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# HIGHWAY TRAFFIC NOISE MEASUREMENTS AT ACOUSTICALLY HARD GROUND SITES COMPARED TO PREDICTIONS FROM FHWA'S TRAFFIC NOISE MODEL®

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## INTRODUCTION

Since March 1998, the United States Federal Highway Administration's (FHWA) Traffic Noise Model® (TNM®) has been available for highway traffic noise analysis and barrier design [1]. Prior to release, the model was assessed for accuracy by comparing TNM computations to measurement data collected by various researchers and another model's results. The agreement between measured, other model-predicted, and TNM-predicted data was found to be quite good in most cases, the results of the comparisons published in the TNM Technical Manual [2]. Since the release, various States and consultants have performed independent, specific comparisons. Although all the above comparisons are useful, the measurements as a group do not represent a structured study performed with consistent data collection, reduction, and analysis techniques. Further, not all aspects of TNM computations have been investigated.

In order to better assess the accuracy and make recommendations on the use of TNM for the FHWA, the Volpe Center Acoustics Facility is performing an extensive validation study. The study involves highway noise data collection and TNM modeling for the purpose of data comparison, where the results will be published to serve as a user reference for TNM. The first phase of the study is nearing completion; this phase incorporates measurement sites with acoustically soft and hard ground, with and without a noise barrier, and with various degrees of undulating terrain. At least one other phase will follow in order to incorporate more TNM features in the validation.

For Phase 1 of the TNM Validation, measurements were performed at 17 sites around the country, obtaining over 100 hours of highway traffic noise data. Of the 17 sites, four consist primarily of acoustically hard ground. When compared to the TNM-predicted sound levels, data collected at these sites help assess the accuracy of the model.

## MEASUREMENT SITES

Measurement sites for Phase 1 of the TNM Validation were chosen for their relative simplicity (i.e. they contained no interfering diffractive or reflective objects other than those desired). Four of the sites provided a highway noise propagation path over acoustically hard ground. The ground at these sites was either pavement or water.

The first site is identified as 13CA, located in Sonoma, California. This is a water site at a wildlife refuge next to a busy two-lane highway. A levee at the back of the site provided a solid surface for the instrumentation.

The second site is identified as 15CA, located in Oakland, California. This is a pavement site located in the parking lot for the Oakland Coliseum. A very heavily traveled eight-lane highway is adjacent to the parking lot.

The third site is identified as 16MA, located in Wayland, Massachusetts. This is a pavement site located in the parking lot for a state park. A heavily traveled three-lane highway is close to the parking lot, the lot separated from the highway by a 21.3-m (70-ft) strip of field grass with a trough.

The fourth site is identified as 17CT, located in the vicinity of Stafford, CT. This is a water site at a small lake next to a three-lane highway. A small beach area on the back side of the lake provided a solid surface for the instrumentation.

## INSTRUMENTATION

The primary instrumentation deployed at each site includes Bruel & Kjaer microphone systems, Larson Davis Laboratory spectrum analyzers, Sony DAT recorders, and Qualimetrics meteorological systems. The microphones are deployed at several distances from the center of the near travel lane and at two heights above the ground, the number of microphones used being site dependent. Table 1 summarizes the sensor locations; these sensors are arranged in a line perpendicular to the roadway, with the exception of some meteorological sensors being offset. For purposes of model calibration, the position closest to the roadway at a height of 5 ft is considered to be the reference microphone. Also deployed are video cameras for traffic count and composition data; these are generally located on nearby highway overpasses. In addition to measurement day instrumentation, a differential global positioning system is deployed in advance to collect site terrain survey data.

| | Microphones distance; height | | | | Meteorological Sensors distance; height | |
|---|---|---|---|---|---|---|
| Site | location 1 | location 2 | location 3 | location 4 | location 1 | location 2 |
| 13CA | 50 ft; 5 ft and 15 ft | 900 ft; 5 ft and 15 ft | | | 100 ft (offset); 5 ft and 15 ft | 900 ft (offset); 5 ft and 15 ft |
| 15CA | 40 ft; 5 ft and 15 ft | 100 ft; 5 ft and 15 ft | 200 ft; 5 ft and 15 ft | 400 ft; 5 ft and 15 ft | 105 ft; 5 ft and 15 ft | 300 ft; 5 ft and 15 ft |
| 16MA | 78 ft; 5 ft and 15 ft | 100 ft; 5 ft and 15 ft | 150 ft; 5 ft and 15 ft | 200 ft; 5 ft and 15 ft | 90 ft; 5 ft and 15 ft | 175 ft; 5 ft and 15 ft |
| 17CT | 60 ft; 5 ft | 1273 ft; 5 ft and 15 ft | | | 60 ft (offset); 5 ft and 15 ft | 1273 ft (offset); 5 ft and 15 ft |

Table 1: Sensor locations. Distance is from the center of the near travel lane and height is above the ground.

## DATA

At each measurement site, up to six hours of data are collected. The data are processed, analyzed, and compared to TNM-predicted data. All of the data are collected and analyzed in general conformance with ANSI standards [3 and 4] and FHWA's procedures [5].

**Data Collection and Reduction.** For each site, acoustical, meteorological, and traffic data are collected simultaneously throughout the measurement period. Spectrum analyzers are used to collect 5-second 1/3-octave band A-weighted equivalent sound levels ($L_{Aeq}$) at all microphone locations, some locations being processed at a later time by performing spectrum analysis of the DAT recordings offline. During all acoustical measurements, an incident noise log is maintained to record the start and stop times and identify any sound that may be intrusive to the highway traffic noise measurements. The meteorological data (including the wind speed, wind direction, temperature, and relative humidity) are collected every second. A visual record of all highway traffic is recorded continuously on 8 mm video tape during the measurement period.

The data are processed in 15-minute blocks, which include: 1/3-octave band and broadband $L_{Aeq}$s; averages of wind speed, wind direction, and relative humidity; and average wind speeds in the upwind and downwind directions according to the microphone line / roadway configuration. Each data block is analyzed for contamination using the incident noise log, contaminated data blocks being eliminated before final data analysis. For the data presented in this paper, no blocks are eliminated due to wind conditions.

The traffic video recordings are processed both manually and with an automated video traffic detection system. For each traffic lane the vehicles are counted and categorized and speeds are recorded. The manual and automated results are averaged, where final results serve as traffic input to TNM. Also key terrain features are extracted from the site survey data and used as input for the object coordinates in TNM.

**TNM-Predicted Data.** Each measurement site is modeled according to the site survey data, meteorological data, and traffic data. Object input includes all roadways, receivers, terrain lines, and ground zones (field grass, pavement, etc.). Then, for each time block, the corresponding average temperature and relative humidity and the corresponding traffic data are applied. Each time block is run separately, ultimately providing 15-minute TNM-predicted 1/3-octave band and broadband $L_{Aeq}$s analogous to the processed measured data.

**Data Analysis.** In comparing the measured data and the TNM-predicted data, the TNM-predicted sound levels at the reference microphone are calibrated to those measured in the field for each site. This same calibration is then applied to all the other TNM-predicted sound levels for that site. The calibration process, as recommended in Reference 3, is performed to eliminate bias associated with the site-specific vehicle noise emission levels. Differences in the measured and predicted data are represented as delta values, or TNM-predicted levels minus measured levels, positive values indicating over-prediction and negative values indicating under-prediction.

## RESULTS

The analyzed data are here presented as comparisons of the measured and TNM-predicted data as a function of distance and height. Results indicate that TNM is adequately modeling sites 13CA and 16MA and somewhat over-predicting for sites 15CA and 17CT. Please refer to Figures 1 and 2 for the results. Here, the data represent the delta values, or calibrated TNM-predicted data minus measured data. The average delta values are indicated along with the standard deviation from those averages. The standard deviation is based on the data set for each microphone at each site, where each data set contains multiple 15-minute data blocks.

For the 5-ft high microphones (Figure 1), the average TNM-predicted sound levels are within 1.5 dB of the measured levels for sites 13CA and 16MA and within 3-4 dB for sites 15CA and 17CT. For the 15-ft high microphones (Figure 2), the average TNM-predicted sound levels are within 1.5 dB of the measured levels for sites 13CA, 15CA, and 16MA and within 3 dB for site 17CT. The conditions for site 15CA, in particular, were very windy. Since TNM does not account for wind in its sound level predictions, no data were eliminated due to high wind speeds.

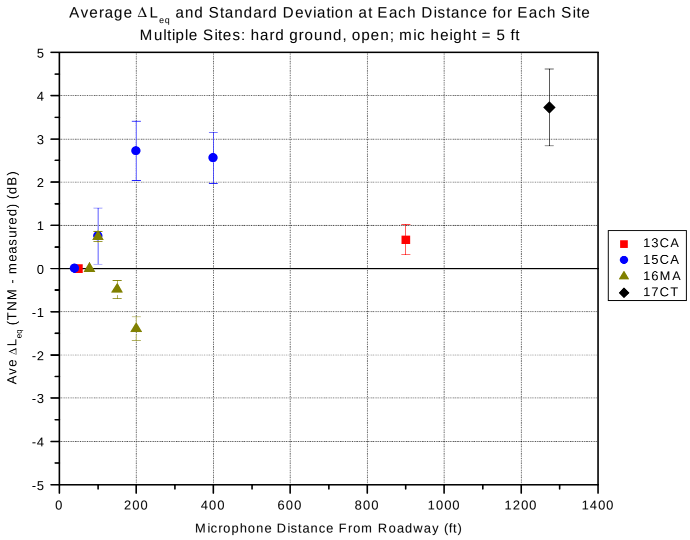


Figure 1: TNM-predicted and measured 15-minute sound levels compared. Data are calibrated to reference microphones. Height above ground is 5 ft.

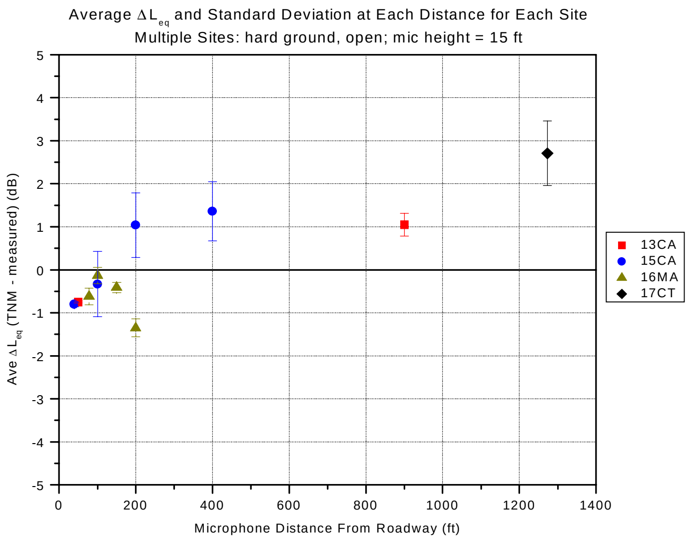


Figure 2: TNM-predicted and measured 15-minute sound levels compared. Data are calibrated to the reference microphones. Height above ground is 15 ft.

## CONCLUSIONS

In a study to assess the accuracy of TNM, many hours of highway traffic noise data were collected at numerous sites (at multiple distances and two heights above the ground). Four of these measurement sites give insight to how well TNM is predicting the sound levels when the sound is propagating over acoustically hard ground. When comparing the measured sound levels to those predicted using TNM, it is found that TNM-predicted levels are within 1.5 dB of those measured in the field for one water site (13CA) back to a distance of 900 ft and one pavement site (16MA) to a distance of 200 ft. In these cases, TNM is doing an excellent job in predicting the sound levels. For the other water site (17CT) back to a distance of about 1300 ft and the other pavement site (15CA) back to a distance of 400 ft, the magnitude of the delta between predicted and measured levels ranges from about 0 to 4 dB. As is seen for the site 17CT data, TNM is over-predicting for the very far distances from the roadway. Wind may be a factor in the differences between predicted and measured sound levels for site 15CA. All data will be analyzed in terms of wind speed and direction for the final TNM Validation Phase 1 report. Because of the varying results at all the sites presented here, it is expected that data will be collected at additional sites with acoustically hard ground, and results will be available for Phase 2 of this study.

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