Field Investigation of Traffic Noise by Pickup Trucks and Sports Utility Vehicles

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Abstract

With an increasing number of PTs and SUVs on the roadways nowadays, it is hypothesized that traffic noise would go up because the size of these vehicles and the tires used are generally larger than those of the passenger cars. This study investigates the noise impact due to these vehicles by collecting and analyzing field data. A comparison is made with the existing FHWA Traffic noise model and significant differences are found between the field measured noise data and the calculated values from the model.

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1. Background

1.1 Traffic Noise

Noise can be broadly stated as unwanted sound. Momentary or persistent presence of noise in an environment will cause pollution, because it will create an undesired physiological and psychological effect in an individual and will hamper individual and group activities such as communication, work, rest, recreation and sleep. Noise of sufficient intensity and duration can induce temporary or permanent hearing loss, ranging from slight impairment to nearly total deafness.

Traffic flows are major contributors to noise, including
- Engine and exhaust systems of vehicles
- Aerodynamic friction
- Interactions between the vehicle and the support system -
  a. tire and pavement interaction
  b. wheel and rail interaction.

1.2 Measurement of sound

(1) The decibel scale
A common method used to compare one sound quantity Q to another quantity Qo (possibly a reference) is to measure their ratio in bels, where

\[ \text{Bel} = \log_{10} \left( \frac{Q}{Q_o} \right) \]  

(1)

This practice is especially useful when the quantity Q assumes values over a very wide range. Because bel represents a large difference in Q, a smaller unit, called decibel (dB) is commonly employed and

\[ \text{Decibel} = 10 \log_{10} \left( \frac{Q}{Q_o} \right) \]  

(2)

(2) Sound intensity level
Sound intensity level is defined by

\[ L = 10 \log_{10} \left( \frac{I}{I_o} \right) \text{ dB} \]  

(3)

where \( I \) and \( I_o \) are sound intensity and reference intensity, respectively. At the threshold of hearing, \( I=I_o \), and the noise level is \( L=0 \). When \( L=14 \), the sound becomes painful to the human ear.

(3) Sound pressure level
Sound pressure level is defined by

\[ L_P = \log_{10} \left( \frac{P^2}{P_o^2} \right) \]  

(4)

where \( P \) is the maximum acoustic pressure in N/sq m and \( P_o \) is the reference acoustic pressure. As \( I=P \text{ rms/pc} \), sound pressure level can be expressed as

\[ L_P = 10 \log \left( \frac{P^2 \text{ rms}}{P_o^2 \text{ rms}} \right) \]  

(5)
(4) Integration of sound

A mathematical expression for the pressure variation in a harmonic wave at a given location can be written as

$$X_1 = P_1 \sin (w_1 t + \delta_1)$$  \hspace{1cm} (6)

where $P_1$ is the maximum pressure amplitude, $w_1$ is the angular frequency, $t$ is the time, and $\delta_1$ is the phase angle. According to superposition principle, the result of adding or subtracting two harmonic waves of different amplitude, frequency, and phase angle, after a series of equation manipulation (Lipscomb and Taylor, 1978), is

$$\frac{P^2}{P_0^2} = \left( \frac{P_1^2}{P_0^2} \right)_{\text{rms}} - \left( \frac{P_2^2}{P_0^2} \right)_{\text{rms}}$$  \hspace{1cm} (7)

2. Model Description

In March 1998, the Federal Highway Administration (FHWA) released the first version of FHWA Traffic Noise Model (FHWA TNM), a state of the art computer program for highway traffic noise prediction and analysis (Lee, 1998). To provide analysts with a quick screening tool for evaluating simple highway geometries, a set of lookup tables for TNM has been developed. The TNM lookup Tables are accompanied by a complementary program called TNMLOOK. This document contains the lookup tables in their entirely, as well as instructions on how to use TNMLOOK. The objective of the lookup tables is to provide a reference of pre-calculated TNM results for simple highway geometries. Specifically, the tables contain results for five vehicle types (automobiles, medium trucks, heavy trucks, buses and motorcycles) at speeds of 0 to 130 kilometers per hour (km/h) in 10 km/h increments. The five TNM vehicles are defined as follows:

1. Automobiles: all vehicles with two axles and four tires—primarily designed to carry nine or fewer people (passenger cars, vans) or cargo (vans, light trucks)—generally with gross vehicle weight less than 4,500 kg (9,900 lb).
2. Medium Trucks: all cargo vehicles with two axles and six tires—generally with gross vehicle weight between 4,500 kg (9,900 lb) and 12,000 kg (26,400 lb).
3. Heavy Trucks: all trucks with three or more axles and gross weight of more than 12,000 kg (26,400 lb).
4. Buses: all vehicles designed to carry more than nine passengers.
5. Motorcycles: all vehicles with two or three tires and an open-air driver/passenger compartment.

To determine sound levels, or barrier insertion loss values, for receivers associated with a particular geometry, the user has a choice of either using TNMLOOK or using the printed lookup tables. While the lookup table data exist in the above fixed parameter increments, data for receivers at distance 10 to 300m in 10m increments—the TNMLOOK program will interpolate data at any distance within 10 to 300m.

In the lookup table each tabulated value represents the $L$ for 1000 vehicles pass-bys. To combine $L_{aeq}$ values for mixed traffic volumes, the following equation may be used:

$$L_{aeq} = 10 \times \log_{10} \left[ \frac{V_{auto}}{1000} \times 10^{L_{aeq(auto)/10}} + \frac{V_{mt}}{1000} \times 10^{L_{aeq(mt)/10}} + \frac{V_{ht}}{1000} \times 10^{L_{aeq(ht)/10}} + \frac{V_{bus}}{1000} \times 10^{L_{aeq(bus)/10}} + \frac{V_{mc}}{1000} \times 10^{L_{aeq(mc)/10}} \right] \hspace{1cm} (8)$$
where $L_{Aeqlh}$ is the hourly equivalent sound level taking into account all of the following input parameters: $V_{auto}, V_{mt}, V_{ht}, V_{bus}, V_{mc}$ is the volume of automobile, medium trucks, large truck, bus and motorcycle, respectively.

$L_{Aeqlh(auto)}, L_{Aeqlh(mt)}, L_{Aeqlh(ht)}, L_{Aeqlh(bus)}, L_{Aeqlh(mc)}$ represent the hourly equivalent sound level associated with automobiles, medium trucks, large trucks, bus and motorcycles, respectively, which can be interpolated from the appropriate lookup table for the appropriate input parameters.

3. Data Collection

Noise data was collected from three stations at 15-minute intervals at each station for the northbound and southbound directions during the peak hour on Interstate 77 near Exit 137A in Montrose, Ohio. The pavement was dry and the weather was clear with a temperature of 65°F-68°F. The sound level was recorded at 10-second intervals. Seven types of vehicles, namely-passenger cars, sports utility vehicles, pickup trucks, medium trucks, heavy trucks, buses and motorcycles, were included in the study. The number of vehicles for each of the seven types passing the stations every 10 seconds was also recorded. The distance of the lanes from the stations was recorded using a range measurement laser gun.

Sound propagation was over acoustically hard terrain. The height of the noise barrier was measured as 6.6 ft. The barrier from the center from the roadway was measured as 32.8 ft. The distance of each station from the centerline of the road was measured using the laser range finder and was entered into the program. The average distance from the centerline of the road was 137.5 ft for station 1 and 188.5 ft and 95 ft for stations 2 and 3, respectively. The speed information of the vehicles was obtained using video captured in the field and analyzed by the Autoscope image sensing system.

4. Data Analysis

The first step in the data analysis is to calibrate the TNMLOOK program using the field data. From the field video we manually sorted out the number of vehicles in different vehicle classes and obtained the traffic composition data. Adjustments are made to the model parameters based on the traffic composition data for each of the five vehicle classes required by the model. For the automobiles class, however, since the model does not differentiate passenger cars from pickup trucks and sports utility vehicles, we included the latters in the automobiles category.

Field data shows that the percentage breakdown of the five vehicle classes used by the TNMLOOK program generally follows the averages observed in many parts of the country with small fluctuations. At the same time, it also reveals 3.5 percent pickup trucks and 16.6 percent of sports utility vehicles in the traffic flow.

The TNMLOOK program was then run to obtain estimated noise values for the measured traffic composition. Five types of vehicles have been considered for the TNMLOOK program. They are (1) automobiles, including passenger cars, pickup trucks (PTs), and sports utility vehicles (SUVs), (2) medium trucks, (3) heavy trucks, (4) buses, and (5) motorcycles.

A comparison between the field noise data and the calculated noise data shows that a significant difference exists between the two. A t-test was performed which showed that the difference is significant at 95% confidence level. Figure 1 shows the comparison of the field data with the estimated values from the model.
Since the field measured noise level is greater than the calculated level, the difference between the two noise levels was calculated using Equation 7. It is hypothesized that this difference may be due to the contribution of PTs and SUVs. With an increasing number of PTs and SUVs on the roadways, the traffic noise is expected to go up because the size of these vehicles and the tires used are generally larger than those for passenger cars.

In order to determine the contribution of the PTs and SUVs, the noise difference from the two sources was used in a regression analysis. The following equation was used to explore their relationship:

\[
\text{Difference} = A + B \log_{10} \text{SUV} + C \log_{10} \text{PT} \tag{9}
\]

where A, B and C are constants to be determined. Traffic volume data on PTs and SUVs at 10-second intervals were used in the regression. The result of the analysis shows a significant (at 95% confidence level) traffic noise impact by pickup trucks and sports utility vehicles. Due to space limitation, the detailed results are not described here.

Fig. 1. Comparison of field noise data with model estimation
5. Conclusion

This study presents a field investigation of noise impact by the increasing representation of pickup trucks and sports utility vehicles in traffic flow today. The limited test in this study seems to suggest that these two types of vehicles are generating a greater level of noise than the conventional passenger cars. However, there is not enough data to argue if these two types of vehicles should be treated as a separate vehicle category in noise estimation in the FHWA model. A more rigorous study accompanied by various types of statistical testing is required to provide additional insights into the problem.

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