NCHRP Project 25-34 / Report 791 “Supplemental Guidance on the Application of FHWA’s Traffic Noise Model (TNM)”

Overview and Results for Topography, Ground Zones, Tree Zones and Atmospherics

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Objectives of Research Project 25-34

- Supplement existing guidance for using TNM by identifying Best Practices to accurately, consistently, and efficiently model 9 special highway noise scenarios
- Determine the sensitivity and accuracy of the methods to model 5 other special scenarios
- Synthesize the state of practice for analyzing the effects of (1) wind direction and (2) temperature on sound propagation

Research Topics of NCHRP Project 25-34

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1. Structure Reflected Noise and Expansion Joint Noise
2. Signalized Interchanges, Intersections and Roundabouts
3. Area Sources
4. Median Barriers
5. Multi-lane Highways
6. Building Rows
7. Topography
8. Ground Zones
9. Tree Zones
10. Wind and Temperature Gradients
11. Parallel Barriers
12. Tunnel Openings

The 7-Step Process

1. Determine existence of useful information
2. Compile modeling techniques & validation data
3. Identify candidate modeling techniques
4. Prepare interim technical report & receive comments
5. Process existing validation data and/or collect additional data
6. Test and evaluate modeling techniques and identify Best Practices
7. Prepare final technical report

Topography

- **Sensitivity analysis performed for several TNM objects and topography-related concerns:**
  - Outside edge of pavement – horizontal precision
  - Required Terrain Lines along elevated roadways
  - Minimum Terrain Line spacing
  - Terrain Lines: vertical precision
  - Barrier tops: vertical precision
  - Flat-top berms

Topography Best Practices

- **Outside edge of pavement – horizontal precision**
  - "Shoulder" roadway is recommended, carefully following edge of pavement
- **Required Terrain Lines along elevated roadways**
  - Roads on fill - located at toe of slope
  - Roads on structure: located at ground level just off edge of structure

Topography Best Practices

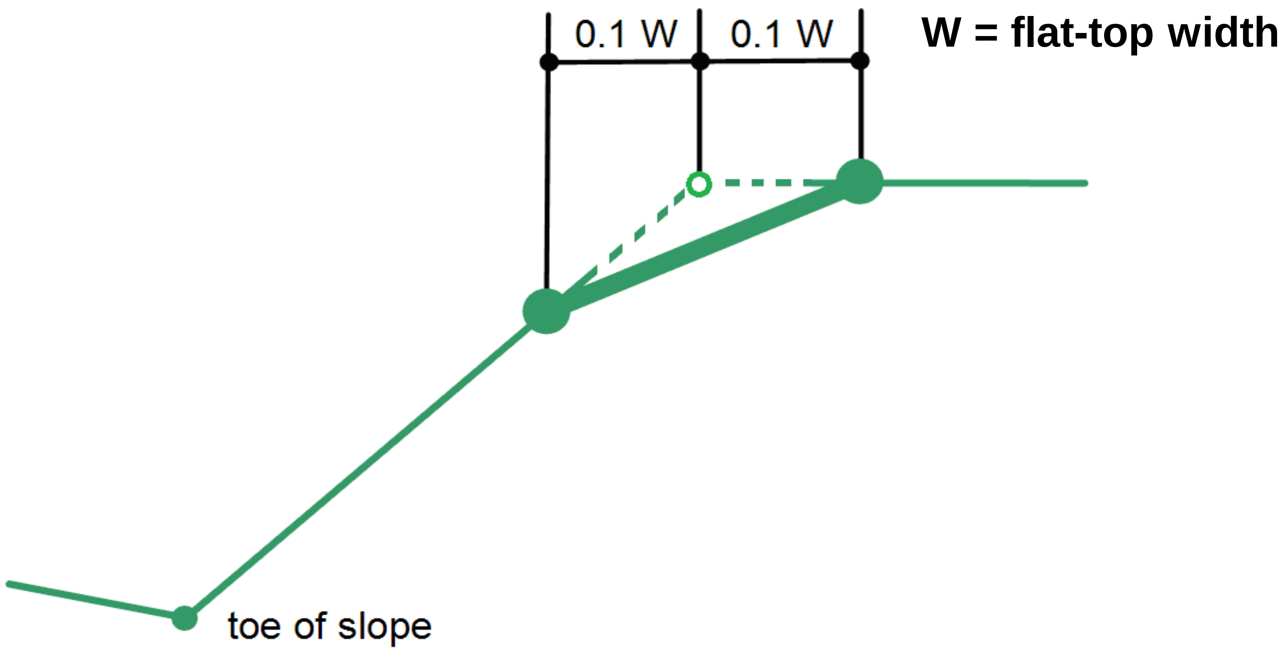
- **Minimum Terrain Line spacing**
  - Never closer spacing than 4 feet, to avoid computational errors
  - Do not duplicate triangular regions produced by digital terrain models
- **Terrain Lines: vertical precision**
  - Keep precision with plus/minus one foot

Topography Best Practices

- **Barrier tops: vertical precision**
  - Sound levels can be very sensitive to barrier top elevation
  - In final barrier-design studies
    - – Carefully specify barrier top elevation for accurate future Leqs
    - – Also, carefully determine future ground elevation for accurate insertion loss calculations

Topography Best Practices

- **Flat-top berms**
  - For greatest accuracy: "Round-off" the edges of flat-top berms



Ground Zones

- **Sensitivity analysis performed and guidance given for aspects of Ground Zones:**
  - Size and location of Ground Zones
  - Expanded list of ground types
  - Bodies of water

Ground Zones Best Practices

- **General size:**
  - Not needed for small patches (e.g. sidewalks and driveways)
  - 20% of source-to-receiver distance for > 1 dBA
- **Coordinate precision:**
  - High precision not needed in horizontal plane
  - 30-foot change in ground zone width may cause 1 dB change
- **Location:**
  - Needed near middle of propagation path where ground zone covers >10 to 20% of distance along path

Ground Zones Best Practices

- **Expanded set of Effective Flow Resistivity (EFR) values in cgs Rayls**
  - Improved match between measured and computed
  - Mostly derived from literature

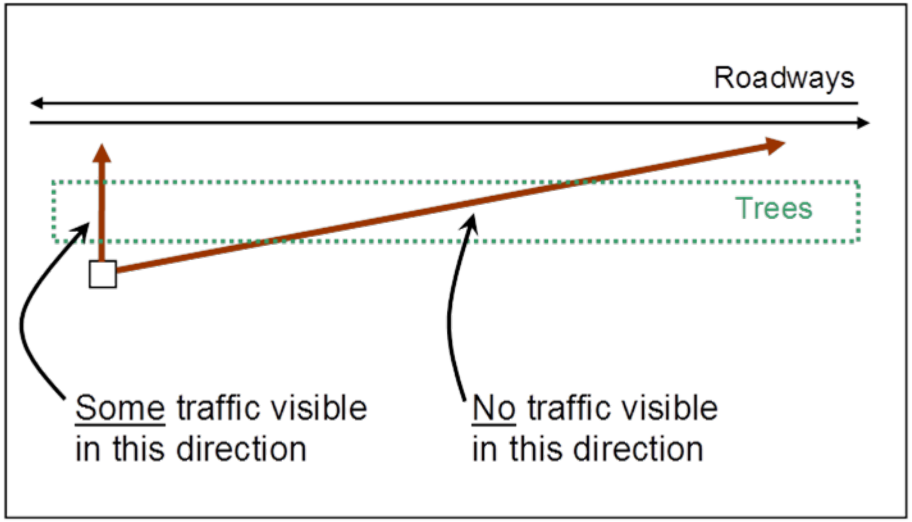
Ground Type	Avg EFR	Ground Type	Avg EFR
Powder snow*	10	Dirt	550
Dry snow	20	Sandy Silt	1,650
Sugar snow	38	Limestone Chips	2,750
Granular snow*	40	Old Dirt Road	3,000
Forest floor	50	Hard Soil*	5,000
Lawn (11.9 to 16.5% moisture content)	58	Hard-packed Dirt	5,800
Field (meadow)*	150	Exposed Dirt	6,000
Lawn (root layer in loamy sand)	188	Asphalt (rain packed)	10,000
Lawn (rough pasture)	212	Water	10,000
Lawn*	300	Quarry Dust	12,500
Lawn (various)	375	Pavement and Water*	20,000
Soil	278	Asphalt (old, sealed with dust)	27,500
Sand	473	Concrete	65,000
Loose Soil*	500	Concrete (painted)	200,000
Roadside Dirt	550	* TNM's built-in EFR values	

Ground Zones Best Practices

- **Use of Expanded EFR values in TNM**
  - Designate "custom" ground zones with appropriate EFR value
  - Default ground type from TNM's pull-down list, overlaid with zones of custom EFR values
- **Bodies of water**
  - Include if water is at middle of propagation path and is more than 10 to 20% of the source-to-receiver distance
  - Include terrain lines and top and bottom of bank
- **Distances beyond 500 feet – be aware:**
  - Soft ground: TNM under-predicts
  - Hard ground: TNM over-predicts

Tree Zones

- **Sensitivity analysis performed and guidance given for aspects of Tree Zones:**
  - Consider modeling narrow tree zones (parallel to roadway) that are 50 to 100 feet deep
    - – Reduce needed barrier length & cost
  - No overlaid ground zone needed with tree zones
  - Consider visibility through tree zone using Fang & Linn equation



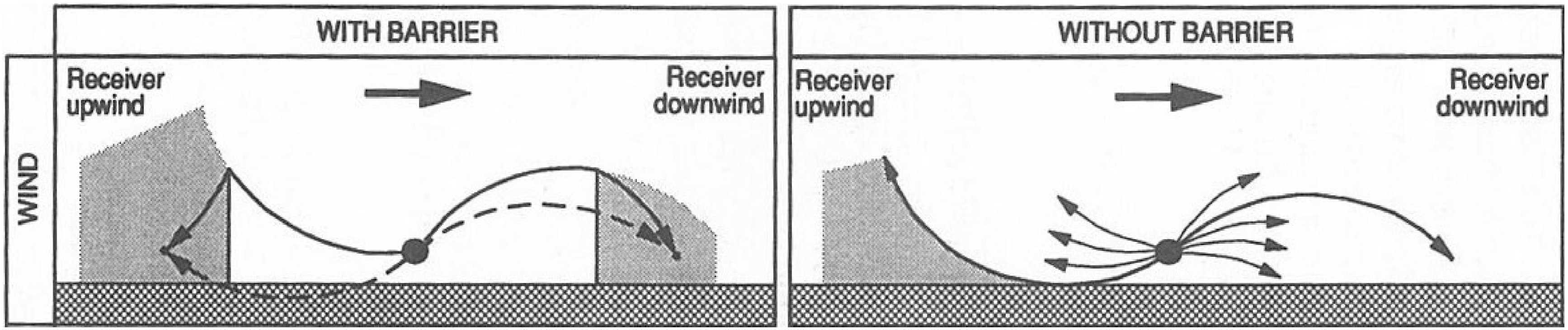
Tree Zones Best Practices
Visibility through Trees

- **Vegetation attenuation (Fang and Linn):**

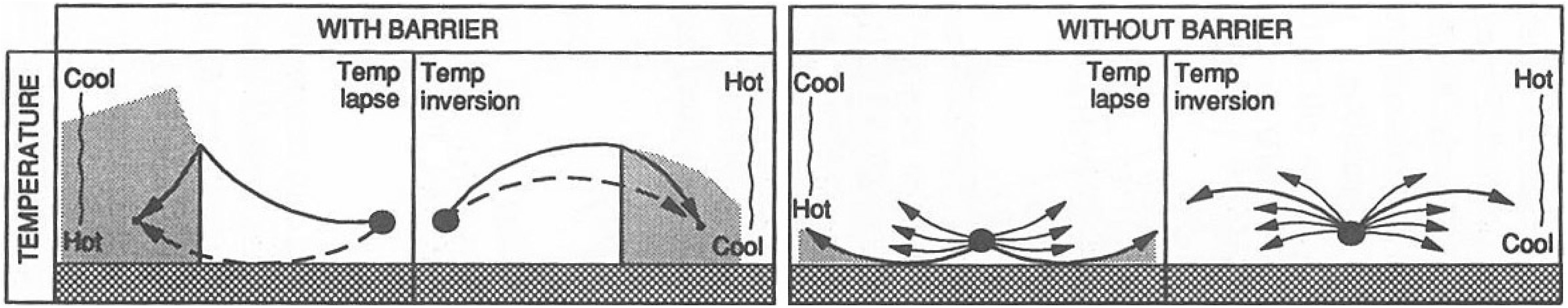
$$\frac{A_{Veg}}{dBA/50ft} = \left[4.08 - 2.87\, log\left(\frac{D_{Vis}}{1ft}\right) + 2.32 log\left(\frac{L_{VegProp}}{1ft}\right)\right]$$

- **Compare A_{veg} in dBA / 50 feet to TNM's tree attenuation (compute TNM with and without tree zones)**
  - If $A_{veg} \approx A_{tree,TNM} \approx 0 \rightarrow$ tree zone not needed
  - If $A_{veg} \approx A_{tree,TNM}$, and both non-zero $\rightarrow$ TNM tree zone is computing well enough
  - If $A_{veg} \neq A_{tree,TNM}$, and both non-zero $\rightarrow$ compare values and choose appropriate tree attenuation

Wind and Temperature Gradients



Sound Propagation under Downwind and Upwind Conditions



Sound Propagation under Temperature Inversion and Lapse

Wind and Temperature Gradients

- **Extensive literature review**
  - Very few quantitative studies of atmospheric effects on highway noise
  - Among those, limited data universally applicable
- **Nord2000 propagation model incorporates wind and temperature gradient effects**
  - Atmospheric effects validated through measurements

Wind and Temperature Gradients

- SoundPLAN® prediction program incorporates Nord2000 and TNM implementations
- Nord2000 and TNM show comparable results under calm, neutral atmospheric conditions
- Nord2000 run under a wide range of scenarios to determine atmospheric effects

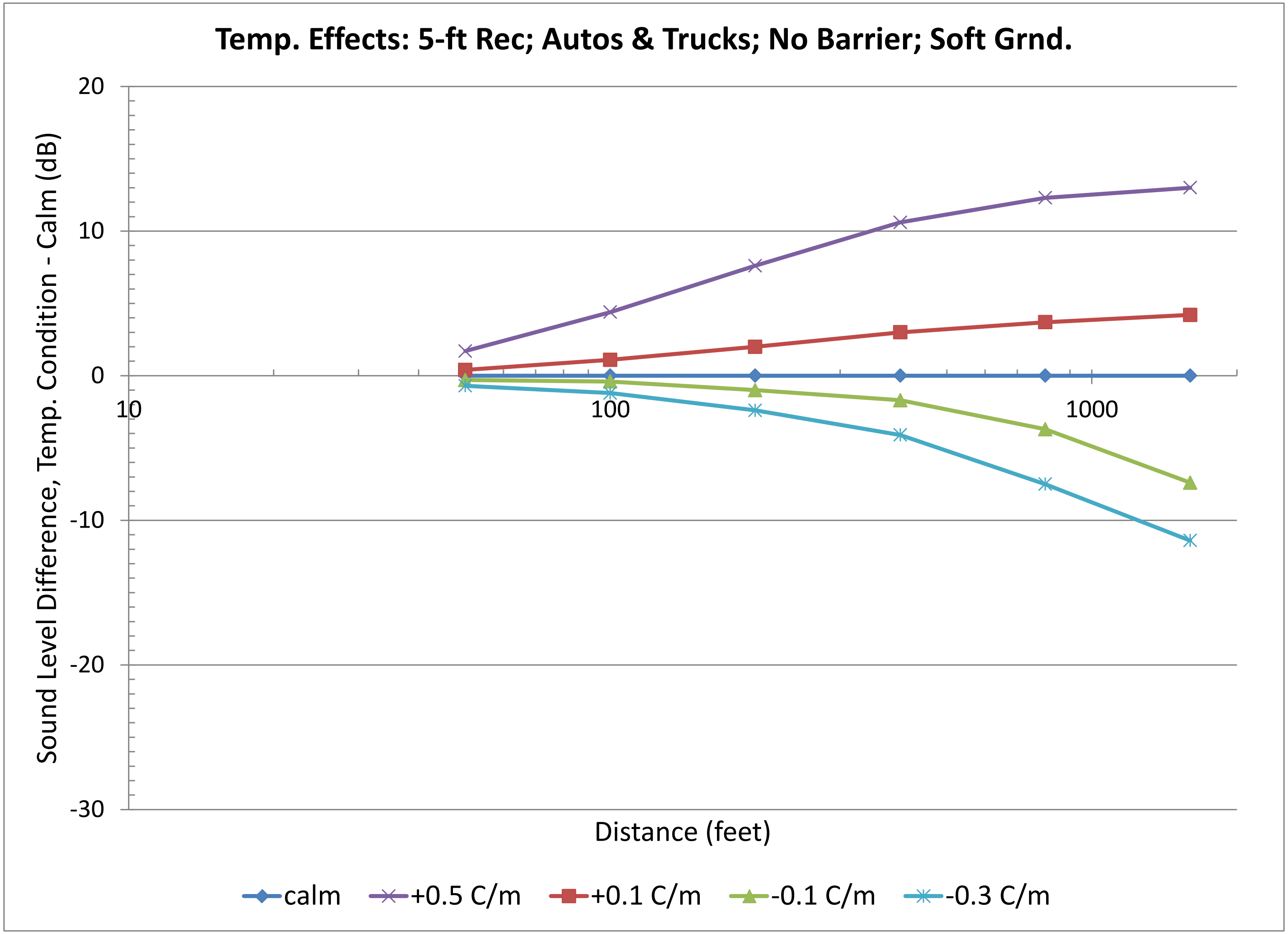
Wind and Temperature Gradients Variables Run with Nord2000

- **Typical 4-lane highway geometry**
  - Autos/Truck mix and Autos only
  - Receiver distances: 50, 100, 200, 400, 800, 1600 ft
  - Receiver heights: 5 ft and 15 ft
  - Soft ground and hard ground
  - No barrier and 17-ft high barrier
- **Upwind and downwind:**
  - Calm, 2.5 m/s (5.6 mph), 5 m/s (11.2 mph)
- **Temperature inversion: +0.1 ºC/m, +0.5 ºC/m**
- **Temperature lapse: -0.1 ºC/m, -0.3 ºC/m**

Wind and Temperature Gradients Example Results Table

Automobiles and Trucks, Hard Ground, With Noise Barrier									
Receiver Distance (ft)	Receiver Height (ft)	Sound Level Difference (dB)							
		Wind Condition				Temperature Condition			
		Moderate Upwind (2.5 m/s)	Strong Upwind (5 m/s)	Moderate Downwind (2.5 m/s)	Strong Downwind (5 m/s)	Weak Lapse (–0.1°C/m)	Strong Lapse (–0.3°C/m)	Weak Inversion (+0.1°C/m)	Strong Inversion (+0.5°C/m)
50	5	–2	–4	6	11	–1	–1	3	8
100	5	–2	–4	6	10	–1	–2	3	9
200	5	–2	–3	5	10	–1	–2	3	10
400	5	–1	–3	4	9	–1	–2	3	11
800	5	–2	–6	3	8	–1	–4	2	13
1600	5	–4	–9	5	9	–3	–11	5	17
50	15	–3	–5	7	12	–1	–2	3	7
100	15	–2	–4	6	10	–1	–2	4	9
200	15	–2	–3	4	8	–1	–2	4	10
400	15	–1	–2	3	8	–1	–2	4	12
800	15	–1	–2	3	7	–1	–3	3	14
1600	15	–1	–5	6	9	–2	–10	6	17

Wind and Temperature Gradients Example Results Graph



Team Members & Acknowledgements

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