5aEA1.  Study for how to reduce highway noise levels using TNM

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Median barriers are widely used on roadways in the US. The purpose of this paper was to evaluate a median barrier performance in reducing traffic noise using the Traffic Noise Model version 2.5. For this study, median barriers were modeled on three different roadway configurations at grade, depressed, and elevated. The analysis results indicated that the range of insertion loss for a median barrier at grade was less than 1.5 dBA with a barrier height of 2.5 ft to 10 ft. The range of insertion loss for a median barrier on a depressed roadway (5 ft, 10 ft, and 20 ft below grade) was 0 dBA to 2.8 dBA with a barrier height of 2.5 ft to 4.5 ft and insertion loss increased up to 4.3 dBA with a taller barrier height of 6 ft to 10 ft. On an elevated roadway (5 ft, 10 ft, and 20 ft above grade), the range of insertion loss for a median barrier was 0 dBA to 1.7 dB with a barrier height of 2.5 ft to 10 ft. Given the results of this research, it is reasonable to conclude that a standard median barrier would not provide a significant level of noise reduction.

Published by the Acoustical Society of America through the American Institute of Physics
INTRODUCTION

Environmental noise has become a serious social problem in the United States. Environmental noise is any sound which is generated outdoors by human activities such as from vehicles, railways, air traffic, construction, industrial and recreation activities as may be perceived in a domestic environment such as near homes, in public parks, schools etc (Suter, 1991). While noise emanates from many different sources, transportation noise is probably the most pervasive and difficult source to avoid in society today (FHWA, 1995).

The primary component of the noise arising from surface is road traffic. The noise emission from traffic has been rising, continuously. In cities, the night time levels have increased by up to 3 dBA since 1975 (Cavanaugh and Tocci, 1998). It has been estimated that in the United States, about 90 million people suffer from noise levels which are considered to be unacceptable (Harris, 1985).

The National Environmental Policy Act (NEPA) of 1969 provides broad authority and responsibility for evaluating and mitigating adverse environmental effects including highway traffic noise. The NEPA directs the Federal government to use all practical means and measures to promote the general welfare and foster a healthy environment. A more important piece of Federal legislation which specifically involves abatement of highway traffic noise is the Federal-Aid Highway Act of 1970. This law mandates the Federal Highway Administration (FHWA) to develop noise standards for mitigating highway traffic noise.

PROBLEM STATEMENT

Noise barriers are typically located outside the traffic lanes beyond the shoulder and within the Right-Of-Way (ROW). Noise barriers reduce the sound which enters a community from a busy highway by absorbing the sound, reflecting it back across the highway, or forcing it to take a longer path over and around the barrier. A noise barrier must be tall and long enough to block the view of a highway from the area that is to be protected (the receiver). A noise barrier can achieve a 5 dB noise level reduction when it is tall enough to break the line-of-sight from the highway to the home or receiver (FHWA, 2003). After it breaks the line-of-sight, approximately, 1.5 dB of additional noise level reduction for each meter of barrier height can be achieved (FHWA, 2003).

There are different types of median barriers (concrete, plastic, steel, and cable), and all are used primarily to prevent vehicles from crossing the median and encroaching into opposing lanes (Wright and Dixon, 2003).

Therefore, the purpose of this research is to investigate how traffic noise can be reduced through the use of a median barrier. The effectiveness of various median barrier heights will be examined. The barriers will reflect standard highway hardware and aesthetically fit into the highway scheme.

TRAFFIC NOISE MODEL CHARACTERISTICS

1. Traffic Noise Model (TNM 2.5)

The Federal Highway Administration Traffic Noise Model (TNM 2.5) is used for predicting traffic noise. TNM calculates the noise contribution of each roadway segment to a given noise receptor. The noise from each vehicle type is determined as a function of the reference energy-mean emission level corrected for vehicle volume, speed, roadway grade, roadway segment length, and source-receptor distance. Further adjustments needed to model the propagation path include shielding provided by rows of buildings, the effects of different ground types, source and receptor elevations, and the effect of any intervening noise barriers. The program repeats this process for all roadway segments summing their contributions to generate the predicted noise level at the given receptor. The same procedure is repeated for all other receptors in the study area. (FHWA, 1998)

TNM takes the entire frequency spectrum into account and determines each vehicle type’s total noise emissions as shown in Figure 1.
2. TNM 2.5 Input Types

2.1 Roadway

Roadway traffic is TNM’s source of sound energy. Every roadway segment and point have three coordinates: X, Y, and Z, where Z is the ground elevation of the roadway. The X and Y coordinates of all roadway points are in the direction of traffic flow; however, the Z coordinate is the elevation of roadway pavement. Vehicle speed and traffic volume are also needed as inputs for each different vehicle type. Generally, the data of the vehicle type for TNM 2.5 is composed of automobiles, medium trucks, heavy trucks, buses, and motorcycles.

<table>
<thead>
<tr>
<th>TABLE 1. An Example of the Vehicle Type Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobiles: All vehicles with two axles and four tires (vehicle weights: Less than 9,900 lbs)</td>
</tr>
<tr>
<td>Medium Trucks: All cargo vehicles with two axles and six tires (vehicle weights: 9,900 lbs - 26,400 lbs)</td>
</tr>
<tr>
<td>Heavy Trucks: All vehicles with three or more axles (vehicle weights: More than 26,400 lbs)</td>
</tr>
<tr>
<td>Buses: All vehicles designed to carry more than nine passengers</td>
</tr>
<tr>
<td>Motorcycles: All vehicles with two or three tires and an open air driver/passenger compartment</td>
</tr>
</tbody>
</table>

2.2 Receiver

Receiver Input also has three coordinates similar to the Roadway Input. However, there are two additional inputs: the number of Dwelling Units per receiver location and Height Above Ground. In addition, TNM 2.5 automatically combines the receiver’s Z (ground) with its height above ground, to determine the receiver’s ear height for calculation. The height is normally defined as 5 ft.

2.3 Barrier

TNM 2.5 barriers are either walls or berms that intervene between roadways and receivers to diffract sound waves; therefore, sound levels are reduced. This barrier input table in the TNM 2.5 has three coordinates, X, Y, and Z. The X and Y coordinates of all barrier location points are defined along roadways; however, Z coordinate is in the elevation of barriers.
2.4. Terrain Line

Terrain lines in TNM 2.5 are defined where the terrain is located, both horizontally and vertically. Where terrain lines overhang vertically through lines-of-sight, it reduces sound levels like berms. Also, terrain lines are zero height barriers without perturbations. This terrain line input has three coordinates, X, Y, and Z like the previous input, mentioned above.

2.5 Others

Results tables contain information based on calculated results with basic header information such as organization name, project name, date, the program version, etc. There are five different types of results tables such as Sound Levels, Diagnosis by Barrier Segment, Diagnosis by Vehicle Type, Barrier Description, and Barrier Segment Description. It should be noted that the results for this report are based on the Sound Levels Table. Table 2 is an example of a Sound Levels Table.

**TABLE 2. Sound Levels Tables (Source TNM 2.5)**

<table>
<thead>
<tr>
<th>BARRIER DESIGN:</th>
<th>INPUT HEIGHTS</th>
<th>ATMOSPHERICS: 68 deg F, 50% RH</th>
<th>Average pavement type of a different type with a State highway agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver Name</td>
<td>No.</td>
<td>Existing No Barrier</td>
<td>With Barrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of DUs</td>
<td>LAeq1h</td>
</tr>
<tr>
<td>Receiver1</td>
<td>1</td>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>Receiver2</td>
<td>2</td>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>Receiver3</td>
<td>3</td>
<td>1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Dwelling Units | # DUs | Noise Reduction | Min | Avg | Max |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All Selected</td>
<td>3</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5</td>
</tr>
<tr>
<td>All Impacted</td>
<td>3</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5</td>
</tr>
<tr>
<td>All that meet NR Goal</td>
<td>3</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5</td>
<td></td>
</tr>
</tbody>
</table>

This example shows project title, date, atmospherics such as temperature and humid, pavement type, receivers, sound level without noise barrier, sound level with noise barrier, and noise reduction between ‘Without noise barrier’ and ‘With noise barrier.’ Simply, in this example, receiver 1 is 72 dBA of sound level without noise barrier and 59.5 dBA of sound level with noise barrier. Therefore, noise reduction is 12.5 dBA.

**METHODOLOGY**

The purpose of this study was to determine the effects of the median barrier in reducing highway noise levels. Therefore, to set the basic parameters, the geometrical conditions of the highway, the estimated traffic volumes (cars and trucks) and average vehicle speeds at each receiver distance (50 ft, 100 ft, and 200 ft), were entered into the Traffic Noise Model program, TNM 2.5.

TNM 2.5 computes sound levels for all possible combinations of barrier heights and then stores partial results for later use. Also, TNM 2.5 uses these partial results to determine sound levels for specific barrier designs. The following is a description of the procedure that was used to obtain the results for this study.
1. Median Barrier Modeling Design

1.1. TNM 2.5 Parameters for This Study

Example parameters of this study are as follows.
Receiver distance from the middle point of northbound roadway: 50 ft, 100 ft, 200 ft.
Receiver height above ground: 5 ft.
Ground elevation: 0.0 ft
Dimensions of roadway: 24 ft
Median Barrier heights: 2.5 ft, 3.5 ft, 4.5 ft, 6 ft, 8 ft and 10 ft.
Noise Barrier heights: 8 ft, 10 ft, 12 ft, 14 ft, 16 ft and 18 ft
Traffic Parameters, refer to Table 3.

1.2. Modeling Process

Predictions of highway noise were made TNM 2.5 at specified receiver distances (50 ft, 100 ft, and 200 ft) to the north of the roadway centerline. This study consisted of creating roadway models, which were 24 ft wide westbound lanes and 24 ft wide eastbound lanes in level, lowered and elevated geometry. Each single lane was treated as a single roadway element including with/without noise barrier and with/without median barrier conditions.

The first step was running the models for various heights of the noise barrier (0 ft to 18 ft) and median barrier (0 ft to 10 ft) using the TNM 2.5 program.

In order to examine what effect various heights of the median barrier would have on the sound level at the receivers, all results (sound level and insertion loss) for each different noise barrier and median barrier height along with each different geometric case were compared and explained and results and summary. Examples of plan view and input data for this study are shown in Figure 2 and Table 3.

FIGURE 2. Plan View of the Study
RESULTS AND ANALYSIS

All models that were generated by the Traffic Noise Model program (TNM 2.5) and the corresponding results were evaluated to determine the difference of the absolute noise levels between ‘with/without noise barrier’ and ‘with/without median barrier’ for different receiver distances. There are three models for this study: (1) grade (2) 5, 10, and 20 ft of depression, (3) 5, 10, and 20 ft of elevation.

1. Effects of Median Barriers on Traffic Noise

The goal of this research was to investigate the effects of various heights of the median barriers on reducing traffic sound levels. Median barrier heights from 2.5 ft to 10 ft were used along with noise barriers from 8 ft to 18 ft in height. This combination was selected to examine the maximum range (shortest to tallest) of barrier designs. As mentioned previously, three receivers of 50, 100, and 200 ft, behind the West Bound barrier, were studied for each barrier height combination.

2. Median Barrier at Grade

2.1. One Lane (24 ft Width)

For a median barrier (2.5 ft to 4.5 ft in height), the range of insertion loss was from 0.7 to 1.3 dBA without a noise barrier. In contrast, the range of insertion loss for combination of a noise barrier (8 ft to 12 ft in height) and a median barrier was from 0.0 to 1.0 dBA and the taller noise barriers (12 ft to 18 ft) were mostly 0.0 dBA.
For the taller median barriers (6 ft to 10 ft in height), the range of insertion loss was from 1.0 to 1.5 dBA without a noise barrier. However, insertion loss range was from 0.7 to 2.4 dBA with a noise barrier (8 ft to 18 ft in height).

3. Median Barrier at Depression (5 ft, 10 ft, 20 ft)

3.1. One Lane (24 ft Width)

3.1.1. Depressed Roadway (5 ft)

For a median barrier (2.5 ft to 4.5 ft in height), the range of insertion loss was from 0.2 to 2.2 dBA without noise barrier. However, the range of insertion loss for combination of noise barrier (8 ft to 18 ft in height) was 0.0 dBA. For taller median barrier (6 ft to 10 ft in height), on the other hand, the range of insertion loss was from 1.0 to 3.2 dBA without noise barrier and insertion loss range was 0 to 2.5 dBA with noise barrier (8 ft to 18 ft in height).

3.1.2. Depressed Roadway (10 ft)

For a median barrier (2.5 ft to 4.5 ft in height), the range of insertion loss was from 0.1 to 2.8 dBA without a noise barrier. However, for tall median barrier (6 ft to 10 ft in height), the range of insertion loss for combination of noise barrier (8 ft to 18 ft in height) was 0.0 dBA. However, for taller median barrier (6 ft to 10 ft in height), the range of insertion loss was from 0.9 to 4.3 dBA without noise barrier and insertion loss range was 0.0 to 2.4 dBA with noise barrier (8 ft to 18 ft in height).

3.1.3. Depressed Roadway (20 ft)

For a median barrier (2.5 ft to 4.5 ft in height), the range of insertion loss was 0.0 dBA either ‘without noise barrier’ or ‘with noise barrier’. For 20 ft depressed geometry condition, it did not matter how tall a median barrier and a noise barrier were.

4. MEDIAN BARRIER AT ELEVATION (5 FT, 10 FT, 20 FT)

4.1. One Lane (24 ft Width)

4.1.1. Elevated Roadway (5 ft)

For a median barrier (2.5 ft to 4.5 ft in height), the range of insertion loss was from 0.2 to 0.9 dBA without noise barrier. However, the insertion loss range for combination of a noise barrier (8 ft to 10 ft in height) and a median barrier was 0.0 to 1.0 dBA and the taller noise barriers (12 ft to 18 ft) were 0.0 dBA.

For the taller median barriers (6 ft to 10 ft in height), the range of insertion loss was from 0.5 to 1.1 dBA without noise barrier and insertion loss range was 0.3 to 2.4 dBA with noise barrier (8 ft to 18 ft in height).

4.1.2. Elevated Roadway (10 ft)

For a median barrier (2.5 ft to 4.5 ft in height), the range of insertion loss was from 0.4 to 1.2 dBA without noise barrier. However, the insertion loss range for combination of a noise barrier (8 ft to 12 ft in height) and a median barrier was 0.0 to 1.0 dBA and the taller noise barriers (12 ft to 18 ft) were largely 0.0 dBA.

For the taller median barriers (6 ft to 10 ft in height), the range of insertion loss was from 0.8 to 1.4 dBA without noise barrier and insertion loss range was 0.3 to 2.3 dBA with noise barrier (8 ft to 18 ft in height).

4.1.3. Elevated Roadway (20 ft)

For a median barrier (2.5 ft to 4.5 ft in height), the range of insertion loss was from 0.3 to 1.2 dBA without noise barrier. However, the insertion loss range for combination of a noise barrier (8 ft to 12 ft in height) and a median barrier was 0.0 to 0.9 dBA and the taller noise barriers (14 ft to 18 ft) were 0.0 dBA.

For the taller median barriers (6 ft to 10 ft in height), the range of insertion loss was from 0.7 to 1.7 dBA without noise barrier and insertion loss range was 0.6 to 2.1 dBA with noise barrier (8 ft to 18 ft in height).
CONCLUSION AND SUMMARY

The main goal of this study was to determine median barrier performance in reducing traffic noise using the recently released Traffic Noise Model, TNM 2.5. For this study, an arbitrary scenario was made as follows. First, the range of insertion loss for a median barrier at grade was less then 1.5 dBA with median barriers (2.5 ft to 10 ft in height). Second, the range of insertion loss for median barriers (2.5 ft to 4.5 ft in height) used for roadway depressions from 5 ft to 20 ft was 0.0 dBA to 2.8 dBA and insertion loss increased up to 4.3 dBA when used with taller median barriers (6 ft to 10 ft in height). Finally, the range of insertion loss for a median barrier at elevation (5 ft, 10 ft, 20 ft) was 0.0 dBA to 1.7dBA with median barriers (2.5 ft to 10 ft in height).

The range of insertion loss would be 0.0 dBA to 2.8 dBA with median barrier (2.5 ft to 10 ft in height) at any of the geometric situations, i.e. at grade, lowered, and elevated. However, the range of insertion loss with a 10 ft depressed roadway and taller median barrier (6 ft to 10 ft in height) was quite high. The reason for this unexpected result may not be easily explained, and it is not within the parameters of this research work to do so. However, this range of insertion loss could possibly be attributed to multiple reflections from the ground and barrier. Reflections from the ground may create extra propagation paths and intermittent wave interference resulting in increased sound pressure at the receiver in TNM 2.5 (FHWA, 1998). Though difficult to model, this interference may indicate wave amplification and wave canceling, respectively.

For further investigation, ground effects were also studied using various ground surface materials in the TNM 2.5 model. The range of insertion loss using the previous median barrier with pavement, water and hard soil was 0.9 dBA to 1.1 dBA and 0.6 dBA to 1.2 dBA on powder snow, lawn or field grass. The difference between soft and hard surface was roughly 0.6 dBA. Although ground effects can intermittently generate variations in the results, it is not a determining factor in the effectiveness of a given barrier.

Given the results of this modeling and research, it is reasonable to conclude that a standard median barrier would not provide a significant level of noise reduction. Although a relationship between median barrier height and noise reduction has been identified, taller median barriers do not impact the results enough to alter this conclusion. When considering the construction of very tall median barriers for noise reduction purposes, the costs would far outweigh the relatively minimal benefits of this approach.

REFERENCES

   http://www.nanoise.org/library/envarticle/index.htm
Federal Highway Administration (FHWA), keeping the noise down- highway traffic noise barriers, August 2003.