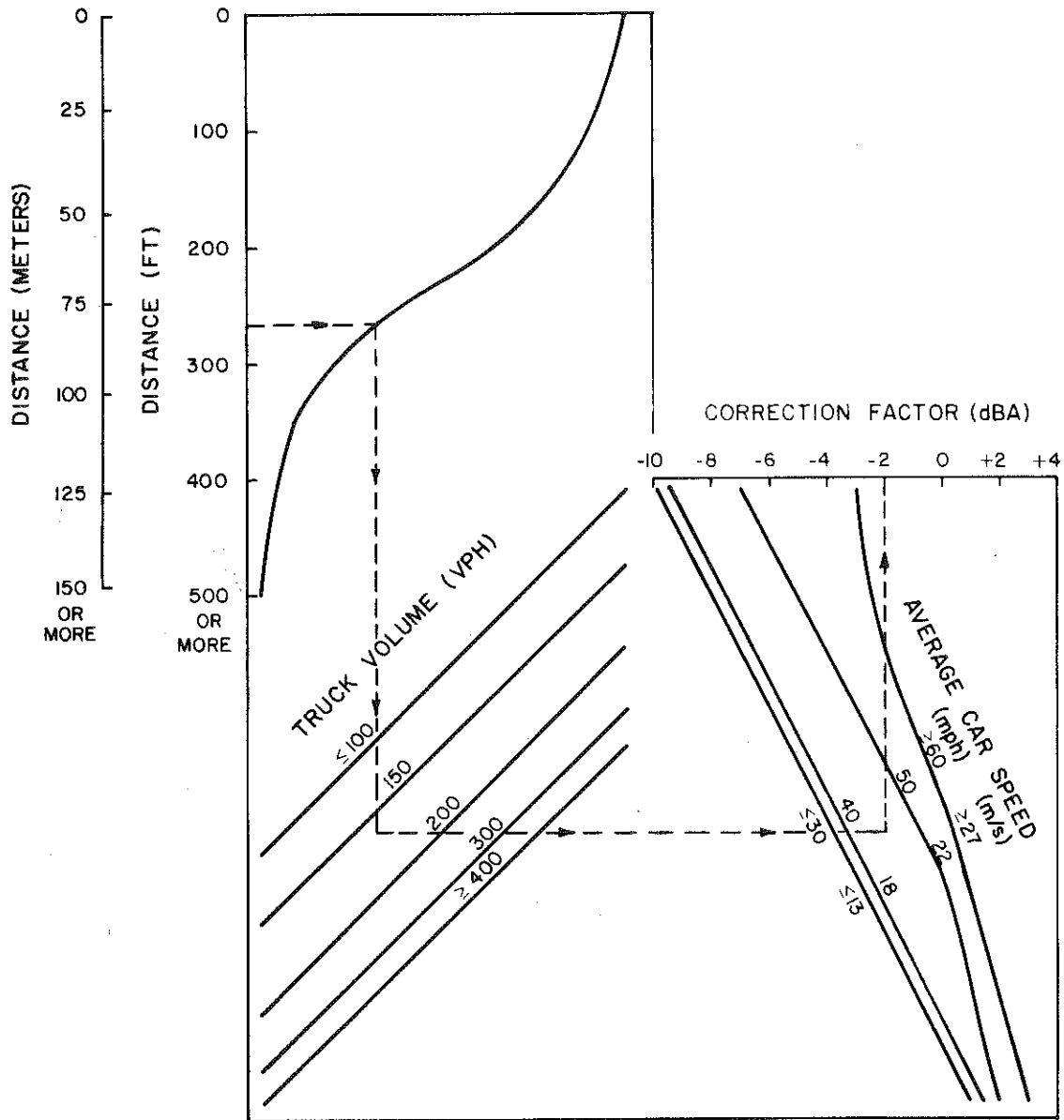


Figure 4. Prediction Correction Factor Nomograph.

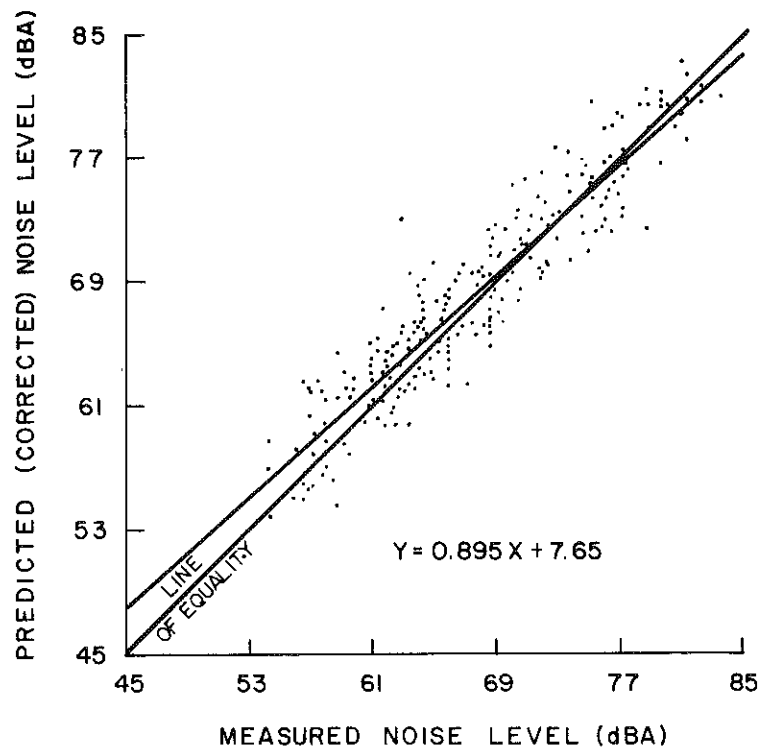


Figure 5. Predicted (Corrected) Noise Levels versus Measured Noise Levels.

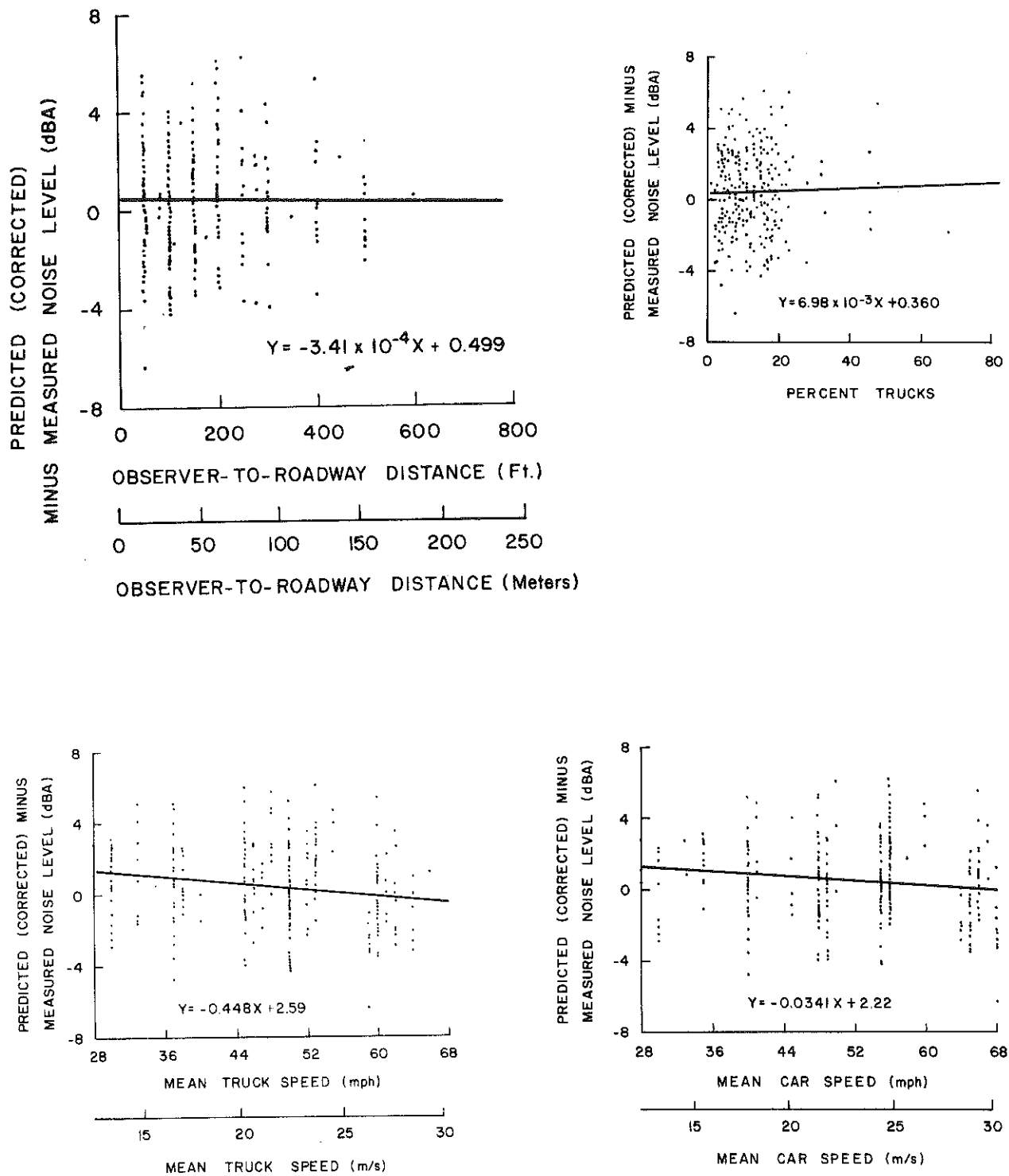


Figure 6. Predicted (Corrected) Noise Level Error as a Function of Several Variables.

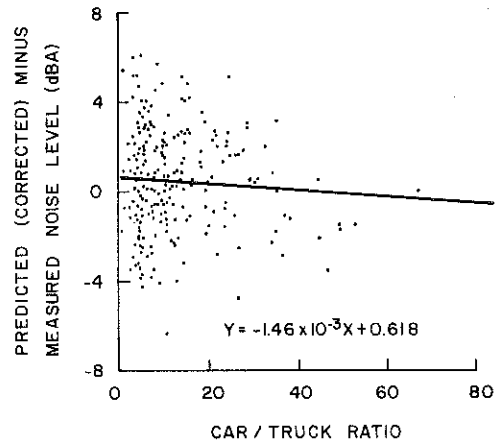
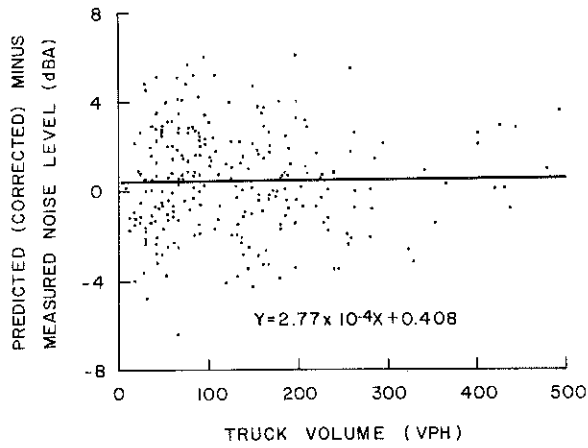
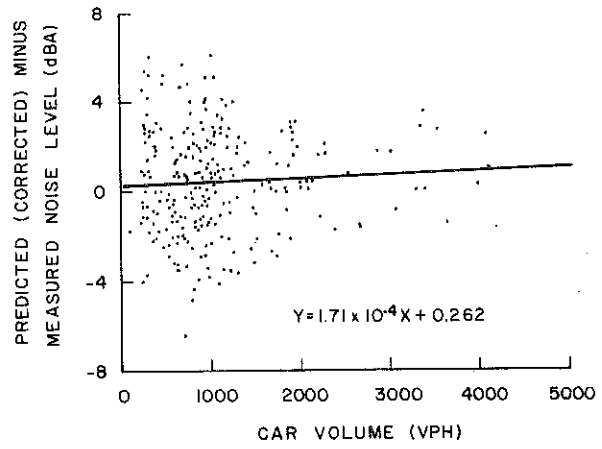
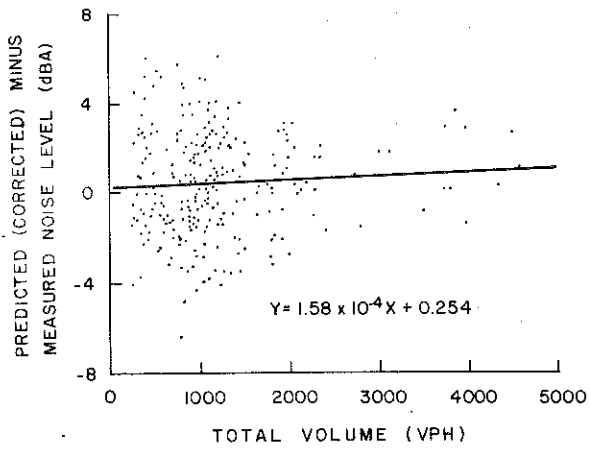


Figure 6. Continued.