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DETERMINATION OF MEAN VEHICLE NOISE EMISSION LEVELS IN MICHIGAN

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Introduction

The Michigan Department of Transportation uses a Federal Highway Administration (FHWA) Highway Traffic Noise Prediction Model, STAMINA 2.0 computer program, to predict highway generated noise. The FHWA's prediction model arrives at a predicted noise level through a series of adjustments to a reference sound level. The reference level is the energy mean emission level. Actual values of these adjustments depend on input data concerning traffic characteristics, topography, and roadway characteristics.

To determine a reference energy mean emission level to be used in their prediction model, the FHWA conducted a nationwide study on vehicle sound emission levels (1). Based on this study, vehicles were placed into three acoustically similar classes. These three groups are: automobiles (A), medium trucks (MT), and heavy trucks (HT). The study also indicated that there are regional differences in vehicle types and emission levels. Since Michigan permits heavier loads and more axles per vehicle than most states, the noise emission levels used in the FHWA prediction model may not be representative of Michigan's vehicle emissions.

Following procedures recommended by the FHWA, the Research Laboratory has conducted a research project to determine noise emission levels emitted by various vehicle types on Michigan's highways (2). With this information, it is possible to convert emission levels to energy mean emission levels for use in the FHWA Highway Traffic Noise Prediction Model. This would provide a more accurate model for determining the amount of noise being generated on Michigan highways.

Data Collection Procedure

Test sites were chosen so that each location consisted of a level, open space free of large reflecting surfaces within 100 ft of both the vehicle's path and the pick-up microphone. A clear line of sight to the roadway from the microphone, located 50 ft from the roadway, was required. The test roadways selected were smooth, level, dry concrete or asphalt. Geometry of the roadway was such that vehicles are at constant speed and not accelerating or decelerating. Several test sites were chosen for higher speeds and some for lower speeds. All locations were selected to obtain low volumes of traffic so individual vehicle samples could be obtained. The procedures used to measure vehicle noise emission levels were based on

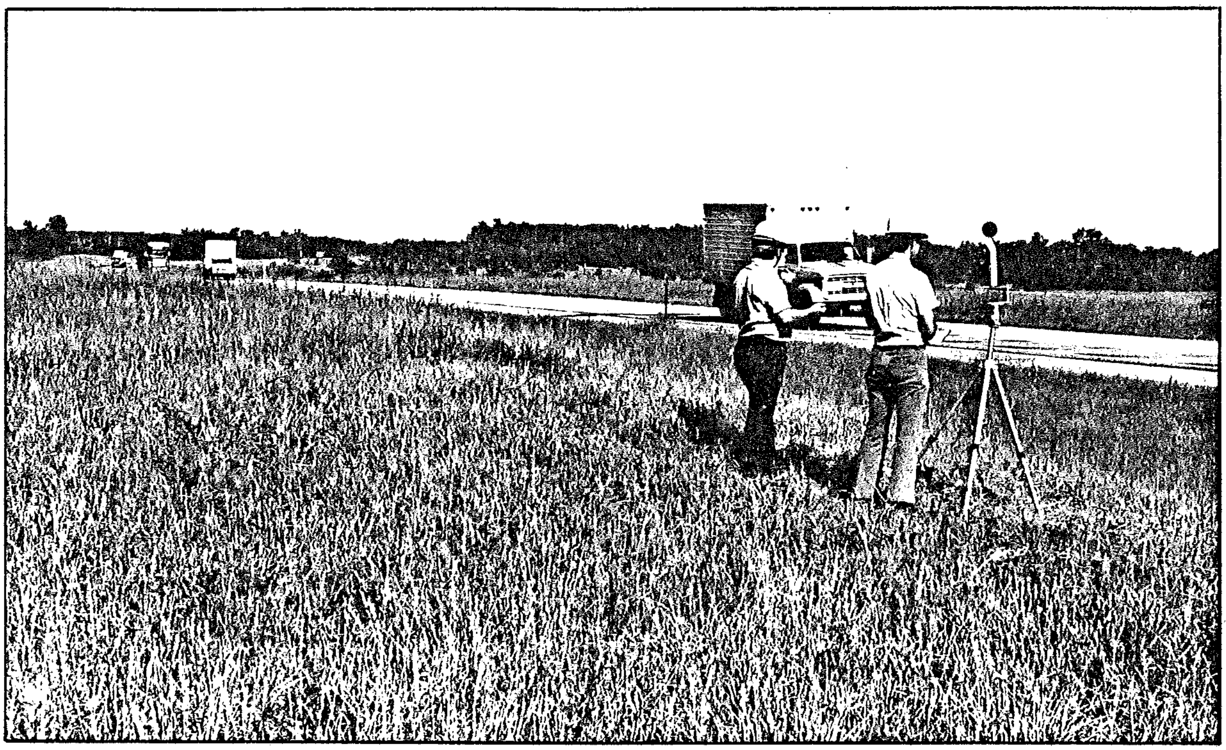

Figure 1. Typical test location on I 96 near the Okemos rest area.

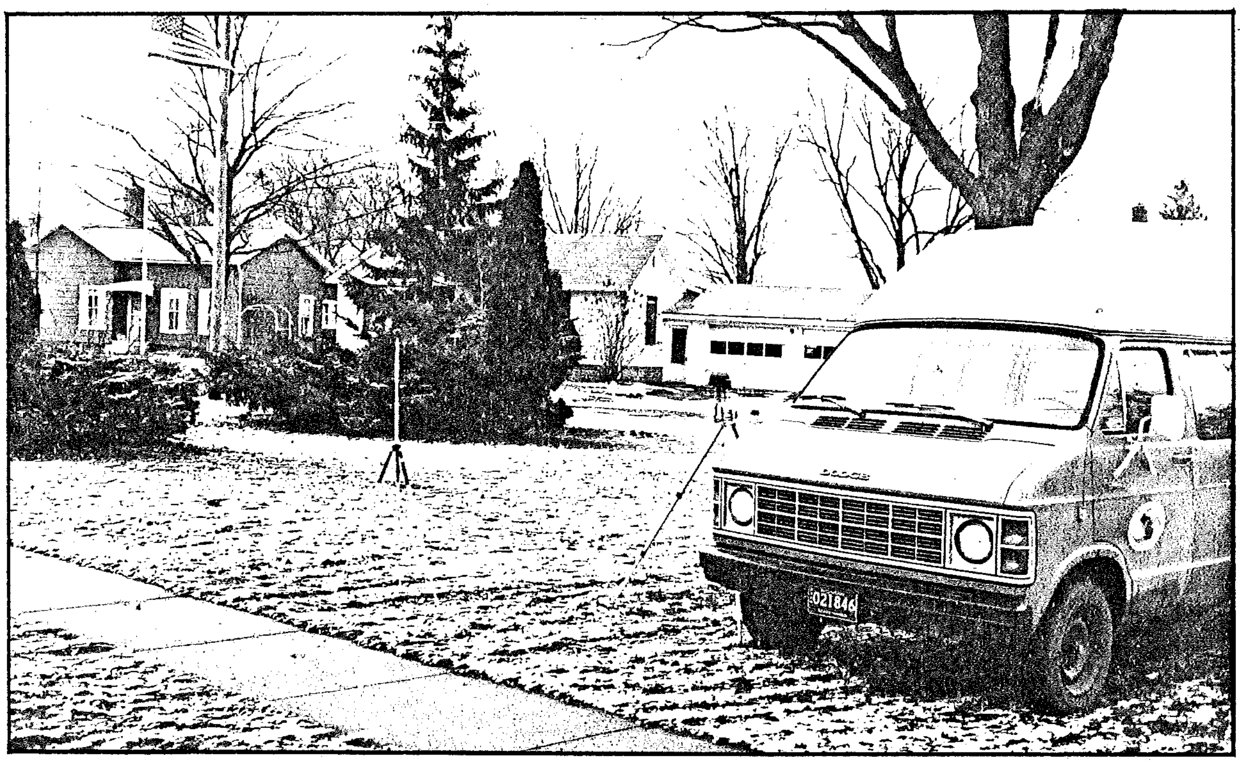

Figure 2. Typical test location and equipment set-up for gathering vehicle noise emission levels.

those recommended by the FHWA (1). The selected test sites are given below.

1. I 96 east of Okemos rest area
2. M 50 in Eaton Rapids
3. M 66 in the northern part of Battle Creek
4. M 60 in Spring Arbor
5. I 94 east of Jackson
6. I 94 at the M 99 interchange
7. High St in Jackson
8. M 78 in Bellevue
9. M 78 east of Bellevue.

Figure 1 shows a typical test location on I 96 east of the Okemos rest area. Figure 2 shows a typical test site and equipment set-up used in the vehicle noise emission level data gathering procedure. Classes and definitions for the three acoustically similar groups, into which the FHWA report divides vehicles, are as follows.

1) Automobiles (A) — All vehicles with two axles and four wheels designed primarily for transportation of nine or fewer passengers, or transportation of cargo. Generally gross vehicle weight is less than 10,000 lb.

2) Medium Trucks (MT) — All vehicles having two axles and six wheels designed for transporting cargo. Gross vehicle weight is greater than 10,000 lb but less than 26,000 lb.

3) Heavy Trucks (HT) — All vehicles having three or more axles and designed for transporting cargo. The gross vehicle weight is greater than 26,000 lb.

Since Michigan permits heavier loads and more axles per vehicle than most states, additional data were taken with vehicles divided into 11 classes. Automobiles, including pick-ups and motorcycles, comprised the two-axle class. Medium trucks, including recreational vehicles, comprised the two-axle with dual wheel class, and heavy trucks with three to 11 axles comprised nine heavy truck classes. Vehicle speeds were grouped in increments of 5 mph, from 30 mph to 65 mph. Table 1 shows the sample size, speed, and average vehicle emission level for the 11 classes of vehicles obtained. Data were taken until most of the speed groups had at least 40 samples for each type of vehicle. Time and money limited continuance of the project to obtain more data. Heavy truck data were particularly difficult to obtain in the 30 mph speed group.

TABLE 1
VEHICLE NOISE LEVEL

Class of Vehicle	Number of Axles	Vehicle Speed, mph: 30		35		40		45		50		55		60		65	
		Sample Size	Avg. dbA	Sample Size	Avg. dbA	Sample Size	Avg. dbA	Sample Size	Avg. dbA	Sample Size	Avg. dbA	Sample Size	Avg. dbA	Sample Size	Avg. dbA	Sample Size	Avg. dbA
Auto-mobile	2	17	64.0	18	65.9	24	67.5	18	69.0	11	75.4	69	76.1	117	77.3	50	77.6
Medium Truck	2	22	71.8	64	73.6	38	75.3	24	75.5	18	78.8	47	80.6	46	82.0	11	82.5
Heavy Truck	3	6	76.0	8	77.9	12	78.4	3	82.5	4	86.9	24	84.7	15	85.0	3	84.8
"	4	2	76.9	5	78.9	5	79.6	2	79.4	11	84.4	29	85.3	19	85.2	7	88.4
"	5	12	76.9	25	79.1	11	79.2	5	81.4	19	84.5	105	85.4	91	86.3	26	85.1
"	6	1	75.9	4	79.3	2	81.0	0	n.a.	2	84.0	15	86.5	19	87.2	6	87.8
"	7	0	n.a.	1	80.2	0	n.a.	1	83.2	1	81.4	4	87.2	8	88.1	1	84.7
"	8	0	n.a.	2	82.8	2	82.8	0	n.a.	1	94.2	5	87.8	4	88.6	2	88.9
"	9	1	77.5	2	85.0	0	n.a.	0	n.a.	0	n.a.	4	88.4	5	88.9	0	n.a.
"	10	0	n.a.	0	n.a.	0	n.a.	0	n.a.	0	n.a.	7	88.3	7	87.9	1	91.0
"	11	5	81.1	2	83.7	12	84.8	4	86.5	6	86.7	15	88.3	9	89.3	4	89.9

n.a. = not available

Results

Noise emission levels must be converted into energy mean emission levels in order to be used in the FHWA Traffic Noise Prediction Model. The field data were combined into three classes: the standard three classes of automobiles, medium truck, and heavy truck. The heavy truck class was further divided into two additional subclasses—one with three to five axles and one with six to 11 axles. Statistical analysis consisted of a linear regression of noise emission level versus speed using the equation:

$$\text{dbA} = C_0 + C_1 \text{Log}_{10} (V)$$

where: dbA = the A-weighted energy mean emission level
C_0 = intercept constant
C_1 = slope constant
V = vehicle speed in miles per hour.

Table 2 shows the results of this analysis compared to values used in the FHWA Highway Noise Prediction Model. The standard error of estimate (S_0), and the coefficient of determination (R^2) were also calculated from the data for each class of vehicle.

TABLE 2
EQUATION CONSTANTS, STANDARD ERROR, AND COEFFICIENT OF DETERMINATION

	Michigan Data					FHWA Data		
	Automobile	Medium Trucks	3 to 11 Axles Heavy Trucks	3 to 5 Axles Heavy Trucks	6 to 11 Axles Heavy Trucks	Automobile	Medium Trucks	3 to 5 Axles Heavy Trucks
Intercept (C_0)	-5.99	20.53	38.26	33.19	45.61	4.80	22.06	42.63
Slope (C_1)	46.70	34.35	27.12	29.67	23.93	38.05	33.91	24.56
Standard Error (S_0)	2.65	3.26	2.92	2.55	2.95	2.60	3.37	2.84
Coefficient of Determination (R^2)	0.76	0.57	0.46	0.55	0.44	n.a.	0.26	0.15

n.a. = not available

Utilizing the established coefficients, C_0 and C_1 from Table 2, the A-weighted energy mean emission levels are plotted in Figures 3 and 4 illustrating the difference between the FHWA's levels and those calculated for Michigan.

Conclusions

Comparison of automobiles in Table 2 shows that this vehicle class has a higher energy emission level and standard error of estimate (S_0) in Michi-

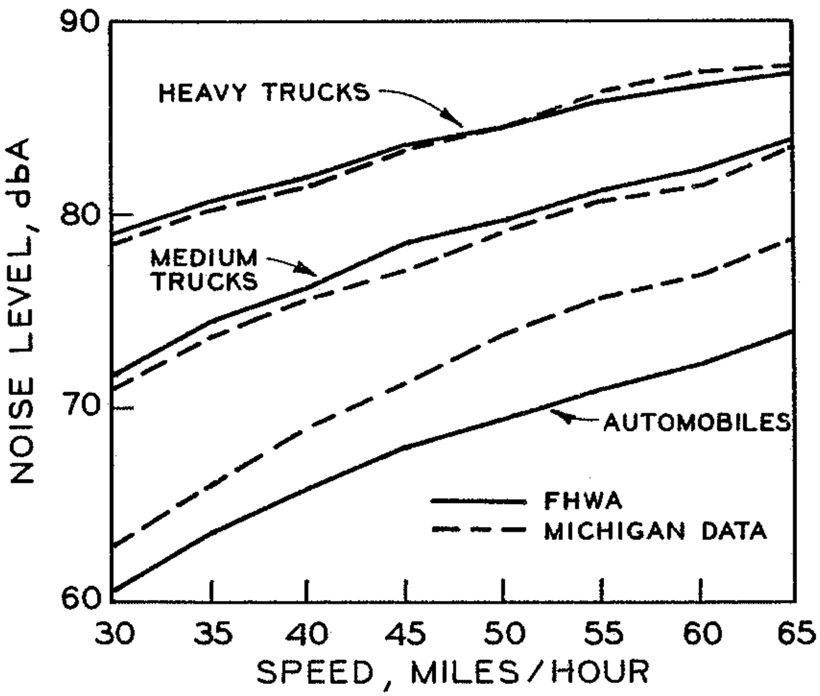

Figure 3. Noise comparison of Michigan data and FHWA values for automobiles, medium trucks, and heavy trucks.

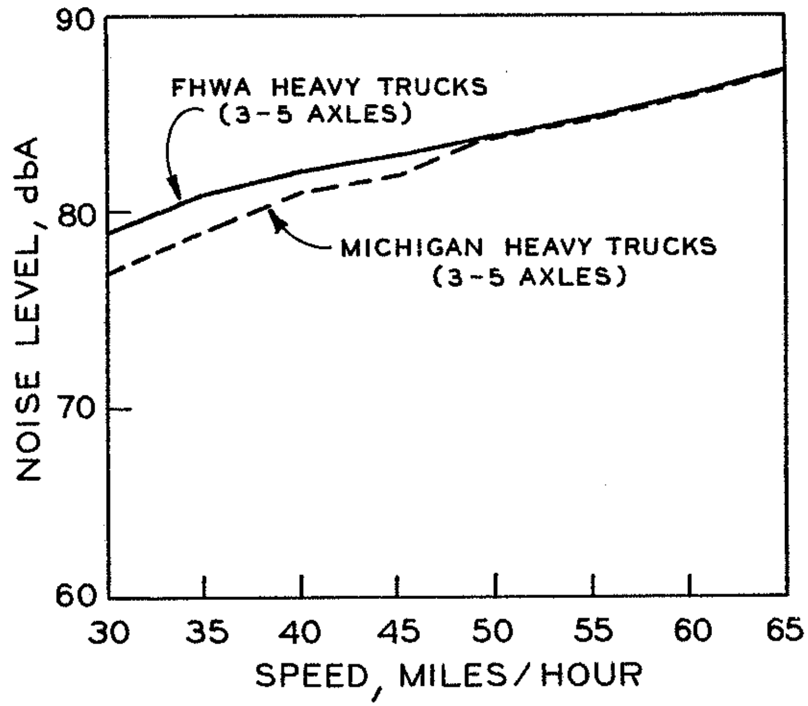

Figure 4. Comparison of Michigan's three to five-axle heavy trucks to FHWA's three to five-axle heavy trucks.

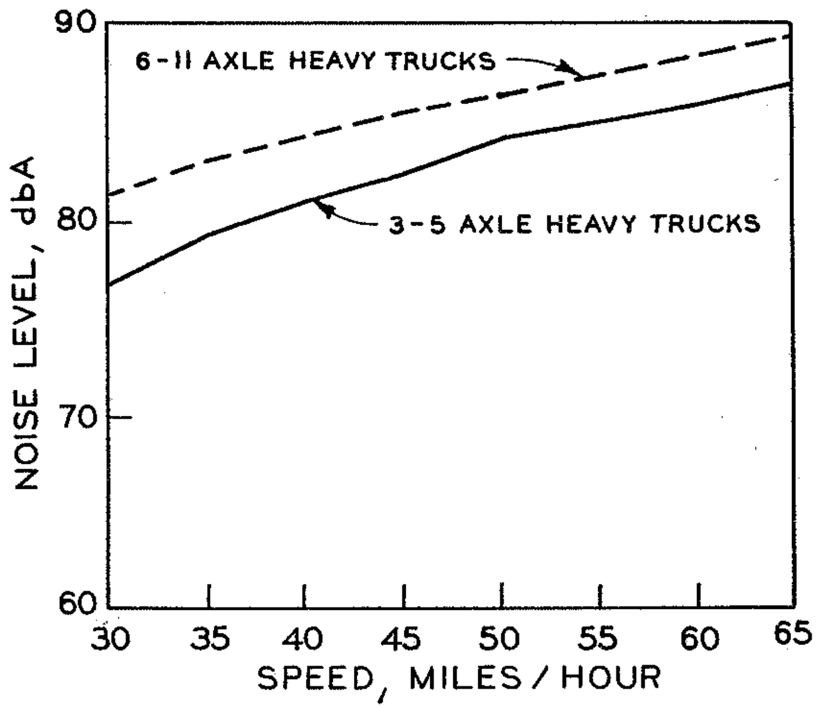

Figure 5. Noise level versus speed of three to five-axle and six to eleven-axle heavy truck types in Michigan.

gan than values used in the FHWA Prediction Model. There are many factors that could contribute to this increase in energy emission levels. Michigan's winter weather causes many vehicles to have tires with all-weather tread that would be noisier than conventional highway tires. There are more four-wheel drive vehicles with mud grip tires in Michigan than in other states. Also, since the FHWA performed their study, the number of four-cylinder and diesel engines have increased significantly. These factors could be the reason Michigan's data have a larger error of estimate (S_0) and higher emission levels than that shown for FHWA data.

Medium truck comparisons in Table 2 show that Michigan data have a smaller standard error of estimate (S_0) than the FHWA's data. However, as shown in Figure 3, the noise level of medium trucks is slightly lower than that from the FHWA study. It was noted during field data collection that a large number of medium trucks were recreational vehicles with dual rear axles. These vehicles were considerably quieter than more conventional commercial type medium trucks. This factor may contribute to the finding that Michigan's medium truck energy emission levels are less than shown for the FHWA's study.

Comparison of the heavy truck class, vehicles with three or more axles, shows that there is very little difference in emission levels between Michigan's study and that of the FHWA, as shown in Figure 3. Note that the FHWA's study includes heavy trucks having three to five axles; whereas, Michigan's study shows heavy trucks with up to 11 axles. As shown in Table 2, the standard error of estimate (S_0) of the Michigan heavy truck class, three to 11 axles, is slightly higher than the FHWA's estimate for heavy trucks with three to five axles. This is due to the Michigan heavy truck class having a wider range of axles.

Figure 4 shows the comparison of Michigan's heavy trucks, with three to five axles, with the FHWA's three to five-axle heavy trucks. It shows that at speeds up to 45 mph the noise level is considerably less for Michigan's heavy trucks. However, at speeds of 50 mph to 65 mph, noise levels are the same. As shown in Table 2, the standard error of estimate (S_0) for heavy trucks with three to five axles is smaller for Michigan data than for FHWA data.

Figure 5 shows the comparison of Michigan's three to five-axle heavy trucks with Michigan's six to 11-axle heavy trucks. As expected, the noise levels for six to 11-axle trucks are considerably higher than for three to five-axle trucks.

The coefficient of determination (R^2) computed for all classes of vehicles in the Michigan study is a great deal higher than the R^2 for the FHWA study as shown in Table 2. This indicates a significantly higher correlation between speed and energy emission for Michigan data.

In summary, the energy mean emission levels used in the current FHWA Prediction Model for automobiles are not representative of the emission levels that are emanating from Michigan's highways. The study has shown that Michigan's automobiles have higher emission levels than those used in the FHWA's Highway Noise Prediction Model. Michigan's medium class trucks have a slightly lower emission level than the FHWA value, and Michigan's heavy truck class with three to 11 axles have a similar emission level to the FHWA's heavy truck class with three to five axles.

Recommendations

Upon request and with approval from the FHWA, the calculated energy mean emission levels from this study should replace the national levels used in the FHWA's Highway Noise Prediction Model, STAMINA 2.0 computer program used by the State of Michigan. This would give the Michigan Department of Transportation a more accurate means of analyzing and predicting the noise emission levels expected from Michigan's highways.

REFERENCES

1. "Highway Noise Measurements for Verification of Prediction Models," Federal Highway Administration, Report No. DOT-TSC-78-2/DOT-TSC-FHWA-78-1.

2. "Determination of Reference Energy Mean Emission Levels," Federal Highway Administration, Report No. FHWA-OEP/HEV-78-1.