Median Barriers & Multi-Lane Highways

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Prepared for:
National Cooperative Highway Research Program (NCHRP)
Transportation Research Board of The National Academies
Issues Encountered In Modeling Projects Containing Median Barriers

- FHWA TNM 2.5 component that addresses single reflections is “turned off” and not available for use

- Parallel barrier subroutine within FHWA TNM is not intended for use in lower-height barriers such as median barriers

- FHWA TNM 3.0 will eventually be capable of modeling single reflections. However, this version is not yet available for use and its limitations and graphic functionality are still being evaluated
Primary Factors Considered

• Horizontal and vertical relationship of the median barrier to adjacent lanes

• Elevation of adjacent receptors with respect to roadways and the median barrier

• Distances between the roadways and median barrier and adjacent receptors

• Height and shape of the median barrier
Volpe Site 3C – Arizona

- Arizona Quiet Pavement Program (2008)
- 32’ wide paved median with 3’ high median barrier
- Measurements at 50’ & 141’ from center of near lane
- Measurements at 5’ above pavement elevation
- Median barrier modeled as barrier by Volpe
Volpe Site 18PA – PTC Carlisle

• FHWA TNM Validation Project (2001)
• 10’ wide paved median with concrete median barrier
• Measurements at 50’, 200’, 500’ & 1000’ from center of near lane
• Measurements at 5’ & 15’ above pavement elevation
• Median barrier not modeled as barrier by Volpe
Volpe Site 22PA – Camp Hill, PA

- FHWA TNM Validation Project (2001)
- 4’ wide paved median with 3.5’ high median barrier
- Measurements at equal setback distances on both protected (berm) and non-protected locations
- Median barrier not modeled as barrier by Volpe
• Warrendale Mainline Toll Plaza project (early 2000s)
• Narrow paved median with median glare screen
• Adjacent ground 15’ to 20’ lower than Turnpike
• Grid-based modeling of adjacent park
EA – ODOT Project

- ODOT I-71 Columbus, OH Noise Analysis (2006)
- Narrow paved median with median barrier
- Sites level with, above, and below roadway elevation
Modeling Process

• Four techniques evaluated
• Receptors located at various distances (46’ to 1,000’ from center of near traffic lane)
• 49 sets of measurement & traffic information utilized
• Variable topography - receptors below highway (10 locations), near level with highway (9 locations), and above highway (7 locations), with multiple measurement heights at 20 locations
• Median barrier heights from 2.5’ to 4.5’ evaluated for each of the five projects (insignificant differences)
Evaluated Techniques

1. Image roadway technique approximation using “seen” travel lanes

2. Image roadway technique approximation using all travel lanes

3. Ignoring median barrier

4. Ignoring median barrier reflections
Technique 1

Skew Section of base FHWA TNM run

- EB travel lanes sources on or below sight line are assumed to be "seen" by receptor. Only these sources will be modeled in the reflected noise source FHWA TNM run.

- Receptor to median barrier sight line.

- Terrain Line

- 3 EB travel lanes modeled as roadways with traffic. Inside and outside EB paved shoulders modeled as roadways without traffic.

- Glarescreen modeled as barrier. Ground between inside paved shoulders modeled as ground zone.

- 3 WB travel lanes modeled as roadways with traffic. WB inside shoulder modeled as roadway without traffic.
Technique 1

Skew Section of reflected (flipped) FHWA TNM run

Area occupied by 3 EB travel lanes and paved shoulders in base FHWA TNM run replaced with ground zone (pavement).

ALTERNATIVE: Leave 3 EB travel lanes and paved shoulders in, but remove all traffic from roadways.

Median barrier deleted and median area modeled as ground zone (lawn).

3 Reflected noise from 3 EB roadways modeled by "flipping" 3 EB travel lanes along with their respective traffic data plus flipping EB inside shoulder. Model only traffic data related to reflected EB vehicle sources "seen" by receptor, as indicated by solid circles.
Techniques 2, 3, and 4

2. Image roadway technique approximation using all travel lanes
   • More conservative approach assumed all “flipped” roadway sources reflected by the median barrier
   • Resulted in slightly higher values than Technique 1

3. Ignoring median barrier
   • Median barrier not modeled as a TNM barrier
   • No reflections from median barrier assumed

4. Ignoring median barrier reflections
   • Median barrier modeled as a TNM barrier
   • No reflections from median barrier assumed
## Results of Evaluation

<table>
<thead>
<tr>
<th>Project and Point ID</th>
<th>Analysis Point Distance from Center of Near Lane</th>
<th>Height of Receptor Above Elevation of Roadway</th>
<th>Measured $L_{eq}$ in dB(A)</th>
<th>Image Roadway Technique Approximation</th>
<th>Modeled $L_{eq}(h)$ in dB(A)</th>
<th>Measured Minus Modeled $L_{eq}(h)$ in dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Butler M-2</td>
<td>175</td>
<td>-18</td>
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<tr>
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<td>57.7</td>
<td>59.6</td>
<td>2.4</td>
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<td>58.3</td>
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<td>3.5</td>
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<td>18PA Caterle</td>
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<td>63.9</td>
<td>64.4</td>
<td>65.2</td>
<td>1.3</td>
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<tr>
<td>18PA Caterle</td>
<td>200</td>
<td>-4.6</td>
<td>61.5</td>
<td>65.5</td>
<td>66.0</td>
<td>3.5</td>
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<td>ODOT M-7</td>
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<td>-3</td>
<td>73.4</td>
<td>74.5</td>
<td>75.2</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Receptors within 500 feet of the highway and located below the elevation of the highway (Model barrier and ignore reflections):
<table>
<thead>
<tr>
<th>Distance From Middle of Near Travel Lane</th>
<th>Height of Receptor With Respect to Roadway</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Receptor Below Roadway</td>
<td>Receptor 0 to 6 Feet Above Roadway</td>
</tr>
<tr>
<td>50</td>
<td>Model Median Barrier and Ignore Reflections</td>
<td>Model Median Barrier and Ignore Reflections</td>
</tr>
<tr>
<td>100</td>
<td>Model Median Barrier and Ignore Reflections</td>
<td>Model Median Barrier and Ignore Reflections</td>
</tr>
<tr>
<td>200</td>
<td>Model Median Barrier and Ignore Reflections</td>
<td>Model Median Barrier and Ignore Reflections</td>
</tr>
<tr>
<td>500</td>
<td>Model Median Barrier and Ignore Reflections</td>
<td>Model Median Barrier and Ignore Reflections</td>
</tr>
<tr>
<td>1000</td>
<td>Model Median Barrier and Ignore Reflections</td>
<td>Model Median Barrier and Ignore Reflections</td>
</tr>
</tbody>
</table>
Issues Encountered In Modeling Projects Containing Multi-Lane Highways

- Modeling groups of lanes versus each lane as its own roadway
- How much to overlap lanes
- How to represent shoulders and median areas
- How to represent edge of roadway section diffraction points
- Shielding of one roadway by another roadway, such as in a bifurcated roadway section
- Modeling super-elevated roadways
Volpe Site AZ3B – Arizona

- Arizona Quiet Pavement Program (2008)
- Reference microphone at 50’, 5’ above pavement
- Measurements at 95’ & 246’, 5’ above ground
- Lane-by-lane traffic with lanes modeled as 12.1’ wide
- Shoulder modeled as roadway w/o traffic (dummy lane)
Volpe Site 01MA – Rte. 24, Massachusetts

- FHWA TNM Validation Project (2008)
- Measurements at 50’, 100’, & 200’, 5’ above ground
- Lane-by-lane traffic with lanes modeled as 12.1’ wide
- Shoulder modeled as roadway w/o traffic (dummy lane)
Volpe Site 20PA – I-81, Pennsylvania

- FHWA TNM Validation Project (2001)
- Measurements at 90’, 200’, 400’, & 600’, 5’ & 15’ heights
- Lane-by-lane traffic with lanes modeled as 12.1’ wide
- Shoulders modeled as roadway w/o traffic (dummy lane)
- Wide grass median
Volpe Site 19PA – US 30, Coatesville, PA

- FHWA TNM Validation Project (2008)
- Measurements at 50’, 200’, 400’, 500’, & 700’, 5’ & 15’ heights
- Lane-by-lane traffic with lanes modeled as 12.1’ wide
- Shoulders modeled as roadway w/o traffic (dummy lane)
- Narrow grass median with guard rail
• Environmental Acoustics preliminary noise analysis

• Lanes grouped – single roadway in each direction

• Receptors at-grade with, above, and below roadway

• Edge of shoulder diffraction edge defined by the outside edge of the modeled roadway closest to the measurement sites
I-95, Philadelphia, PA

- Environmental Acoustics final design noise analysis
- Limited evaluation of roadway super-elevation
- Receptors at 50’ & 100’, 15’ below roadway
- Each lane’s roadway profile modeled separately
Modeling Process Related to Selected Projects

- Receptors located at various distances (50’ to 700’ from center of near traffic lane)

- 67 sets of measurement & traffic information utilized

- Variable topography - receptors heights varied from 20’ above highway to 29’ below highway

- Median types varied from narrow paved to wide grass
Evaluated Techniques

Modeling roadways
- Grouping lanes (2-lane, 3-lane, and 4-lane grouping)
- Modeling each lane separately:
  1. Directional roadway’s profile applied to each directional travel lane
  2. Different roadway profile applied to each travel lane to represent roadway super-elevation
  3. Lane overlaps of 0.1 foot, 1.0 foot, 5 feet, and 10 feet

Modeling shoulders
- Modeled as separate roadways (dummy lanes) without traffic
- Modeled as Ground Zone
- Incorporated in adjacent modeled roadway lane’s width
Evaluation of Selected Projects - Findings

• Average measured versus modeled absolute differences associated with lane overlap options for each technique were approximately 0.5 to 0.6

• Average differences between measured and modeled noise levels:
  1. Dummy Lane Technique: 1.5 to 2.0 dB, depending upon lane overlap option
  2. Ground Zone Technique: 1.5 to 2.0 dB, depending upon lane overlap option
  3. Adjacent Lane Width Technique: 1.7 to 2.0 dB, depending upon lane overlap option
Evaluation of Selected Projects - Findings

Higher differences of (up to 6 dB) between measured and modeled noise levels:

• Appeared to be unrelated to roadway modeling techniques and due to other factors such as pavement type, ground type, intervening terrain, etc.

• Typically occurred at greater distances from the highway
Comparative Performance of Modeling Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Totals</th>
<th>Individual Lane Overlap Distances</th>
<th>Grouped Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.1'</td>
<td>1'</td>
</tr>
<tr>
<td>Dummy Lane (DL)</td>
<td>56</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Ground Zone (GZ)</td>
<td>56</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Adjacent Lane Width (ALW)</td>
<td>40</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>152</strong></td>
<td><strong>48</strong></td>
<td><strong>28</strong></td>
</tr>
</tbody>
</table>

Observations based on selected projects:

- It may be best to keep lane overlap distances in the 0.1 to 1.0 foot range.
- Roughly equal performance by Dummy Zone and Ground Zone techniques.
- Small individual lane overlap (0.1’ to 1.0’) appears better than grouped lanes.

HOWEVER: These observations, while pointing to some trends, were not sufficient in themselves to formulate a best modeling practice.
Generic Highway Project Evaluated

- 4,000’ long 4-lane divided highway, level grade, elevation = 0’
- 10’ wide paved inside and outside shoulders and paved median
- Default ground type set as pavement, area adjacent to highway modeled as lawn
- Traffic in each direction (2,000 autos, 200 MT, and 200 HT), 60 mph, distributed equally among lanes in individual lane techniques
Generic Highway Project Evaluated

- Receptors at 50’, 100’, 200’, 300’, 400’, and 500’ from the center of the near lane at heights of 5’ and 15’ above ground level at each receptor location

- Adjacent ground level assumed modeled under two scenarios - ground at an elevation of 0’ feet and ground at an elevation of minus 20’, resulting in receptors at minus 15’, minus 5’, plus 5’, and plus 15’ relative to the highway

- Upon review of 4-lane section results, an 8-lane section was also evaluated with additional receptors at lower elevations (-25’ and -35’ below roadway)
No differences greater than 1.0 dB indicated
Evaluation Results - Generic 8-lane Project

- More substantial differences occurred at receptors located closer to the highway at lower elevations.
- Differences greater for heavy truck component than for overall vehicle mix (based on separate analyses performed).
- Grouped Travel Lanes Technique under-predicted noise levels at these locations compared to Individual Lane Technique.
Suggested Best Modeling Practices – Multi-Lane Highways

Most Important:

• Model each travel lane separately when receptors are located below the elevation of the highway.

• Regardless of the receptor’s relationship to the highway, model each travel lane separately when there are any intervening manmade or natural features that block the line of sight between any receptor and any travel lane.
Suggested Best Modeling Practices – Multi-Lane Highways (cont.)

- Set FHWA TNM default ground type to “Pavement” to minimize any possible effects created by inadvertently leaving gaps between roadways when modeling complex roadways with features such as ramp gores, curved roadway sections, and super-elevated roadways.

- Model median areas between paved shoulders and surfaces outside of the roadway section by use of the appropriate FHWA TNM ground zone(s).

- Provide travel lane overlap distances in the 0.1’ to 1.0’ range.
Suggested Best Modeling Practices – Multi-Lane Highways (cont.)

• Use the Dummy Lane technique to model shoulders, especially outside shoulders. It presents less potential for illegal intercepts within FHWA TNM and does not require the addition of a contour line that is required with the Ground Zone technique.

• When modeling super-elevated roadways, model the profile elevations associated with each roadway lane if such data is available at the time of modeling.