Supplemental Guidance for Modeling Building Rows and Parallel Barriers from NCHRP Report 791

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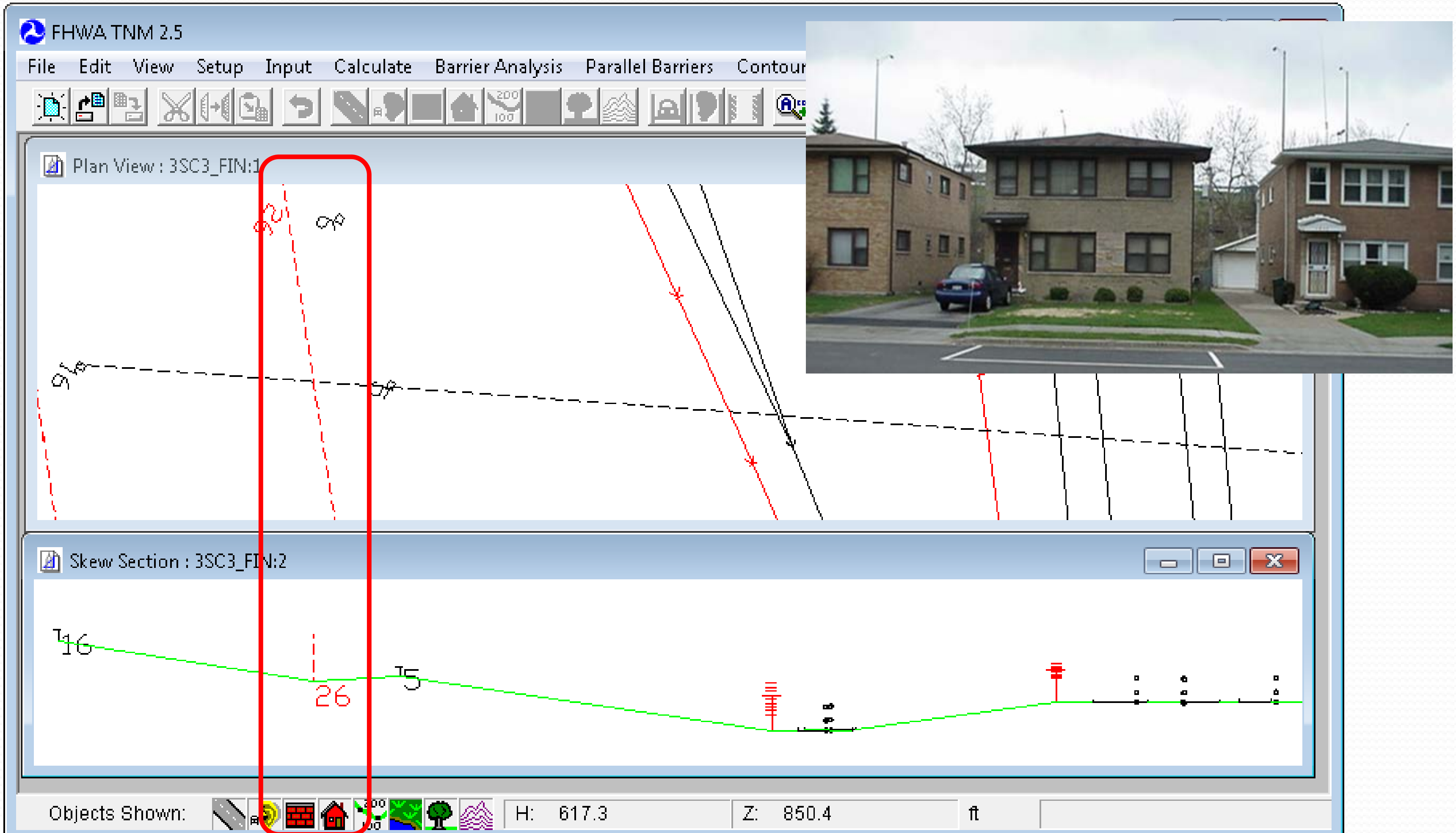
Bowlby & Associates, Inc.

NCHRP Report 791, *Supplemental Guidance on the Application of FHWA's Traffic Noise Model (TNM)*

(NCHRP Project 25-34)

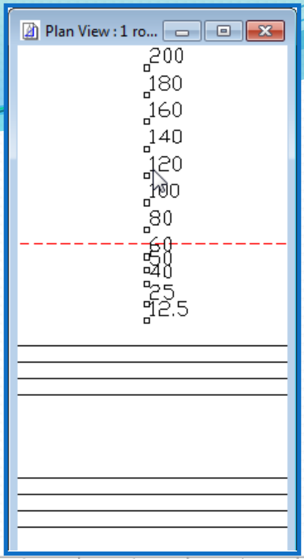
1. Structure Reflected Noise
2. Bridge Expansion Joints
3. Signalized Interchanges
4. Intersections
5. Area Sources
6. Median Barriers
7. Roundabouts
8. Multi-lane Highways
9. Rows of Buildings
10. Topography
11. Wind Direction
12. Temperature Inversion
13. Ground Zones
14. Tree Zones
15. Parallel Barriers
16. Tunnel Openings

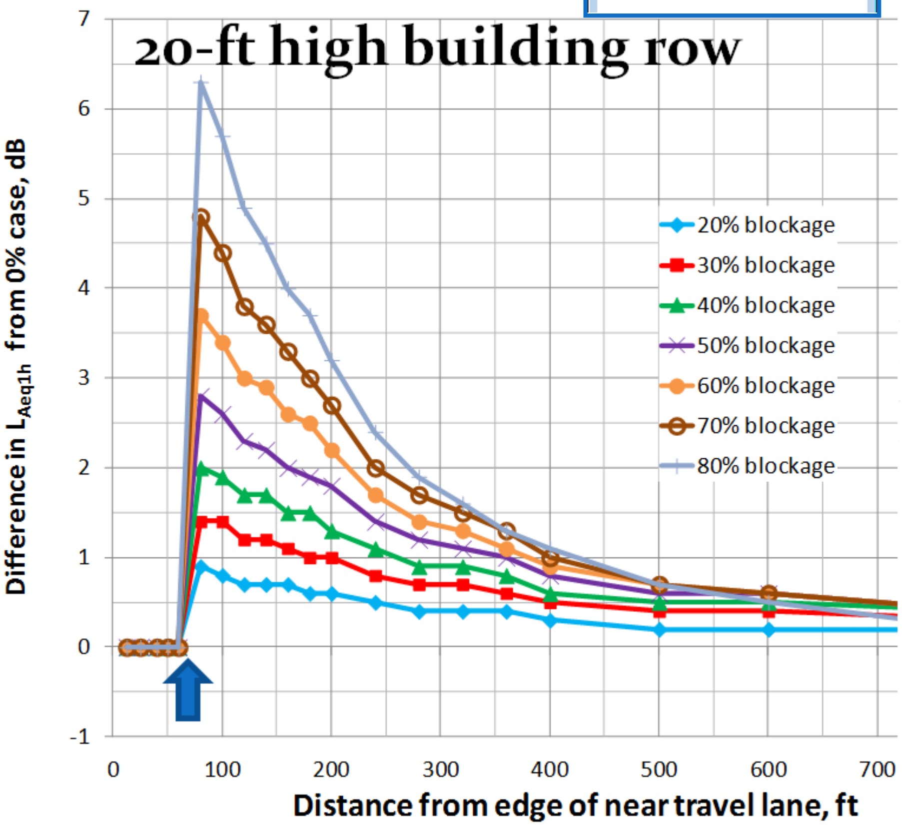
TNM Building Rows – akin to porous noise barriers



Effect of height of building rows and percentage of blockage

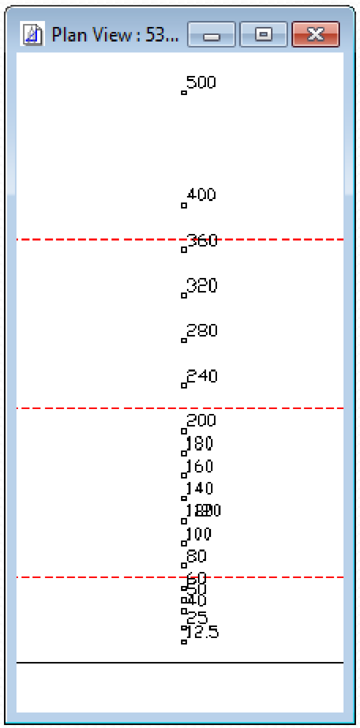
- Amount of noise reduction decreases:
  - As distance from building row increases
  - As building percentage or building height decreases
- Simple guidance is difficult

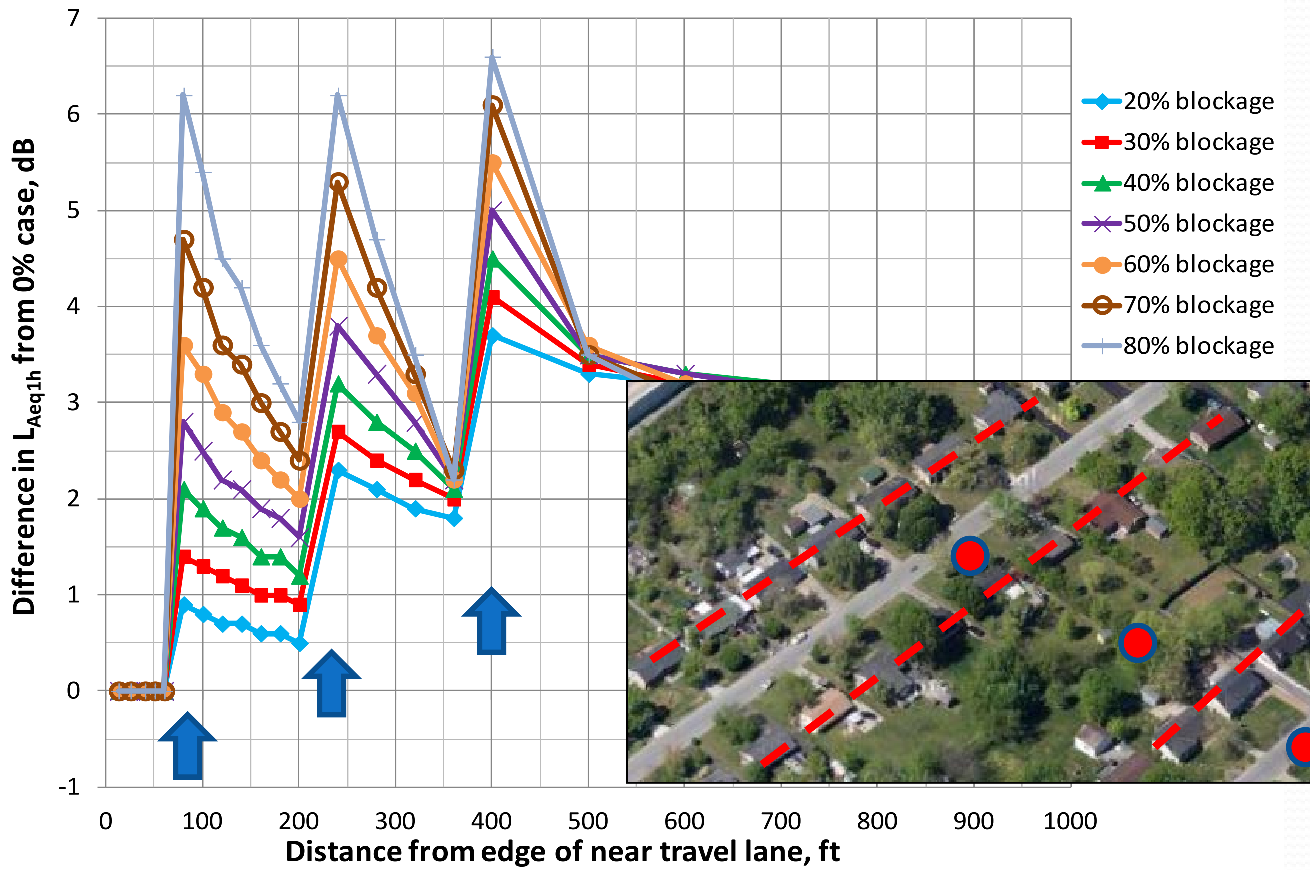




Effect of multiple rows

- **Noise reduction by % blockage for three 20-ft high building rows near a single 12-ft wide roadway**





Effect on noise barrier noise reduction

- Both "no barrier" and "with barrier" levels decrease when building row is added – at different rates
- Compared to "no building row" case, barrier noise reduction can:
  - Increase for low blockage percentage (30%)
  - Decrease for high blockage percentage (70%)

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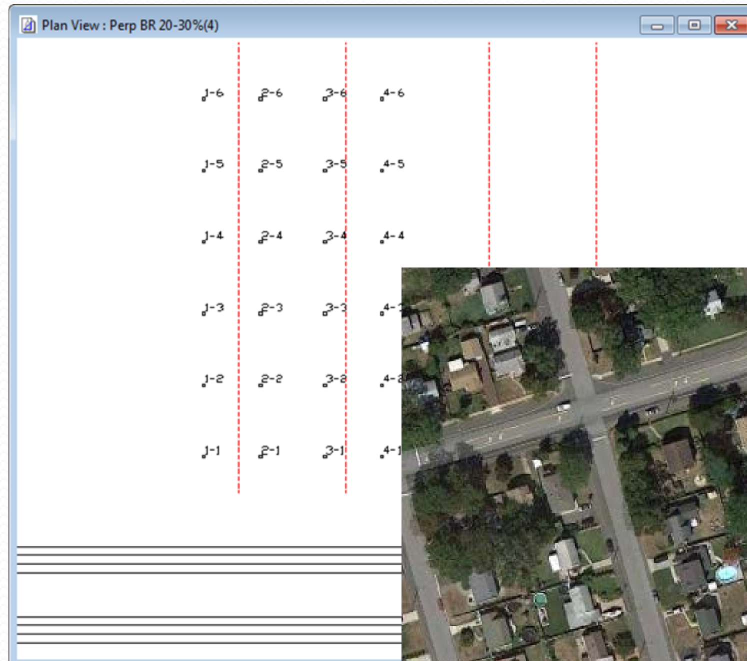
Building rows perpendicular to the roadway

- Noise reductions are not as large as for building rows parallel to roadway
- Example: for 70% blockage, reductions of:
  - 1-2 dB for end receivers
  - 2-3 dB for internal receivers



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Modeling houses as individual TNM Barriers – “building barriers”

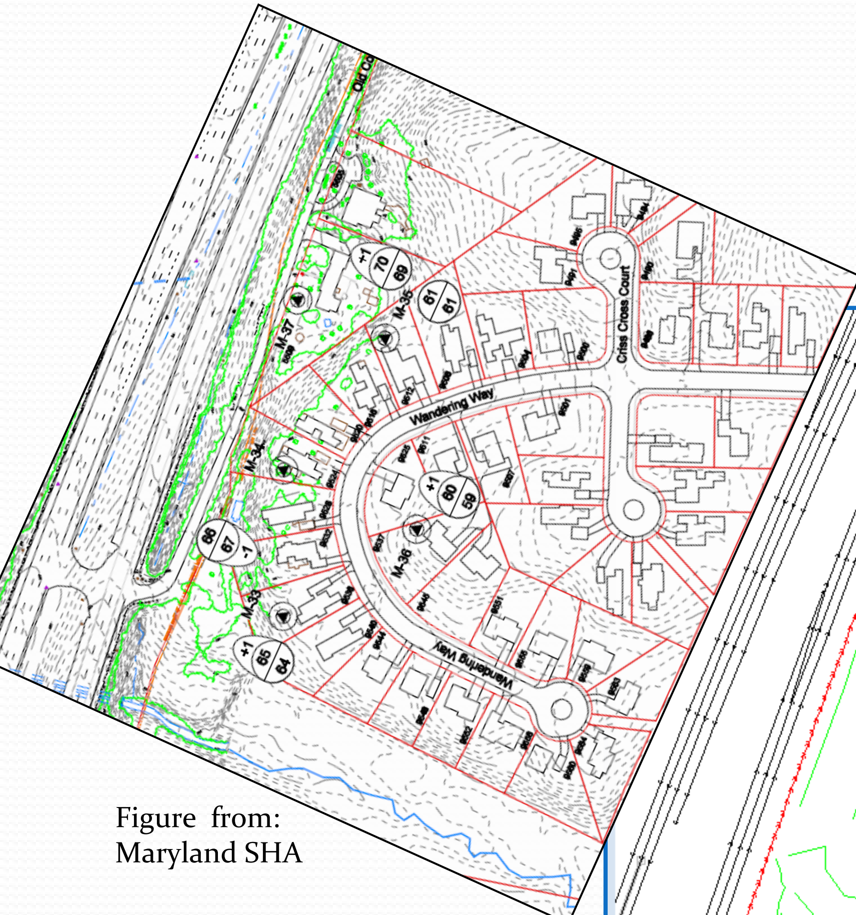


Figure from:
Maryland SHA

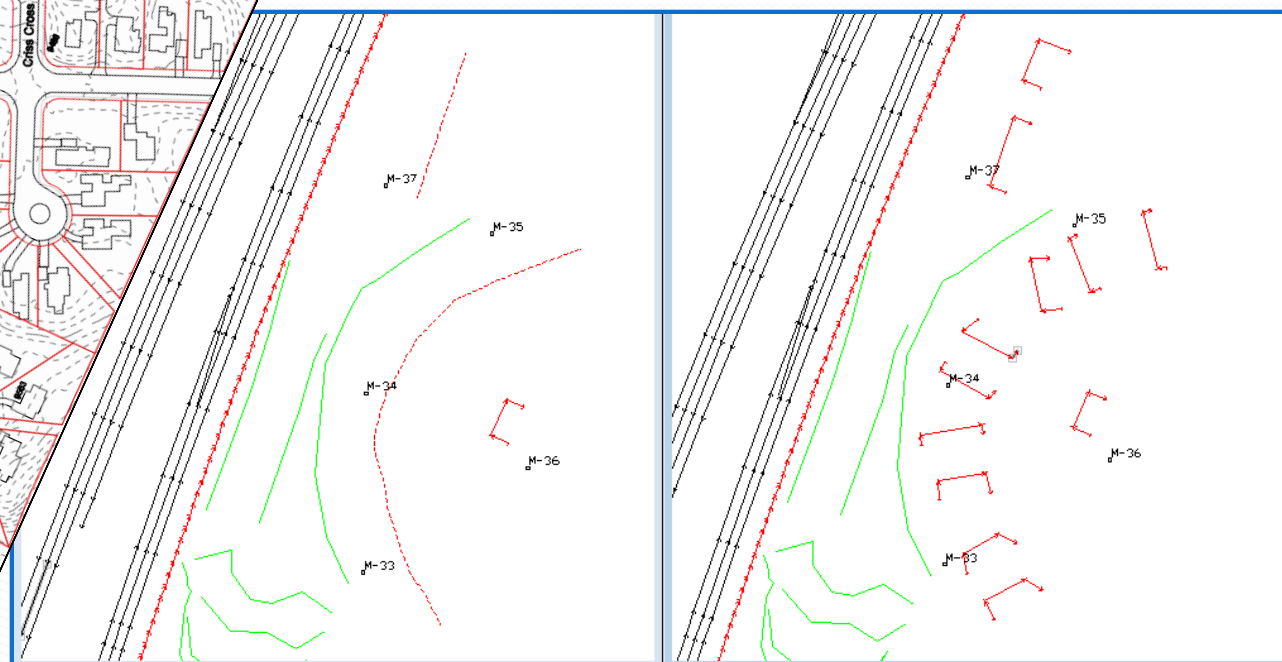


Figure from: Maryland SHA

Building rows vs. building barriers: comparisons to measurements

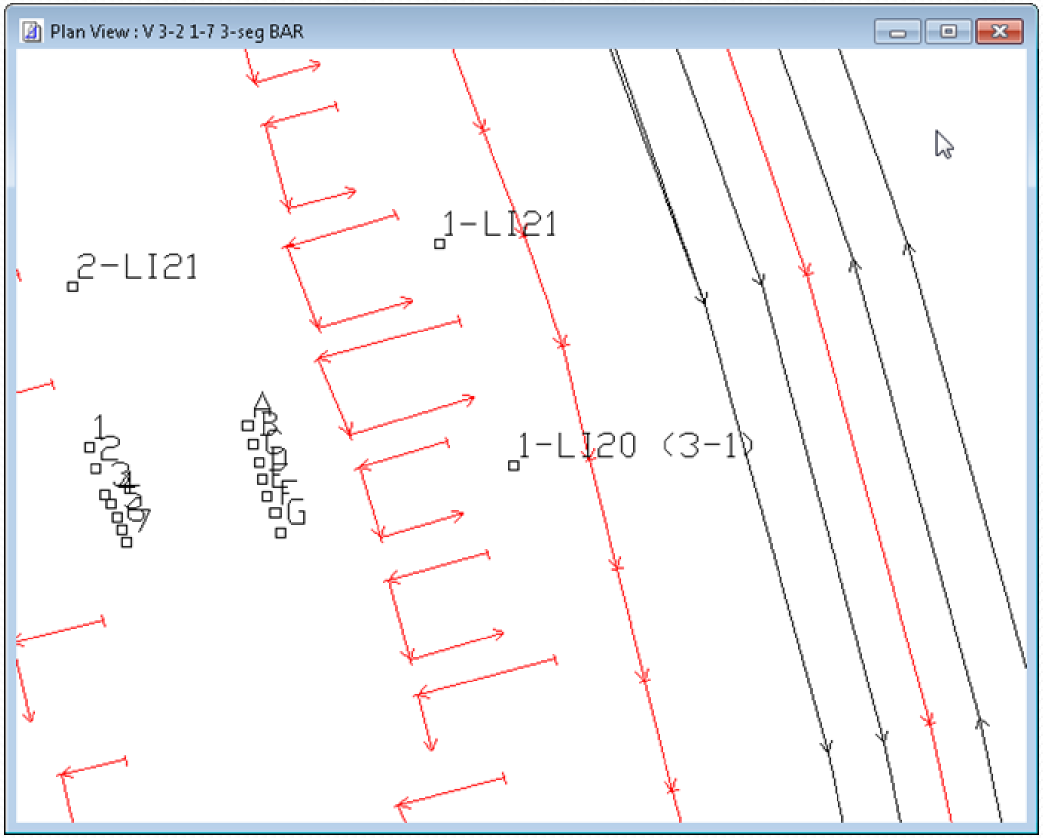
- Analyzed five projects with eight noise study areas
- Difficult to generalize; however:
  - Modeling houses as barriers generally gave lower levels than modeling as a building row, ranging from a slight increase up to a 5 dB decrease
  - Average difference across all cases was 1.5 dB lower
- When normalized to a reference microphone, building *barrier* approach provided better agreement with measurements than building *row* approach

Report is neutral on use of building barriers for houses vs. building rows

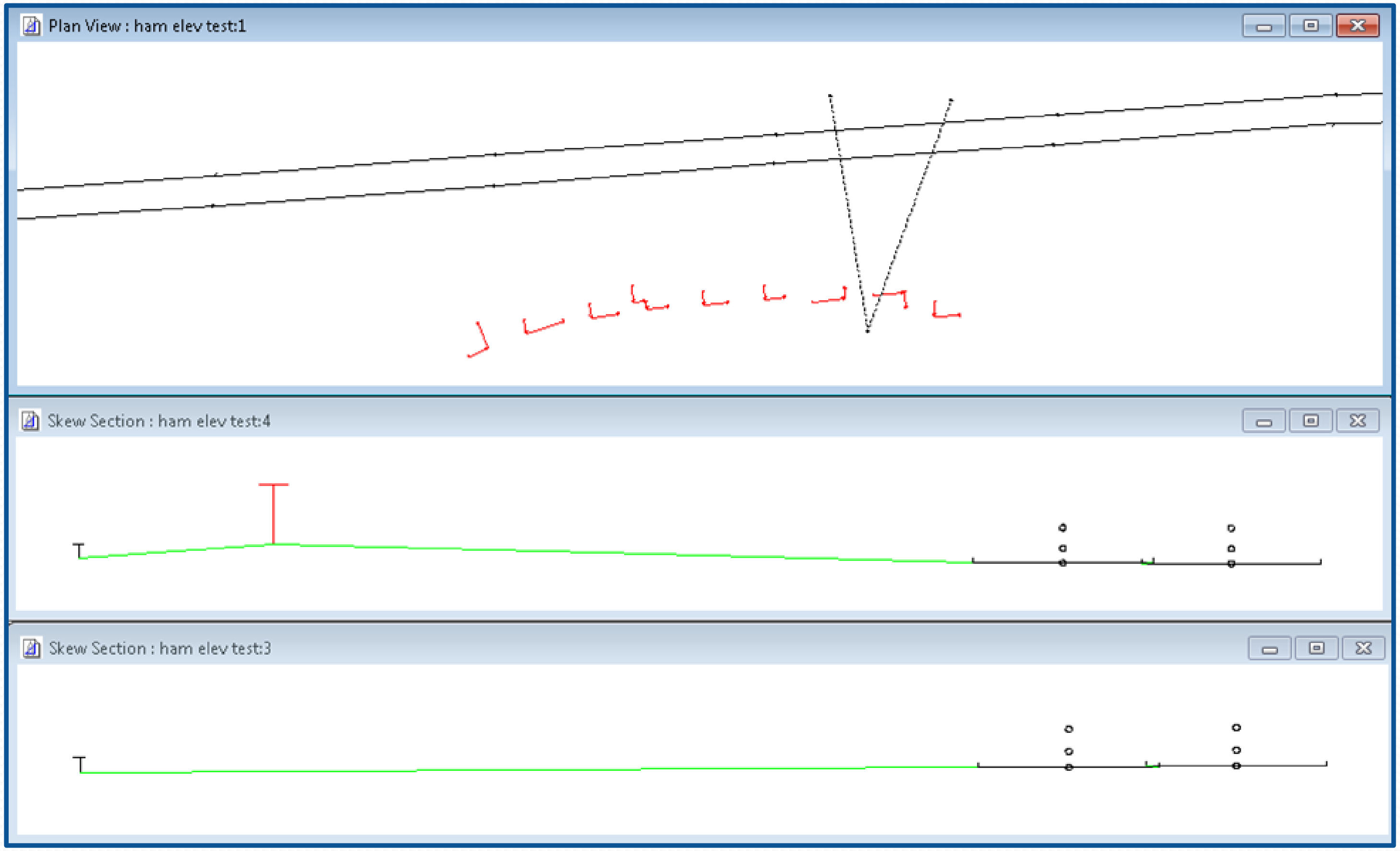
- Considerations
  - Method of modeling buildings as barriers
  - Receiver position behind building barriers
  - Elevation of terrain in gaps between building barriers
  - No modeling of reflections off sides of buildings
- If a State allows modeling of houses as building barriers, it should have well-defined procedures on how and when to do so, and apply them consistently

Receiver position behind building barriers can matter

- Depends on distance back, footprint of houses and percentage of blockage
- In the case shown:
  - Farther back – only 0.3 dB range
  - Up closer – 4 dB range



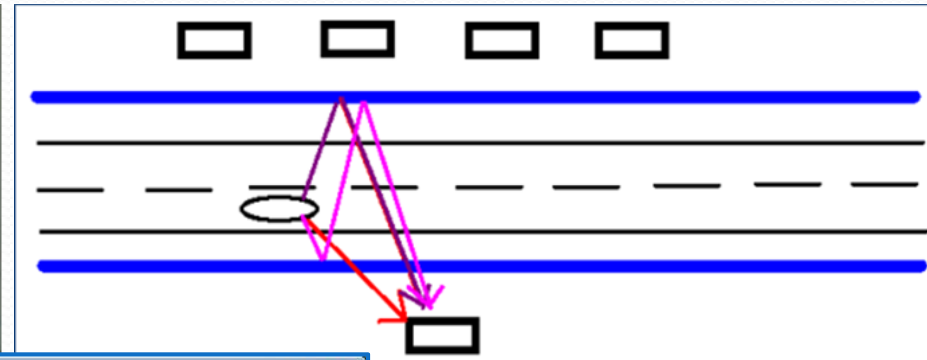
Building barriers do *not* model terrain in between buildings

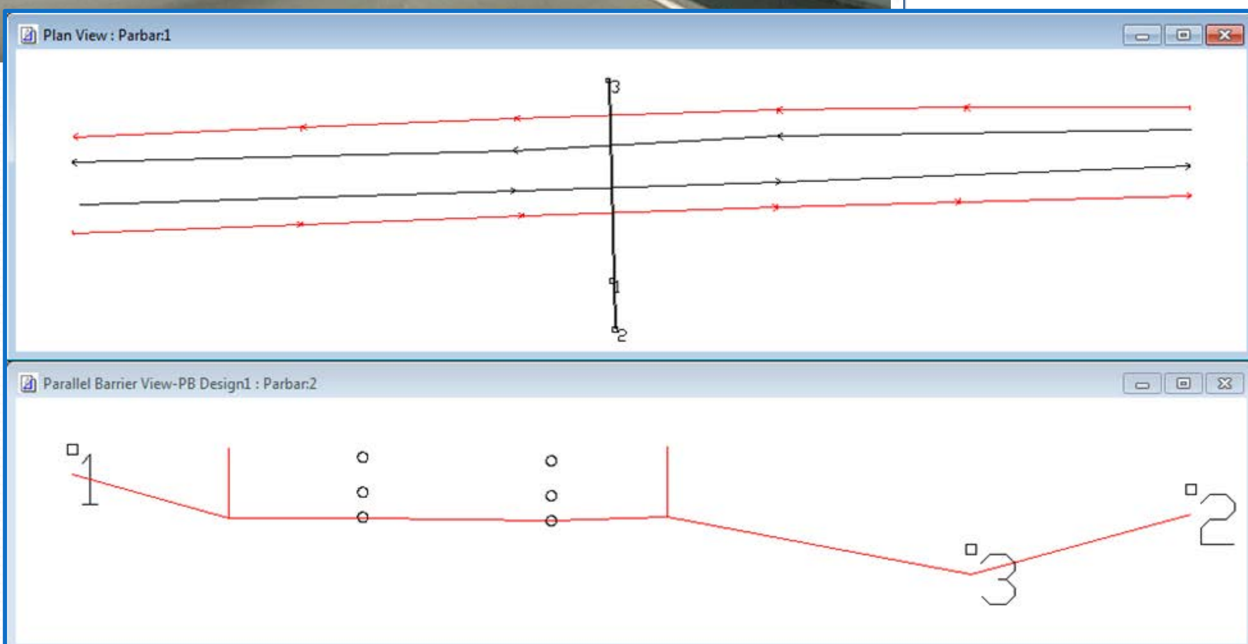


Building rows – final thoughts

- An important modeling object:
  - Impact assessment (how levels drop off away from road)
  - Possibly, noise barrier reasonableness assessment (number of residences benefitted by a noise barrier)
- Effects are not easy to generalize
- Over-modeling will not improve accuracy
- Not easily field-validated
  - Real world gaps are not spatially located by rows
  - Farther back from road, background noise and refractive meteorological effects – all unmodeled – affect measured sound levels

FHWA TNM Parallel Barriers module





Computed Increase in LAeq1h dB
4.6
4.2
0.0
2.7
2.2

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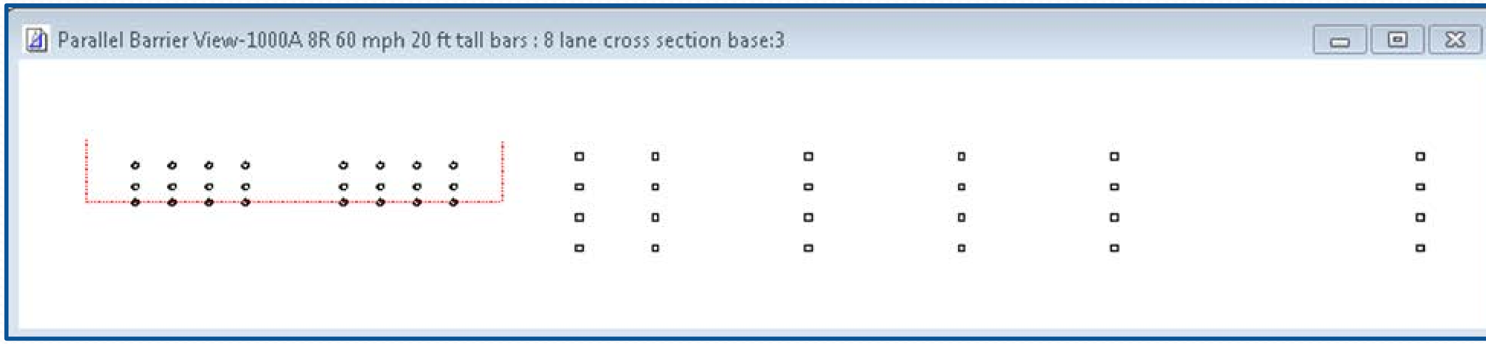
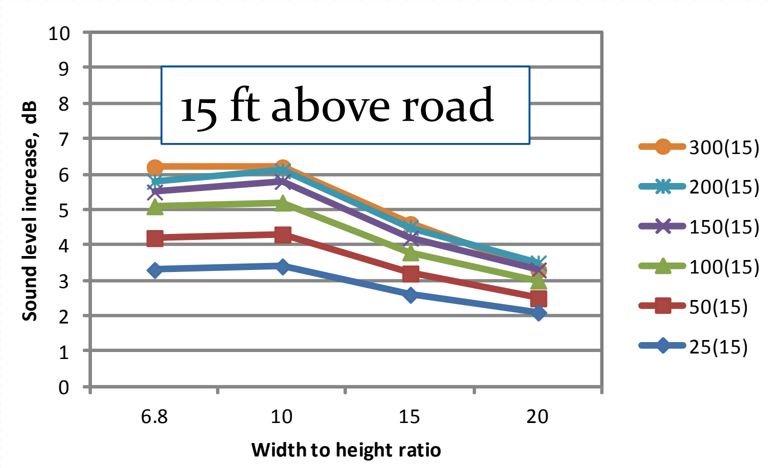
Width-to-height ratio (7:1 to 23:1)

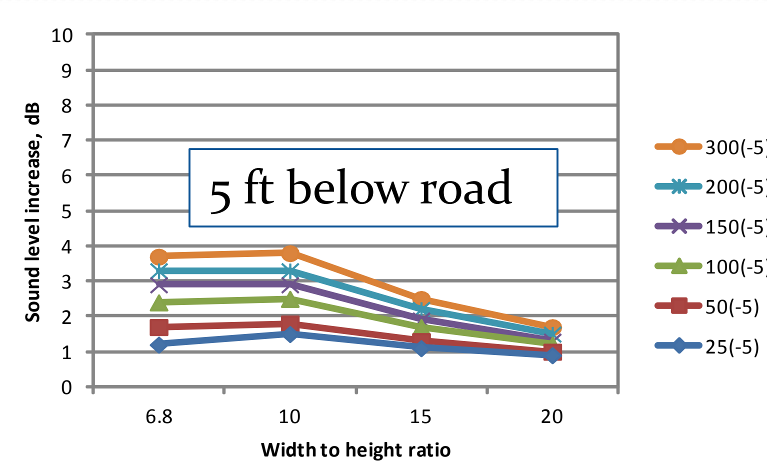


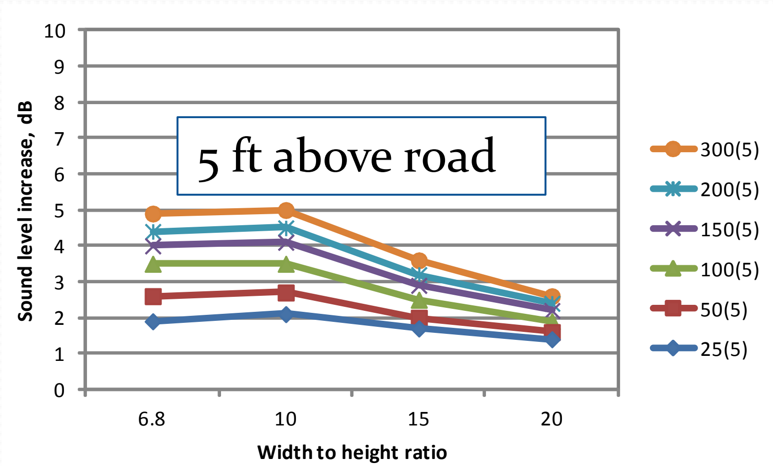
W:H Ratio	Autos	Heavy Trucks
10:1	1 to 6 dB	0 to 4 dB
20:1	0 to 3 dB	0 to 1 dB

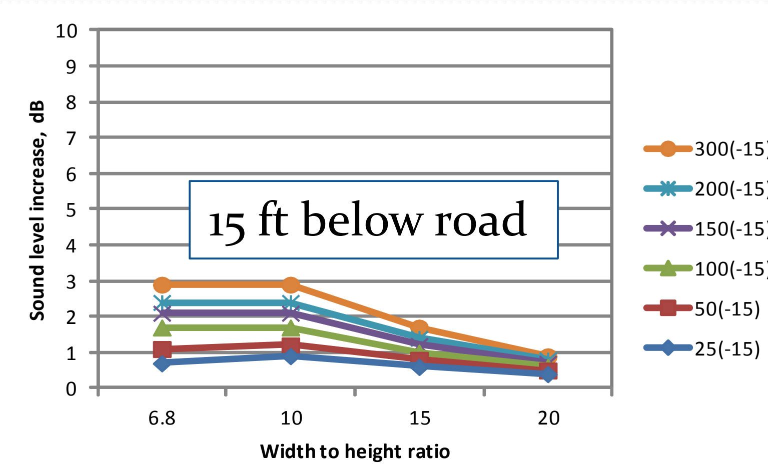
- Sound level increase is:
  - Greater for higher and more distant analysis locations
  - More sensitive to barrier height farther behind near wall

- **Sound level increases for varying W:H ratios for 20-ft high barriers for 8-lane cross-section**









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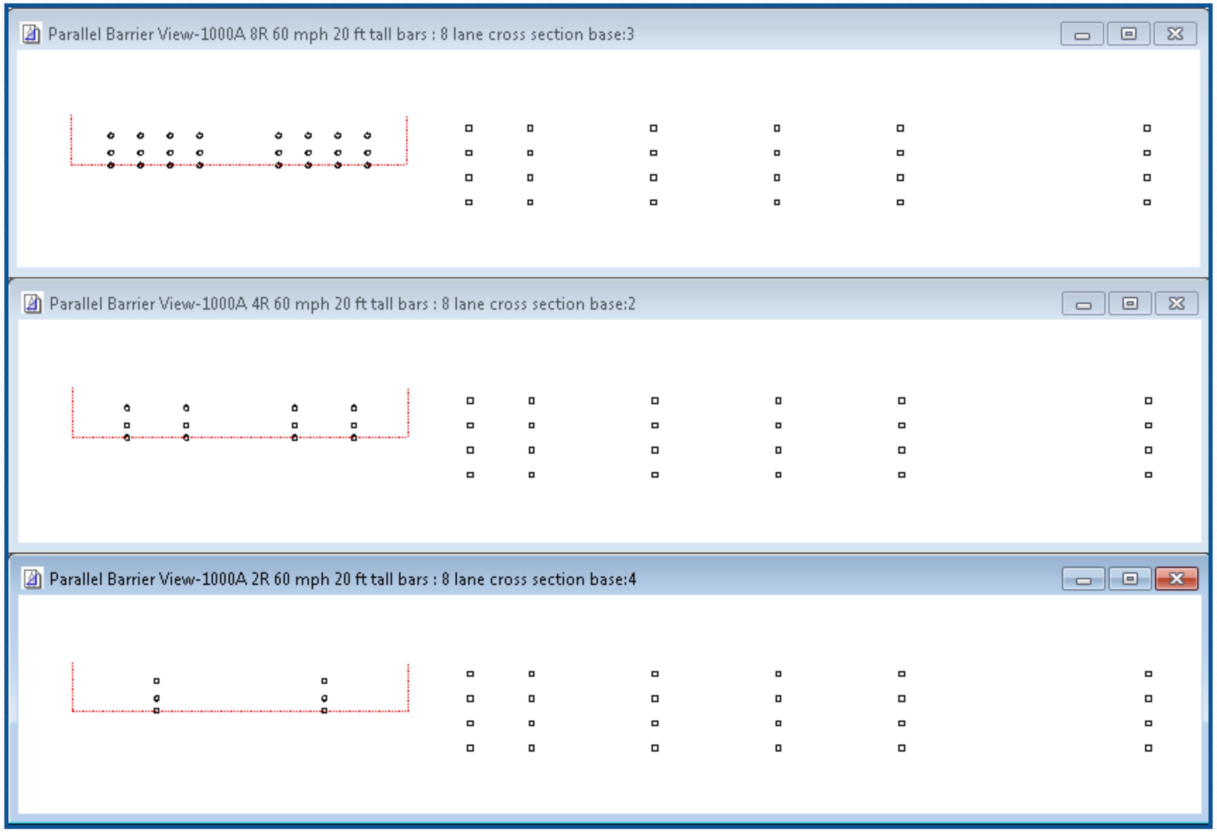
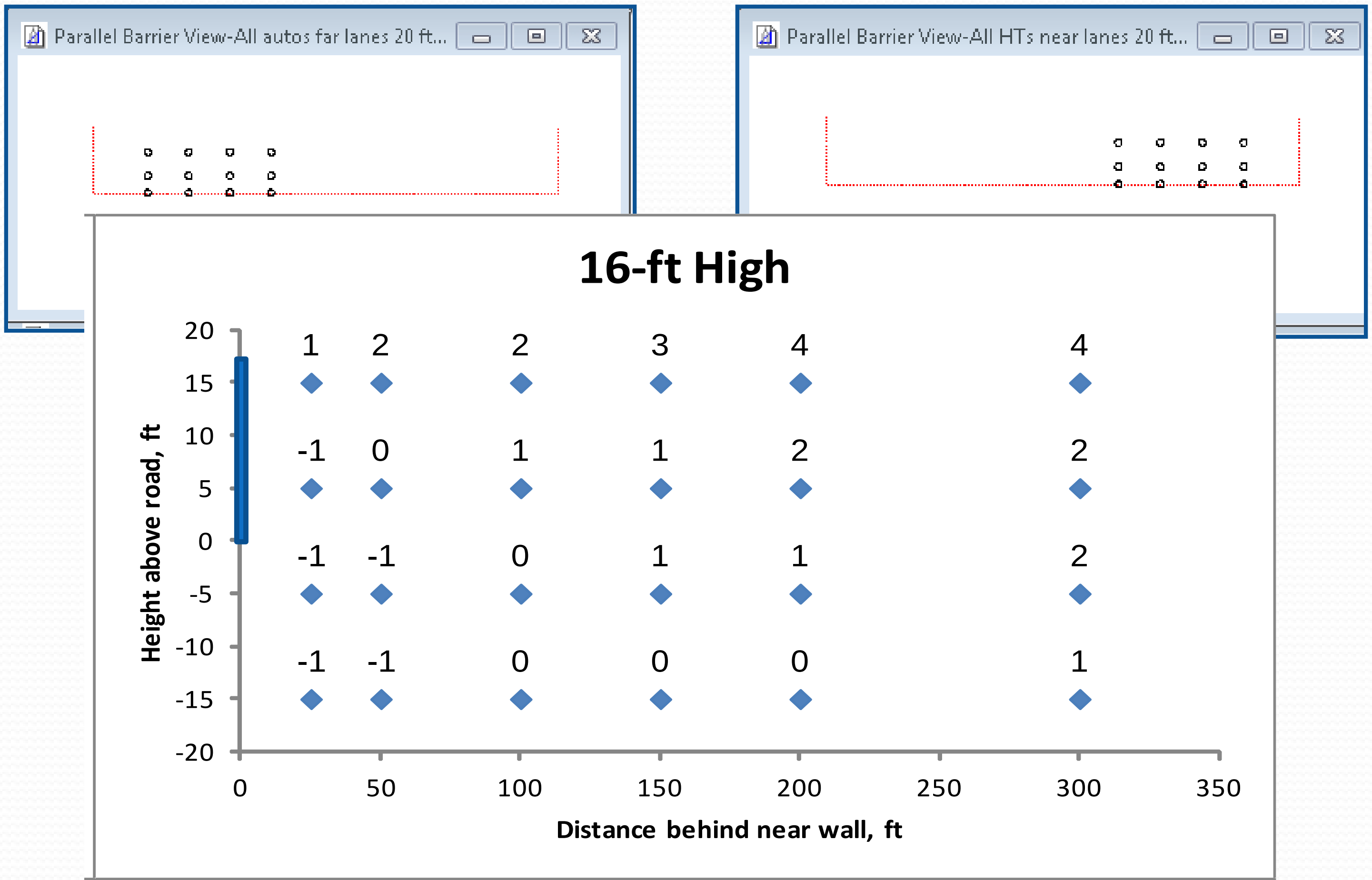
Number of FHWA TNM roadways used to represent travel lanes

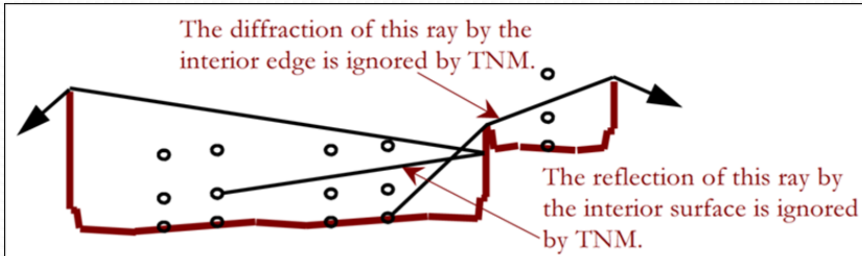
- Modeled an 8-lane cross section by:
  - 4, 2 and 1 TNM roadways per direction
  - Results within a half decibel, with a few exceptions of up to 1 dB



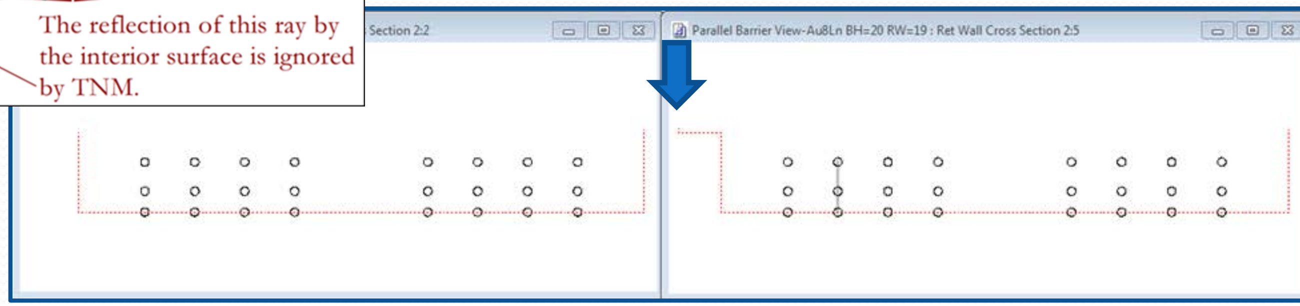
Source position: differences for 4 "far" roadways minus 4 "near" roadways



Internal vertical reflecting surface



From FHWA TNM FAQ



- Tested 20-ft high near wall and 19-ft high far wall
- Added 1-ft high noise barrier offset 10-ft to left of far wall
  - Sound level increases were lower – from 1 dB in close to over 4 dB farther back
- Modeling internal vertical reflecting or diffracting surfaces is not recommended

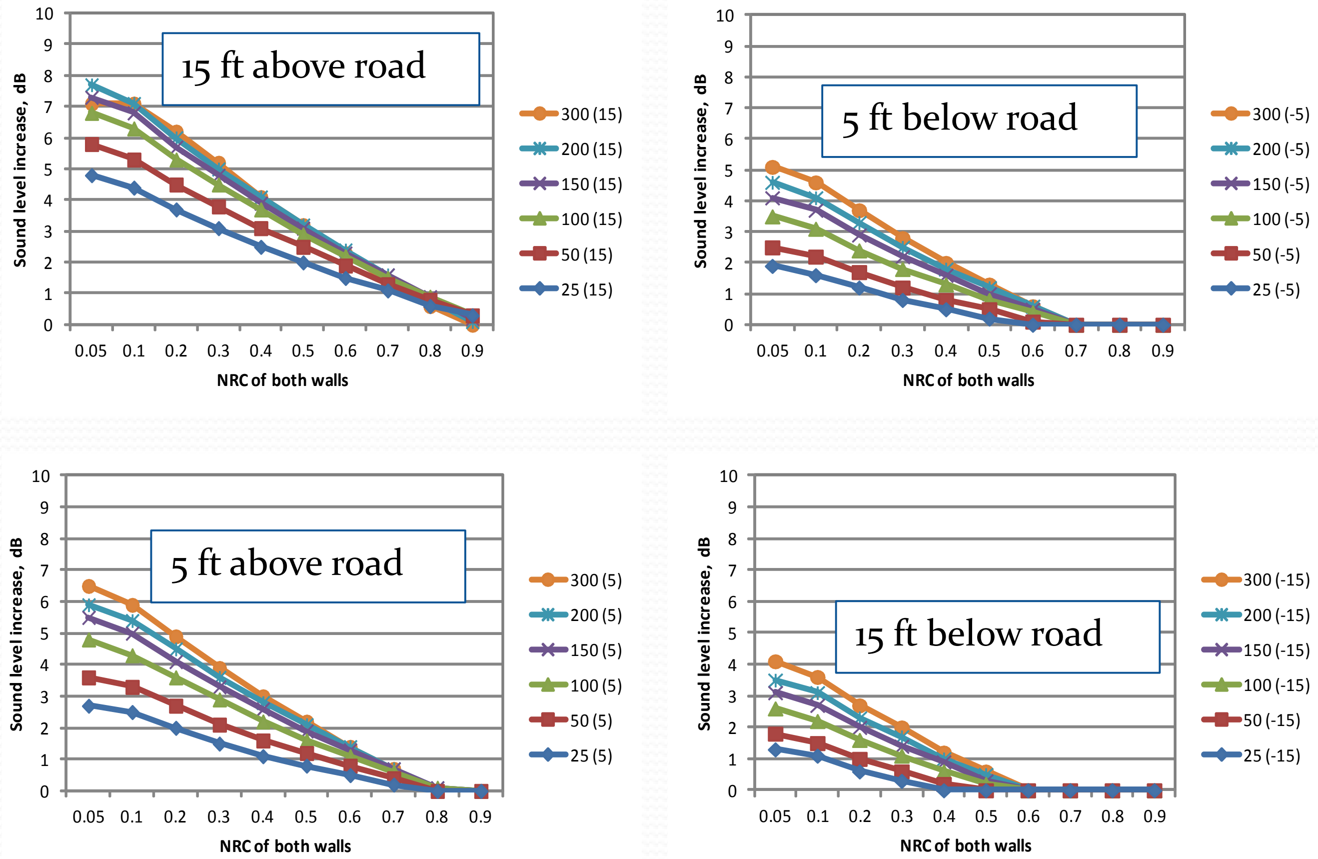
Changes in vehicle parameters

Computed sound level increases are:

- Not very sensitive to changes in vehicle mix:
  - +/- 5% change in percentage of autos changes results by only a few tenths of a decibel
- Independent of hourly volumes
  - Predicting a sound level *increase* in hourly L_{eq}, not L_{eq} itself
  - Same increase for 1 vehicle or 1,000 vehicles per hour
- Independent of speed

Noise reduction coefficient (NRC) of barrier surfaces (example of 8:1 W:H)

- Roughly linear effect
- Function of analysis location distance and height
- NRC = 0.70-0.80 generally reduces sound level increase to under 1 dB



Parallel barriers – final thoughts

- Sound level increases due to multiple reflections can substantially reduce single wall noise reduction
- FHWA TNM's Parallel Barriers module computes generalized effects
  - Two-dimensional look at a 3-D phenomenon
  - Generally insensitive to source position and vehicle parameters
  - Computes diffraction attenuation only at 500 Hz, thus use of NRC cannot test specific sound-absorbing products
- Not for computing single-wall reflections – use image roadways in main part of TNM (or wait for FHWA TNM 3.0)
- Be wary of "0.0" dB sound level increases in reflective cases for analysis locations below roadway elevation

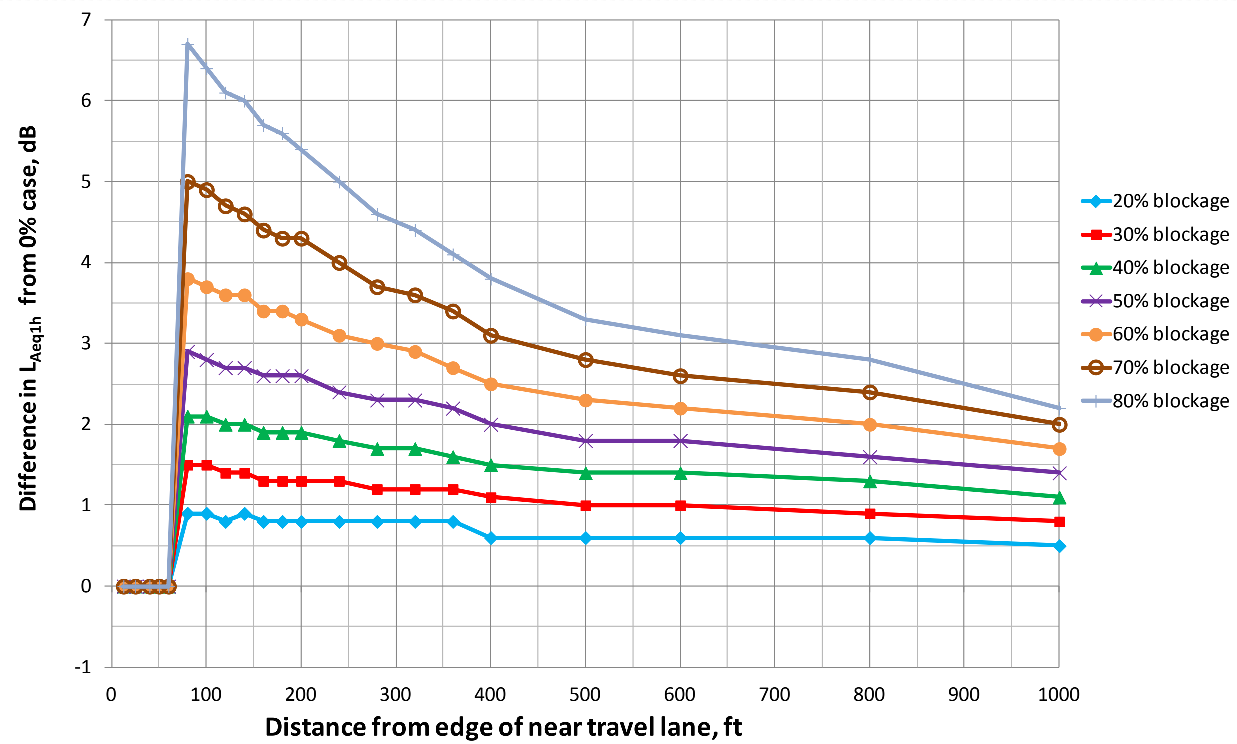
Acknowledgements

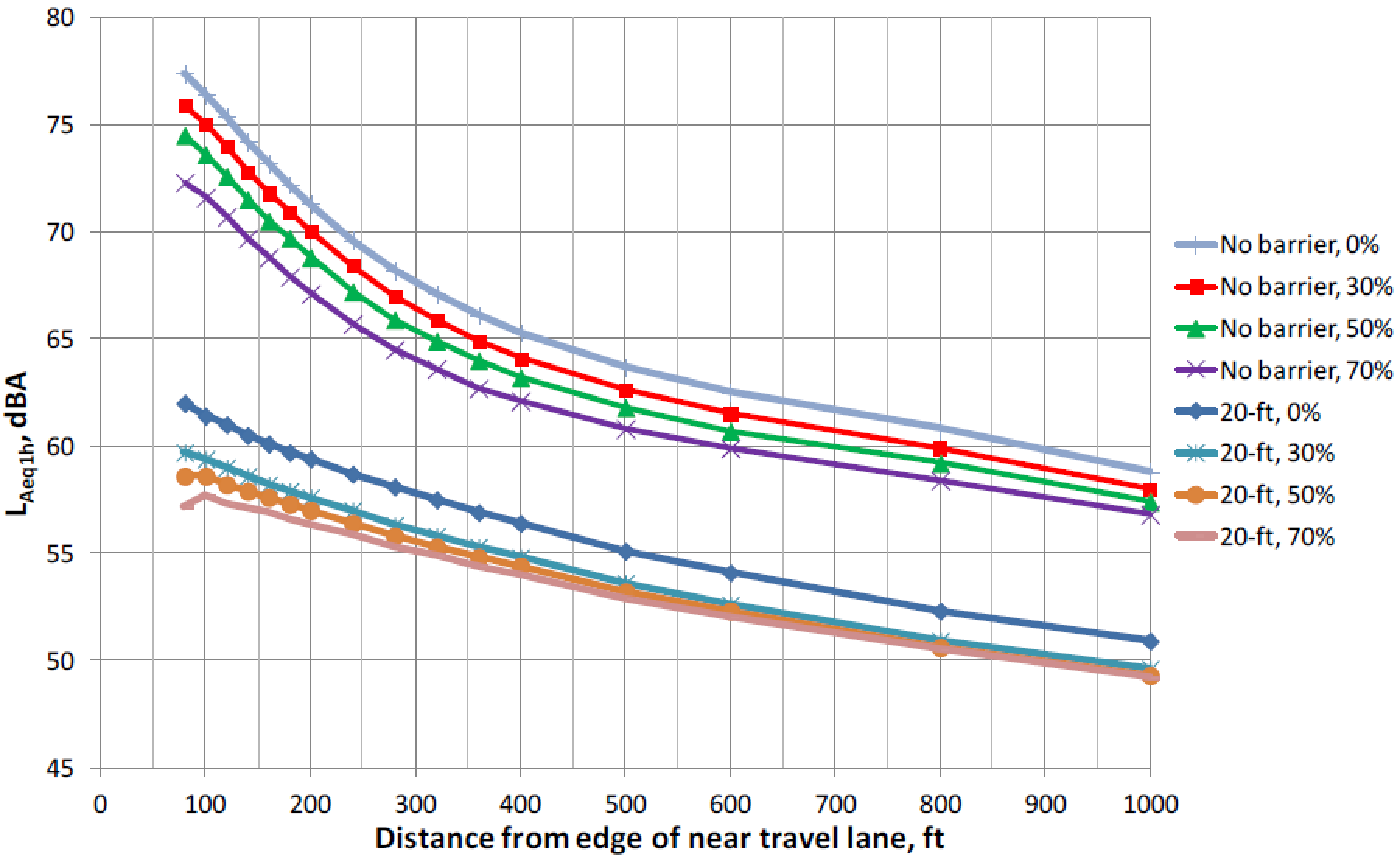
- Colleagues who responded to the survey and provided reports and TNM runs
- NCHRP 25-34 Project Panel and Senior Program Officer Lori Sundstrom
- Research team, with Chris Menge of HMMH as PI

Questions?

The following are not being used….

- Same for a 30-ft high building row





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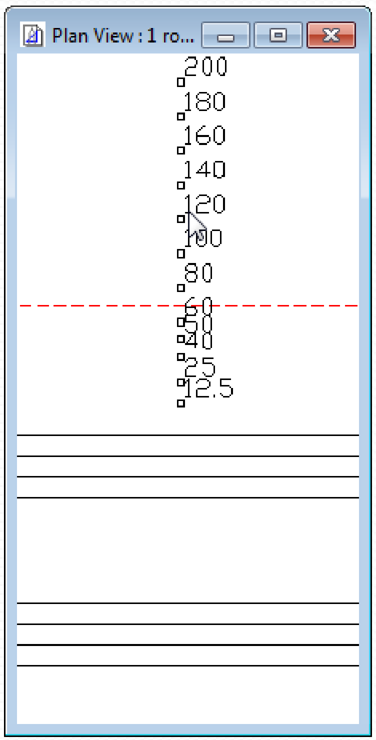
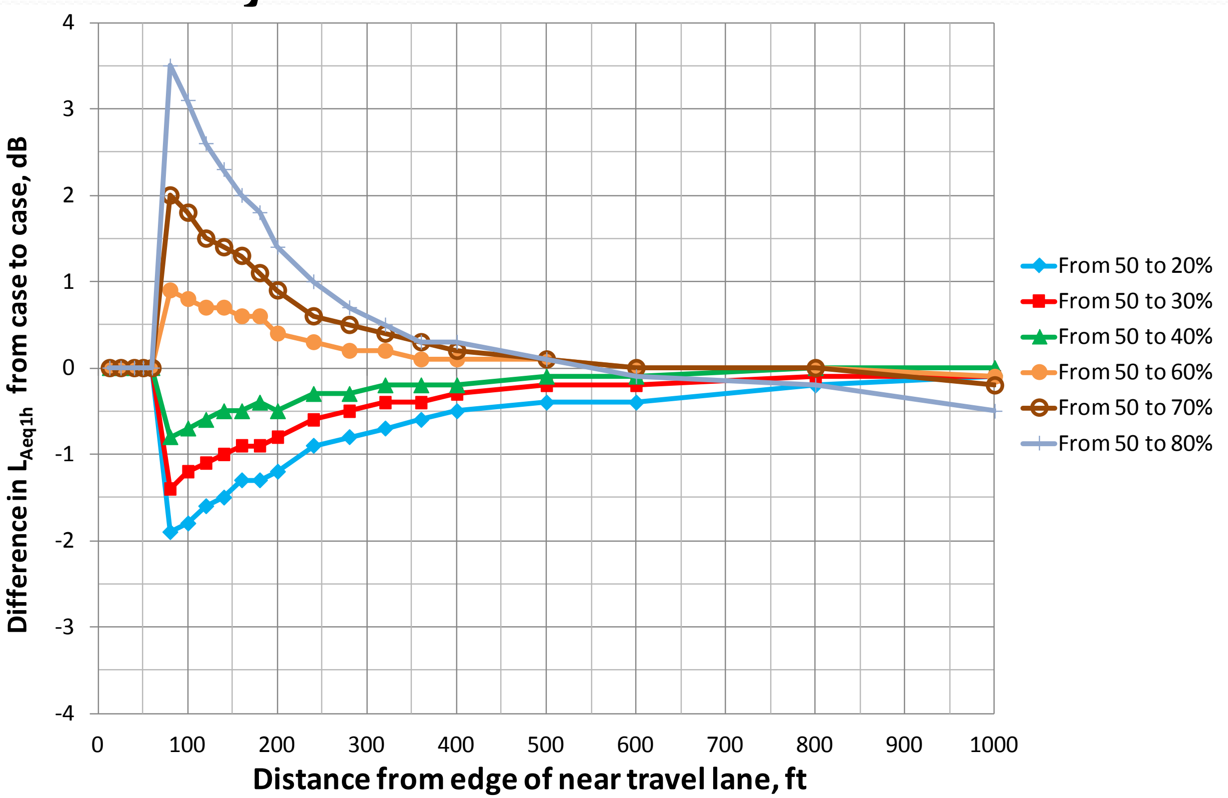
Sensitivity to building row height

- For 20% to 40% blockage: change in height of 5 ft causes little change in noise reduction regardless of receiver distance behind building row
- For higher building percentages: change in noise reduction depends on distance behind building row
  - Maximum difference is less than 2 dB for 5-ft height change from 20 to 25 ft and from 25 to 30 ft

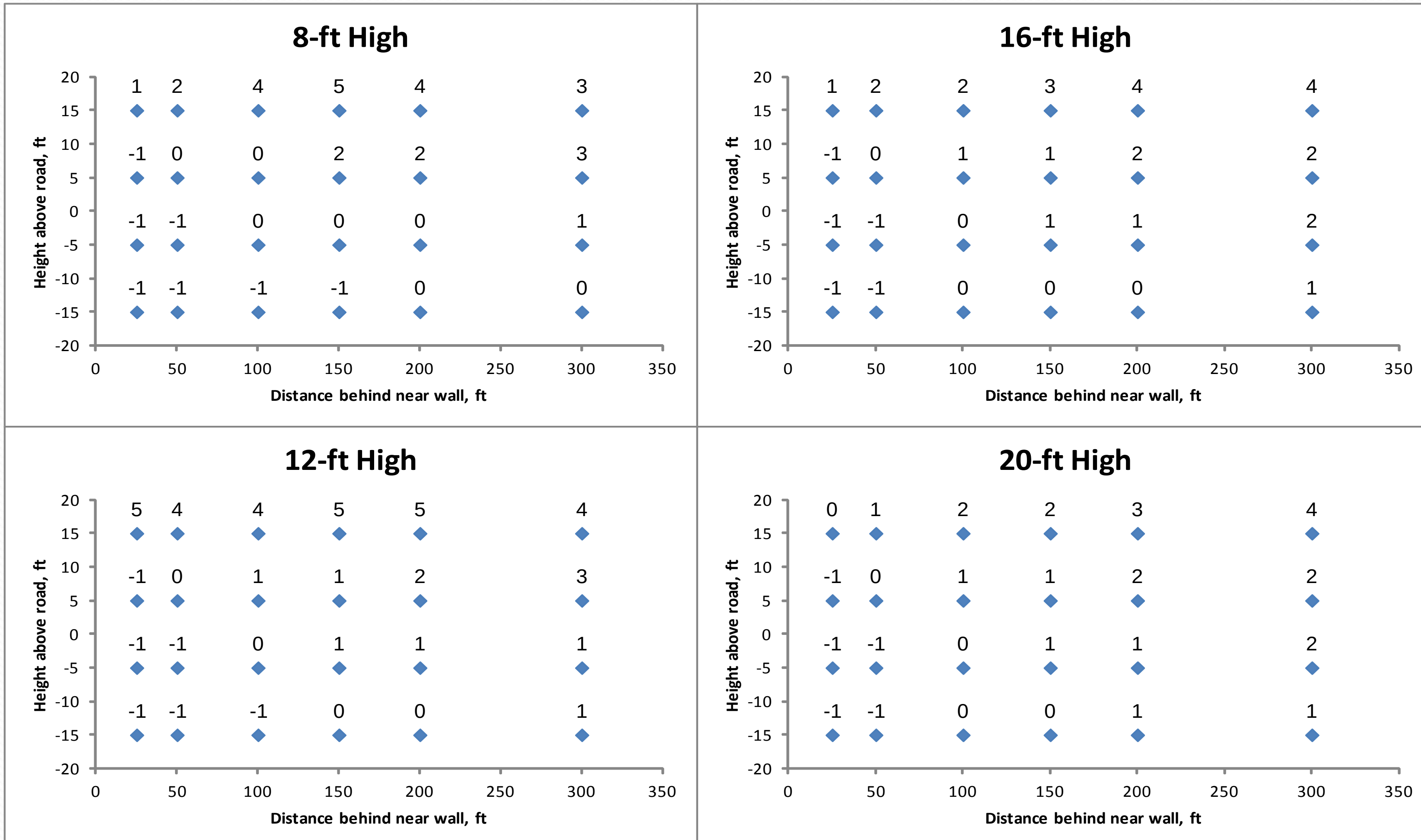
Sensitivity to building percentage

- **Differences in noise reduction compared to 50% blockage for one 20-ft high building row 70 ft from edge of 8-lane roadway**





- Difference in sound level increases for autos, 4 “near” roadways minus 4 “far” roadways



- Sound absorption on the far wall only is also very effective for this cross-section
- In contrast, absorption on just the near wall is far less effective than absorption on the far wall or both walls.
- The results suggest the importance of the first-order far wall reflections on the total sound level at a receiver,

Factors considered

- Building height and blockage percentage
- Multiple rows
- Effect of on calculated noise reduction from noise barrier along the roadway edge
- Noise reduction for building rows perpendicular to the roadway
- Use of TNM Building Row or model individual buildings as TNM Barriers

Studied factors

- Barriers' width-to-height ratio and receiver position behind the barrier
- Number of TNM roadways used to represent the travel lanes and their position
- Differences in top elevations of the two barriers
- Internal vertical reflecting surfaces
- Vehicle mix (e.g., autos only vs. heavy trucks only)
- Hourly volumes and speeds of vehicles
- Noise reduction coefficient of barrier surfaces

Building Row Considerations

- Over-modeling will not improve accuracy
  - 1/3 octave band calculations only for most effective building row
  - Add 1.5 dB attenuation per 1/3 octave band for each additional row
- Yet, an important modeling object:
  - Impact assessment (how levels drop off away from road)
  - Possibly, noise barrier reasonableness assessment (number of residences benefitted by a noise barrier)
- Not easily field-validated because building rows do not spatially locate the real-world gaps through which sound passes
- Additionally, as one moves deeper into a community, background noise and refractive meteorological effects – all unmodeled – affect measured sound levels

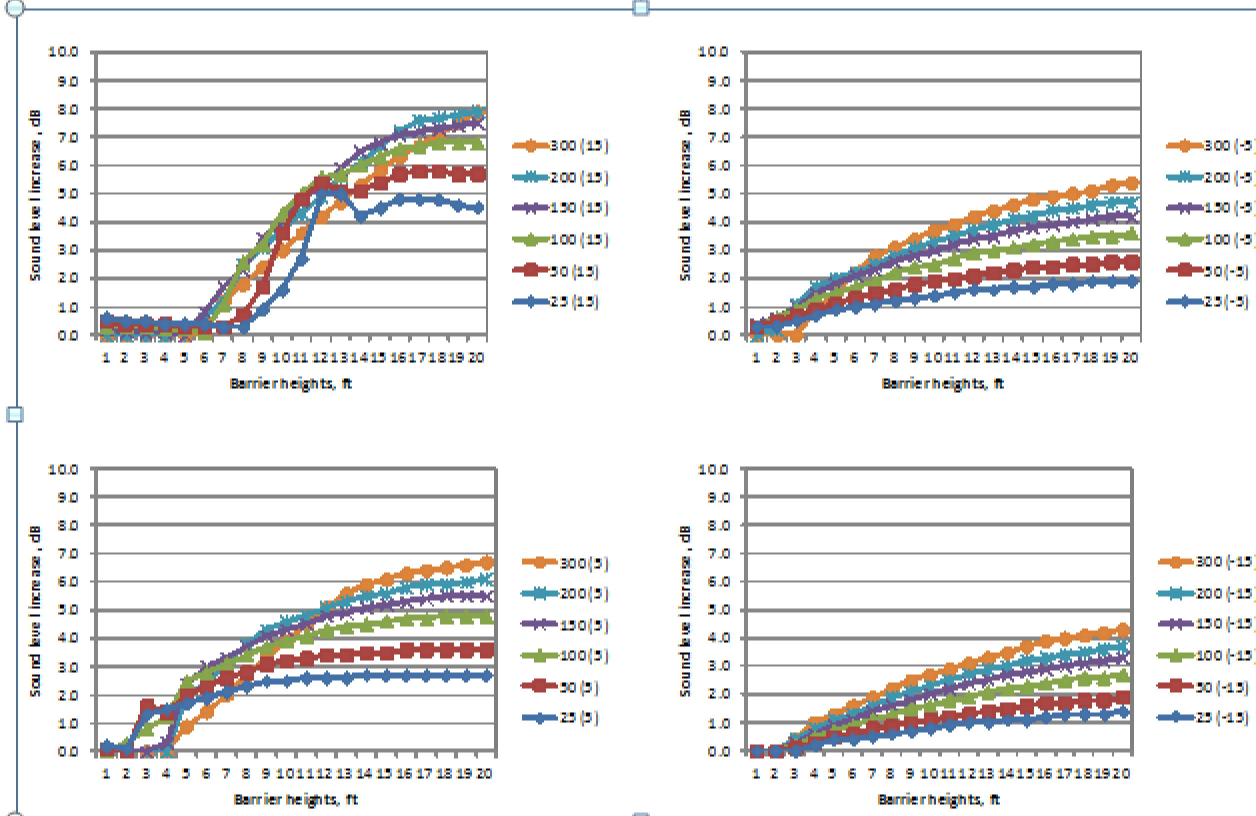


Figure 3. Sound level increases for 1,000 Autos/hr/lane, 8-roadway cross section, varying barrier height, and NRC of 0.05 for both walls.

The parallel barrier sound level increase for autos was equal to or greater than that for heights over all of the receiver positions and all of the tested barrier heights. The greatest differences were in the 6-15 ft