Harmonizing the built and natural environments.

Road Traffic Noise Modeling: Future Trends in Ontario

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The Project

- Project sponsored by the Ontario Ministry of Transportation, in consultation with the Ontario Ministry of Environment and Metrolinx
- Evaluate readily available computerised noise prediction models
- Provide recommendations on the best model for future use in Ontario, for highway, transit, and heavy rail
- **Software Packages** and **Algorithms**
- Qualitative and quantitative review
- Focus of this presentation is on results for Roads
  - Interim results, focus on technical issues
  - Other considerations not covered

Software Review

- Evaluate various ***Software Packages***:
  - STAMSON v 5.1
  - STAMINA v 2.0
  - TNM v 2.5
  - Cadna/A
  - SoundPLAN

- Ranked on:
  - Cost
  - Market Penetration
  - Usability
  - Output
  - Acoustical Performance

Software Review - Ranking

Final Software Ranking

Software Package	General		Usability								Output			OVERALL
	Cost	Market Penetration	Ease of Use	Hardware	Portability	Input	Update	Speed	Custom-ization	Import	Points of Reception	Partial Levels	Contours	
STAMSON 5.1	1 Free	1	4	4	5	4	5	3	5	4	3	1	4	4
STAMINA 2.0	1 Free	3	5	4	4	5	4	4	4	4	3	4	4	4
TMN 2.5	3 $ 700	4	3	1	3	3	3	5	3	3	5	5	3	3
Cadna/A	5 $ 8000	2	1	1	2	1	1	2	1	2	1	1	1	2
SoundPLAN	4 $ 6000	5	2	1	1	2	2	1	1	1	1	1	1	1

Notes:

Ease of Use:	Pros include GUIs, 3D views, batch processing. Cons include limits on inputs (no. of receivers / no. of sources), documentation, options
Hardware:	STAMINA and STAMSON do no run on 64 bit machines.
Portability:	Ability to export between packages.
Input:	Ability to easily add data. Ease of use of GUI, text files, etc.
Update:	Ability to copy and modify runs, ability to run multiple barrier heights in single runs.
Speed:	Time required for calculation runs.
Customization:	Ability to add custom sources not included in the database.
Import:	Ability to import data from other software packages (bitmaps, cad drawings, files from other modelling packages).
Points of Reception:	Ability to rank impacts at specific points of reception in terms of vehicle contribution.
Partial Levels:	Ability to rank impacts at specific points of reception in terms of roadway link contribution.
Contours:	Ability to easily produce noise contours (isopleths of equal noise levels).

Algorithms

- ORNAMENT
  - The "Ontario Road Noise Analysis Method for Environment and Transportation", developed by the MOE in 1989. ORNAMENT is the basis of the STAMSON model, and is a modification of the FHWA-RD-77-108 algorithm to simplify calculations and to account for Ontario's then-current vehicle fleet.
- FHWA-RD-77-108
  - The Highway Traffic Noise Prediction Model published by the FHWA in 1978. This is the basis of the STAMINA computer program.
- FHWA TNM
  - The "Traffic Noise Model" published by FHWA in 2004. TNM is required to be used on all U.S. Federal-aid highway projects. TNM provides updated vehicle noise emission data and propagation algorithms.
- NMPB-Roads 96 (EC Interim)
  - The French road traffic noise model which has been adopted as the "interim" standard for city-wide noise modelling required under European Commission Directive 2002/49/EC.
- RLS-90 – "Richtlinien für den Lärmschutz an Straßen"
  - The German guidelines for noise protection on roadways, published in 1990.
- VBUS - "Vorläufige Berechnungsmethode für den Umgebungslärm an Straßen"
  - An adaptation of the RLS-90 algorithms to make the results comparable to / compatible with those from NMPB-Roads96.

Algorithms

- Ranked on:
  - Noise emissions
  - Noise propagation

Noise Emission - Factors

- Factors Considered In Noise Emission Predictions

Algorithm	Time Period	Traffic Mix				Engine vs Tire Emissions	Pavement Type	Roadway Gradient	Stops and Acceleration
		Cars	Trucks		Buses				
			Medium	Heavy					
FHWA RD-77-108	1 hour	Yes	Yes > 4500 kg	Yes >12000 kg	No (As Med. or Trucks)	Combined Leq at Ref. Dist	No	No (Incl. in STAMINA)	No
ORNAMENT	User Specified	Yes	Yes > 4500 kg	Yes >12000 kg	No (As Med. or Trucks)	Combined Leq at Ref. Dist	3 types DFC, OFC, PCC	Yes (Gradient specified)	No
FHWA TNM	1 hour	Yes	Yes > 4500 kg	Yes >12000 kg	Yes	Combined Leq at Ref. Dist	4 types Avg, DFC, OFC, PCC	Yes (Throttle Settings)	Yes (Throttle Settings)
NMPB Roads-96	1 hour	Yes	Combined % Comm. > 3500 kg		No (As Trucks)	Engine and Tire Noise Calc'd Separately	6 types DFC, OFC, Smooth PCC, Textured PCC, Pavers, Cobbles	Yes (Through engine noise)	Yes (Through engine noise and speed)
RLS-90	1 hour	Yes	Combined % Comm. > 2800 kg		No (As Trucks)	Combined Leq at Ref. Dist	7 types DFC, Rough DFC, SMA, PCC, PCC w/ steel broom finish, PCC w/ Jute cloth finish, Asphalt Conc. 0/11 mm, OFC 0/11 mm, OFC 0/8 mm	Yes (Gradient specified)	Yes (Based on dist. from Intersection)
VBUS	1 hour	Yes	Combined % Comm. > 3500 kg		No (As Trucks)	Combined Leq at Ref. Dist		Yes (Gradient specified)	Yes (Based on dist. from Intersection)

Noise Emission – Vehicle Mix

- Noise Emission Comparison
  - Typical DFC asphalt
  - Typical vehicle breakdowns

400-Series Highway			Prov. Highway	Arterial Roads		
MTO Default	**Lower % Heavy**	**ISO 11819-1**	**MTO Default**			
100,000 AADT	100,000 AADT	100,000 AADT	20,000 AADT	10,000 AADT	10,000 AADT	10,000 AADT
5% Medium	10% Medium	7.5 % Medium	5% Medium	2% Medium	4% Medium	6% Medium
15% Heavy	10% Heavy	22.5 % Heavy	8% Heavy	2 % Heavy	4% Heavy	2% Heavy
20% Comm.	20% Comm.	30% Comm.	13% Comm.	4% Comm.	8% Comm.	8% Comm.
100 km/h	100 km/h	100 km/h	80 km/h	60 km/h	60 km/h	60 km/h

Noise Emission – Vehicle Mix

- Noise Emission Comparison Results
  - Typical asphalt
  - Typical vehicle breakdowns

Modelling Algorithm	400 Series MTO Default	400 Series Low % HVY	400 Series ISO 11819-1	Prov HWY MTO Default	Arterial Road Dist 1	Arterial Road Dist 2	Arterial Road Dist 3	Overall Average
RD-77-108	-	-	-	-	-	-	-	-
ORNAMENT	0.0	-0.1	0.0	0.0	0.1	0.0	0.1	0.0
TNM	-2.5	-2.3	-2.9	-2.6	-1.7	-2.5	-1.9	-2.3
NMPB-96	-1.9	-1.3	-2.2	-1.1	1.2	0.3	1.4	-0.5
RLS-90	-3.7	-3.1	-4.0	-2.1	-0.7	-1.1	0.0	-2.1
VBUS	-4.0	-3.4	-4.2	-2.3	-0.9	-1.1	0.0	-2.3

- All values are the difference between A-weighted levels (dBA) between FHWA STAMINA and the respective algorithm

Noise Emission – Pavement Types

Pavement Type	Algorithm									
	RD-77-108 / STAMINA		ORNAMENT		TNM		NMPB-96 Roads		RLS-90 / VBUS	
	Adj. dBA	Description	Adj. dBA	Description	Adj. dBA	Description	Adj. dBA	Description	Adj. dBA	Description
"Average"	--	n/a	--	n/a	+1	Average of All US	--	n/a	--	n/a
Standard Asphalts	0	n/a	0	Typical Asphalt or Concrete	0	Dense Graded Friction Course (DGFC)	0	Enrobé bitumé (asphalt pavement)	0	Smooth mastic asphalt, bitumen concrete, or mastic asphalt chippings
Open Graded Porous Pavements	--	n/a	-2.5	Open-graded Friction Course (Speeds ≥ 80kph)	-0.3 to -1.0	Open Graded Friction Course (OGFC)	-0.8 to -3.2	Enrobé drainant (porous asphalt pavement - 20% porosity)	-3	Typical OGFC (From Stndrds)
									-2	Asphalt Concrete (≤ 0/11) [1]
									-4	Porous Asphalt (0/11) [1]
									-5	Porous Asphalt (0/8) [1]
Concrete	--	n/a	0	Typical Asphalt or Concrete	+1.4 to +3.3	Portland Concrete Cement (PCC)	0	Béton lisse (smooth concrete)	-1	Concrete w/ Jute Cloth Finish (Smooth Concrete) [1]
			+7	Grooved Concrete (Speeds ≥ 80 kph)			+3	Béton strié (grooved concrete)	+1	Concrete w/ Steel Broom Finish [1]
									+2	Concrete (From Stndrds)
Concrete Pavers	--	n/a	--	n/a	--	n/a	+3	Pavés en ville (concrete pavers)	+3	Smooth Pavers [1]
Cobblestones	--	n/a	--	n/a	--	n/a	+2	Chaussée cloutée (cobblestone)	+6	Other Pavers [1]

Noise Emission

- Overall Ranking – Noise Emissions

Modelling Algorithm	Traffic Mix	Traffic Speed	Pavement Type	Road Gradient	Stops / Acceleration	Overall Ranking
ORNAMENT	2	1	2	1	2	3
RD-77-108	2	1	3	1	2	4
TNM	1	1	1	1	1	1
NMPB-96	3	1	1	1	1	2
RLS-90	3	1	1	1	1	2
VBUS	3	1	1	1	1	2

TNM has:

- Up-to-date source emission levels, based on NA vehicles
- Considers both buses and heavy trucks
- Includes typical pavement types
- Includes stops and acceleration

Propagation

- Sufficiently diverse number of geometries to identify differences in predictions and difficulties in using software & algorithms
- Predictions made for “standard” traffic volumes
- Hard or Soft Ground
- Receptors heights of 1.5 and 4.5 m
- Setback distances of 20, 50, 100, 250, and 600 m
- Contours where possible (software dependant)
- Noise attenuation mechanisms
  - Noise barriers at 2 m, 3.5 m and 5 m heights
  - 1 row of houses modelled specifically as barriers

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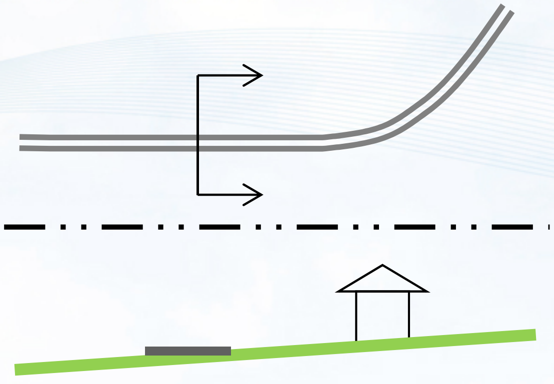
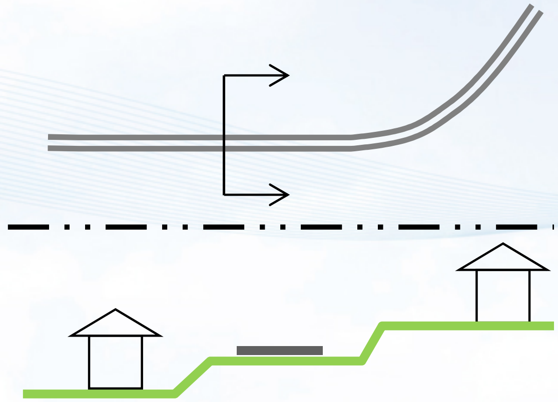
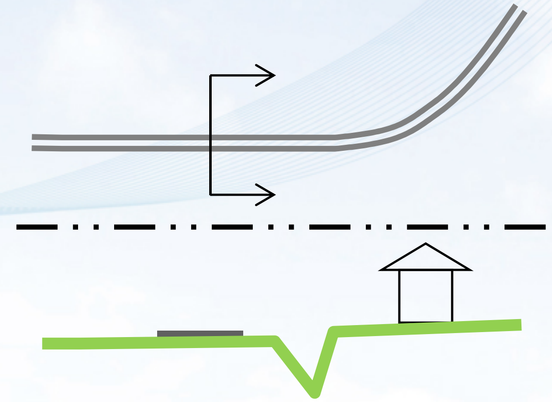
Propagation



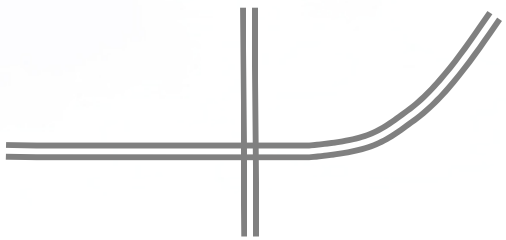
(a) Flat / Sloping Ground



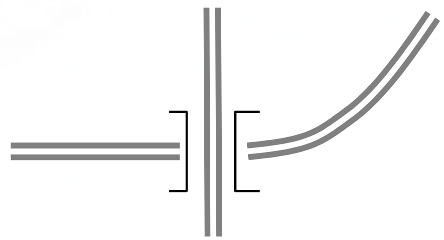
(b) Ground Elevation Change



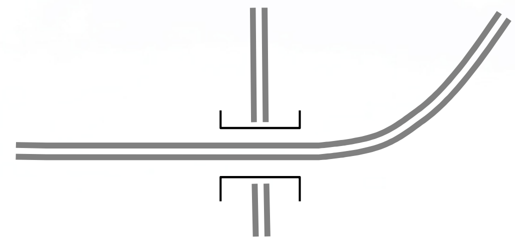
(c) Intervening Ditch



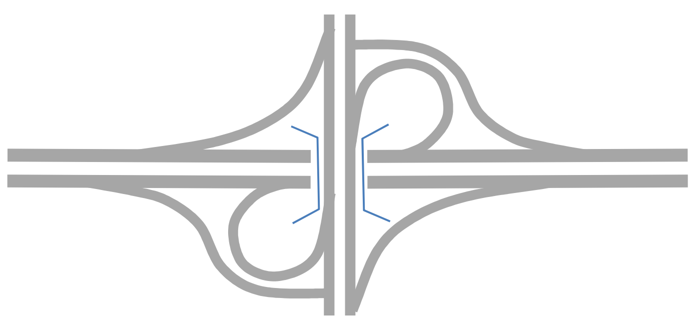
(d) Intersection on Flat Ground



(e) Intersection Overpass



(f) Intersection Underpass



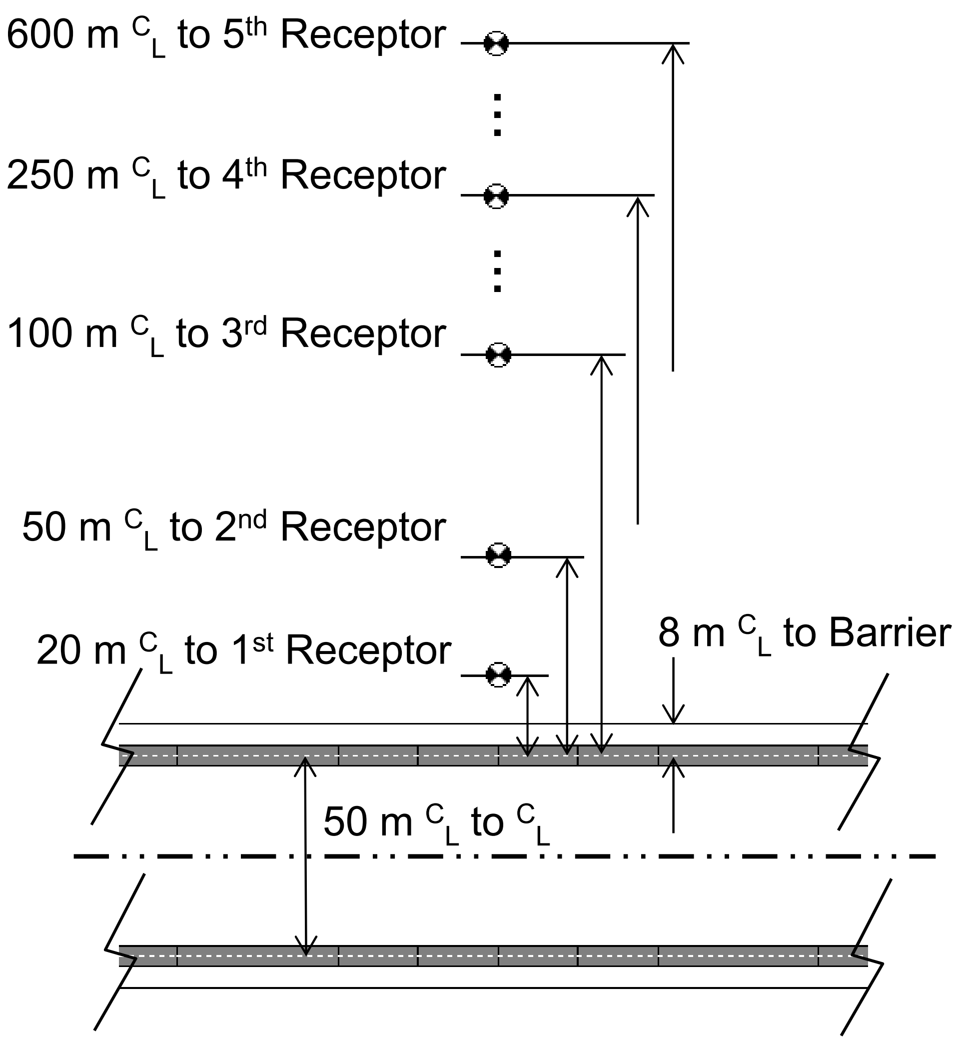
(g) Partial Cloverleaf (A4)
(Roadway Only)

Propagation

- Factors Considered In Noise Propagation Predictions

Algorithm	Distance Attenuation	Ground Absorption	Meteorology
FHWA-RD-77-108	Line Source	Specified α absorption	Neutral
ORNAMENT	Line Source	Hard or Soft	Neutral
FHWA TNM	Line Source	Specified z ground impedance (Most advanced model)	Neutral, User Specified Temp and %RH
NMPB Roads-96	Line Source	Specified α absorption	User Specified % of favourable propagation
RLS-90	Line Source	Absorptive	Neutral
VBUS	Line Source	Absorptive	Neutral

Propagation – Example Results

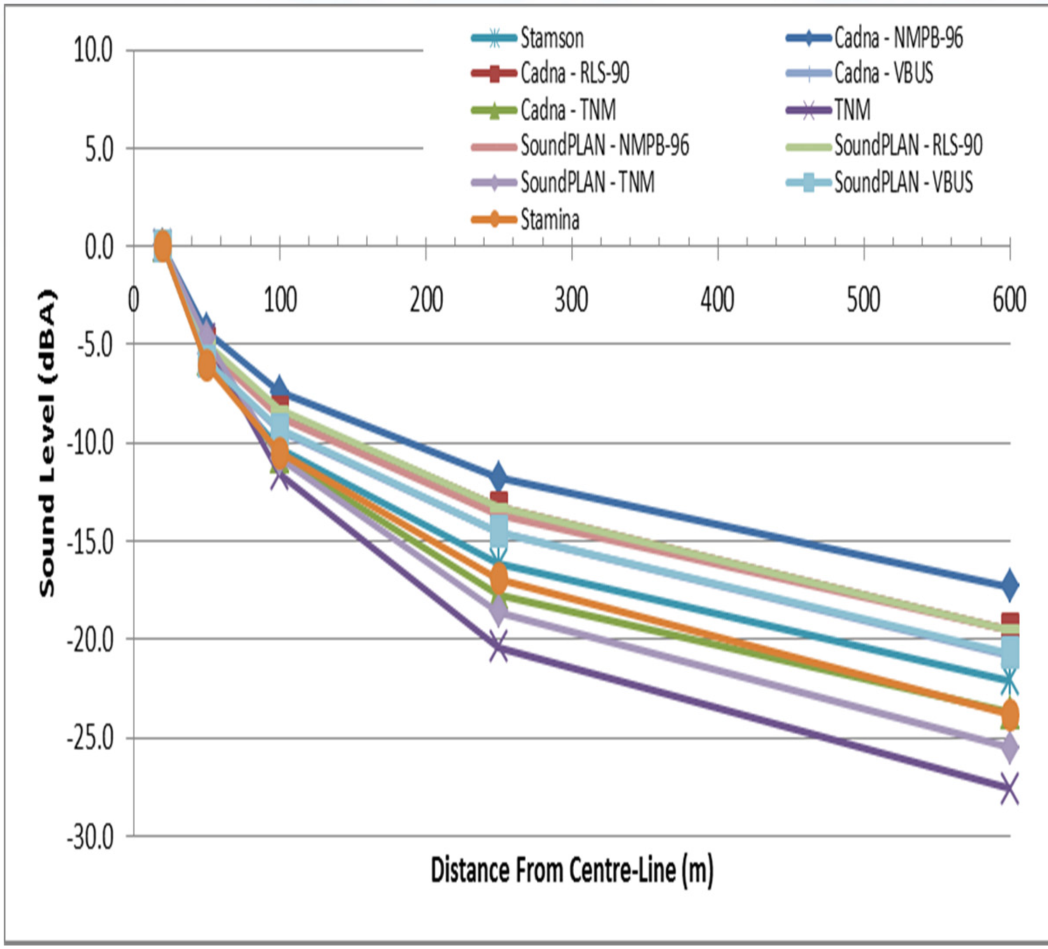


- Test Case A – Flat ground
- Typical 4-lane highway
- "Infinite" length
- 100,000 AADT
- 5% Medium trucks / 15% Heavy or 20% Commercial (as applicable)
- 100 km/h speed
- "Standard" asphalt
- L_{eq} (24 h) values, in dBA
- No barrier, or 5.0 m high barrier
- Reflective or absorptive ground

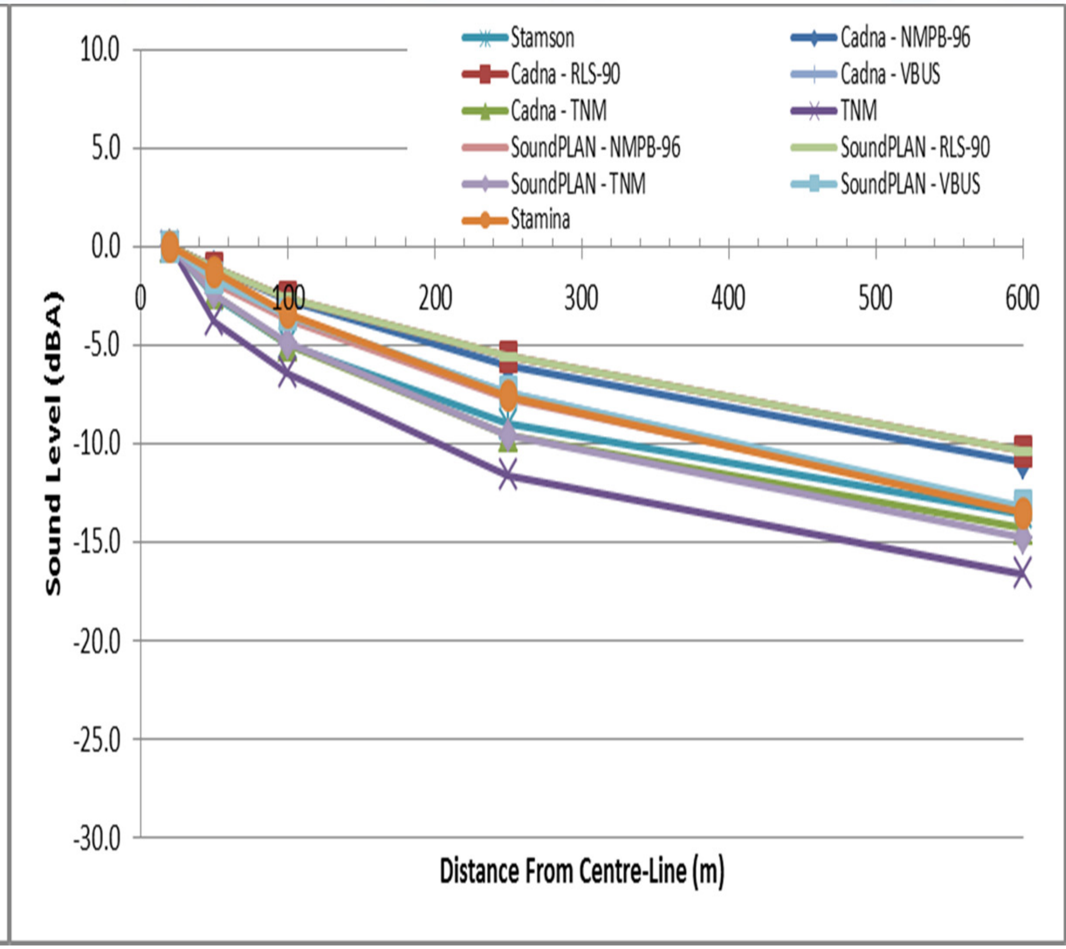
Results –
Absorptive Ground, 1.5 m High Receptor

Ground Abs		0.66	N/A	0.66	N/A	fieldgrass	Absorptive	0.66
Algorithm		NMPB-96	RLS-90	TNM	VBUS	TNM	ORNAMENT	FHWA
Program		Cadna	Cadna	Cadna	Cadna	TNM 2.5	Stamson	Stamina

1.5 m Receptor, Absorptive Ground, No Barrier



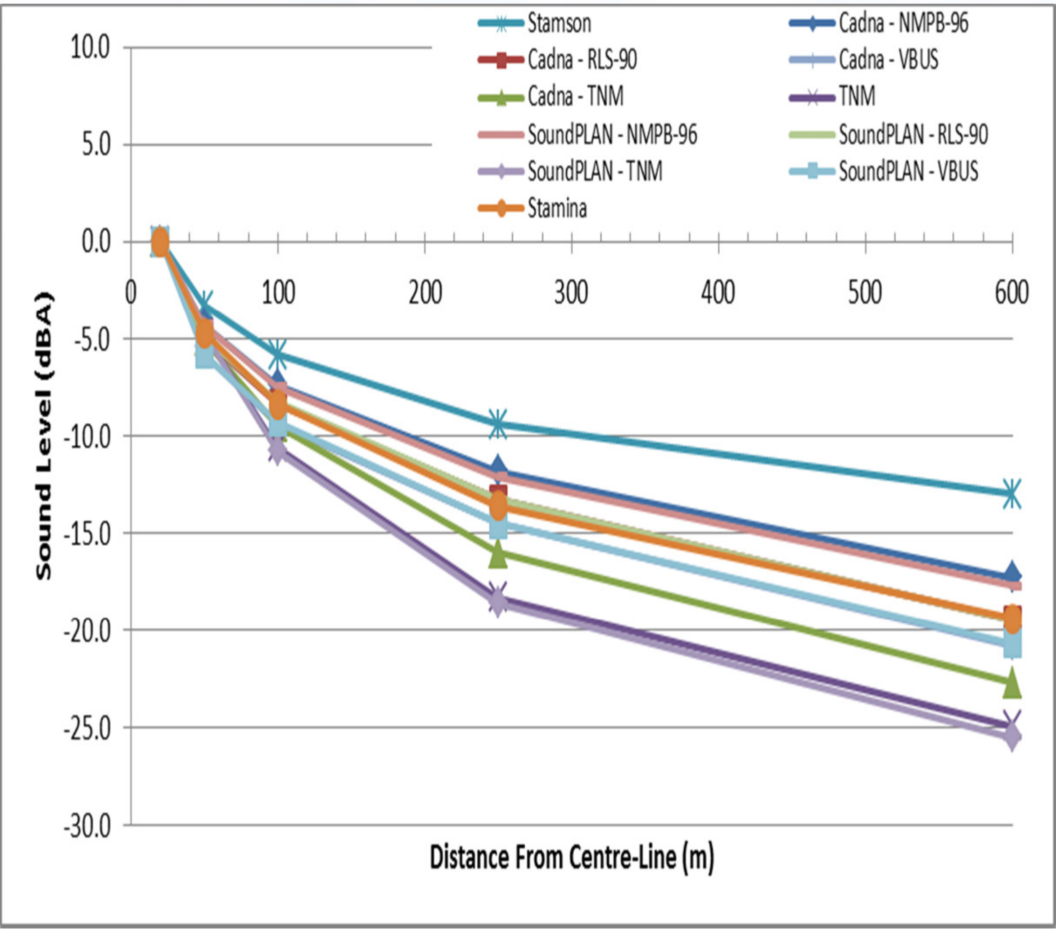
1.5 m Receptor, Absorptive Ground, 5.0 m Barrier



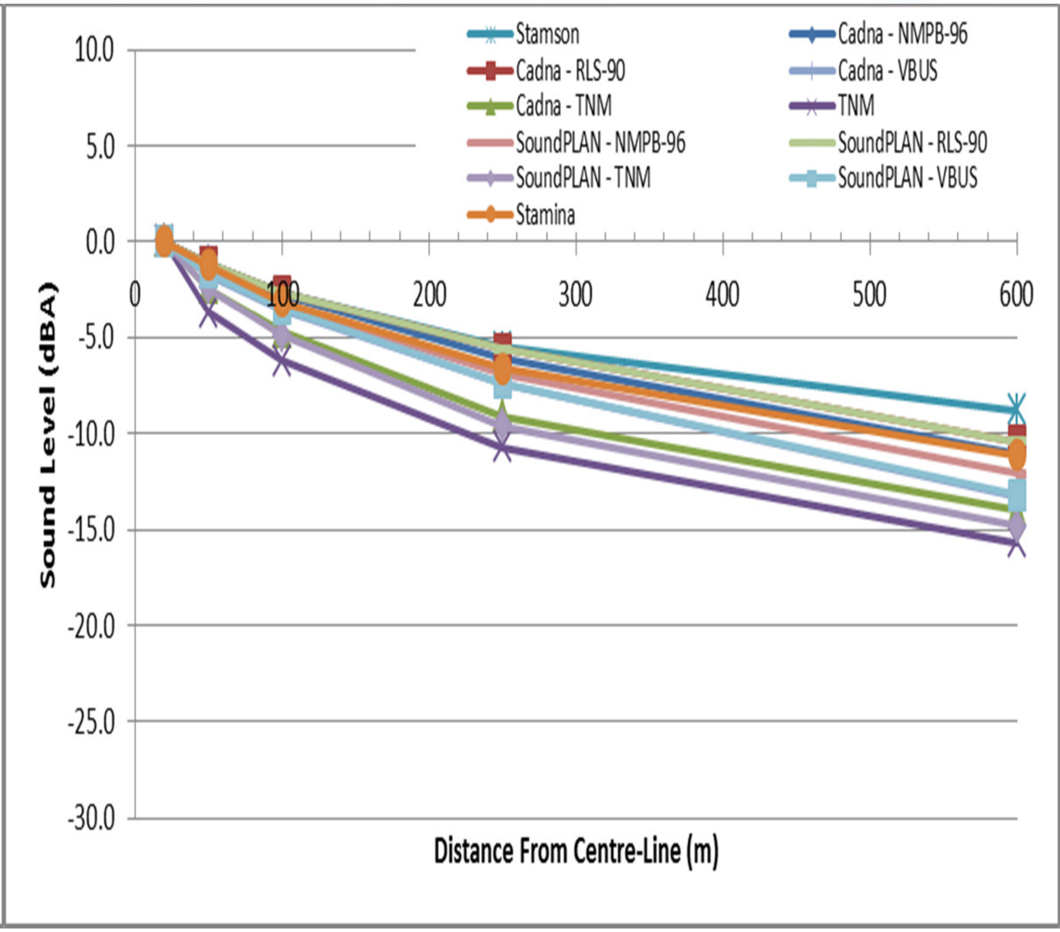
Results –
Reflective Ground, 1.5 m High Receptor

Ground Abs		0.33	N/A	0.33	N/A	pavement	Reflective	0.33
Algorithm		NMPB-96	RLS-90	TNM	VBUS	TNM	ORNAMENT	FHWA
Program		Cadna	Cadna	Cadna	Cadna	TNM	Stamson	Stamina

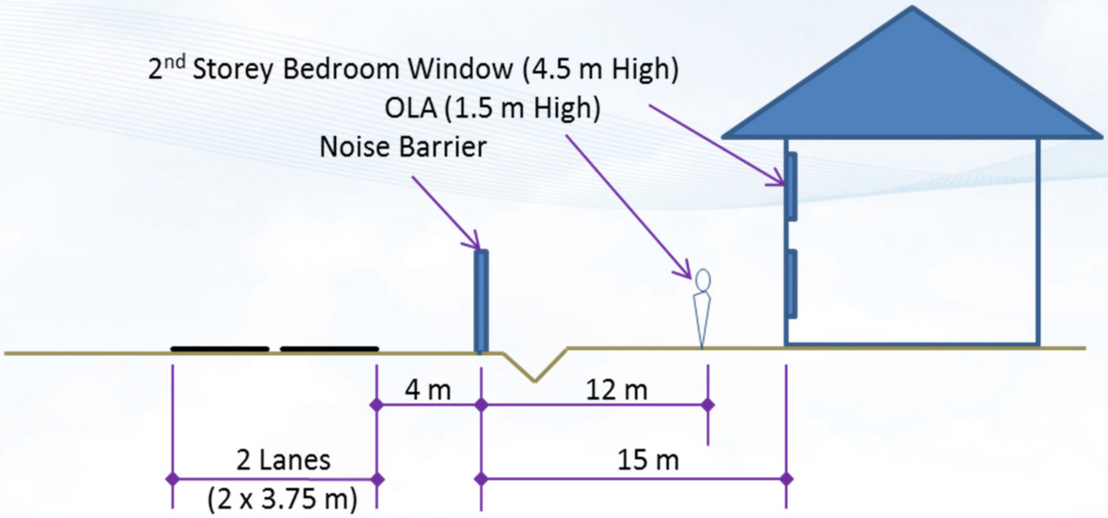
1.5 m Receptor, Reflective Ground, No Barrier



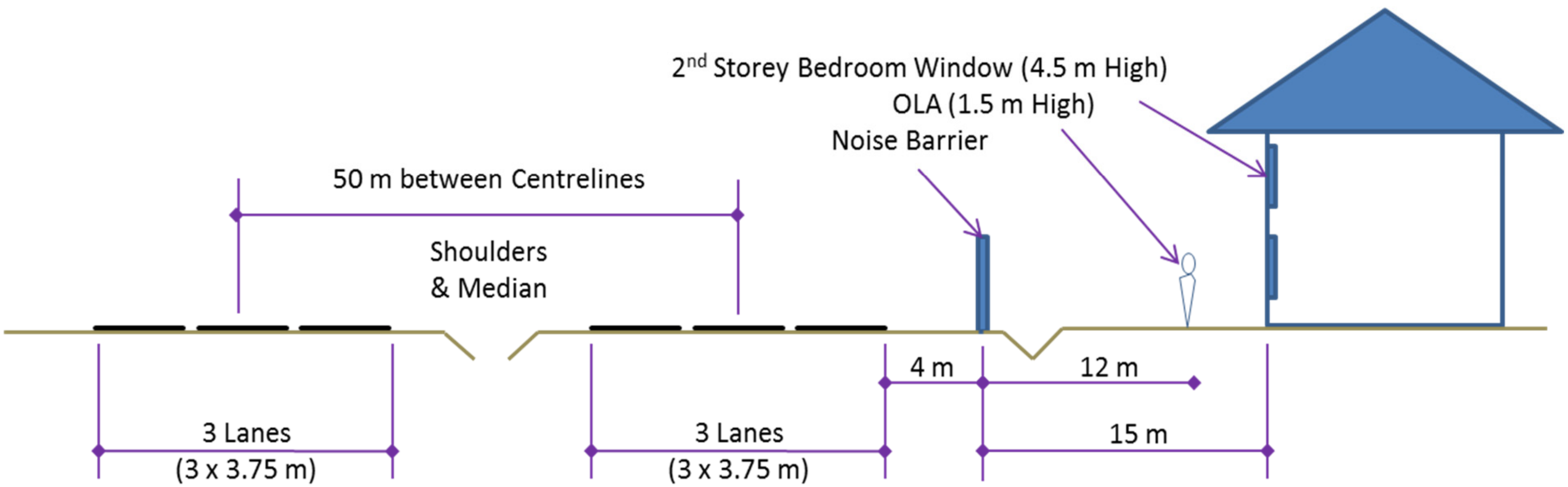
1.5 m Receptor, Reflective Ground, 5.0 m Barrier



Propagation – Barrier Effectiveness



Arterial Roadway

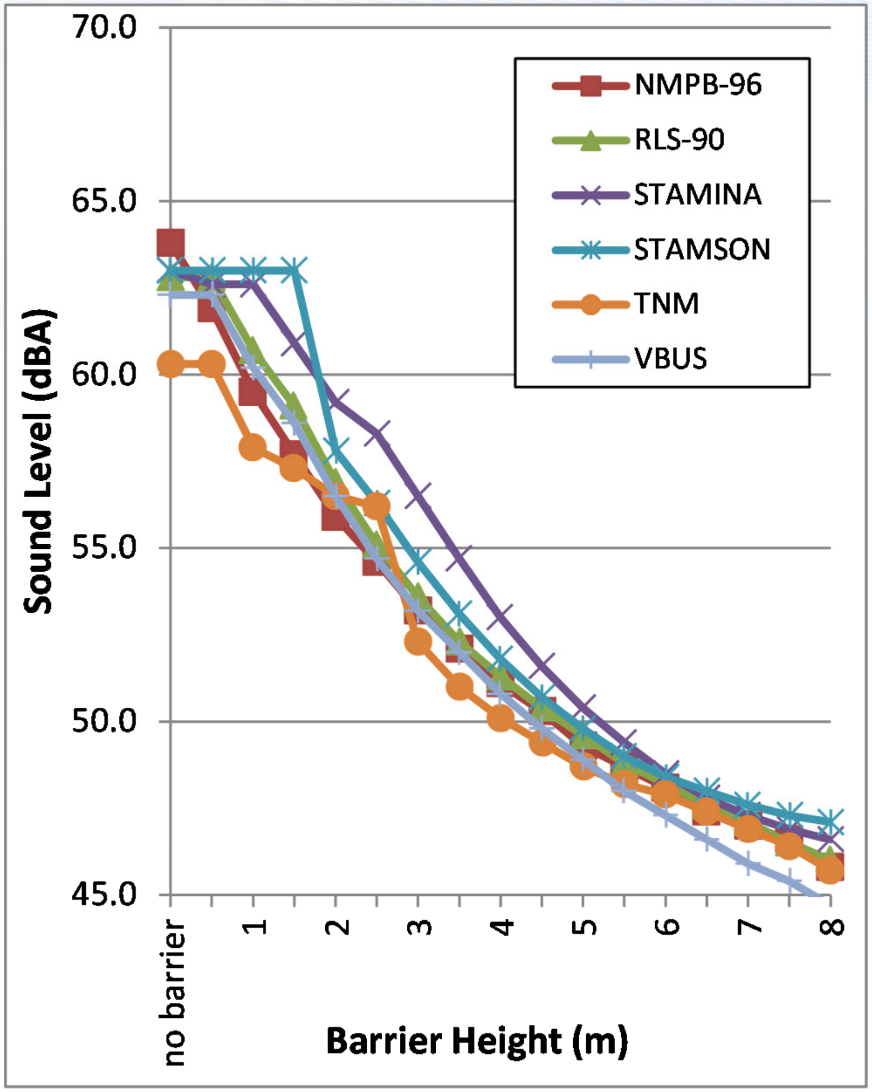


Freeway

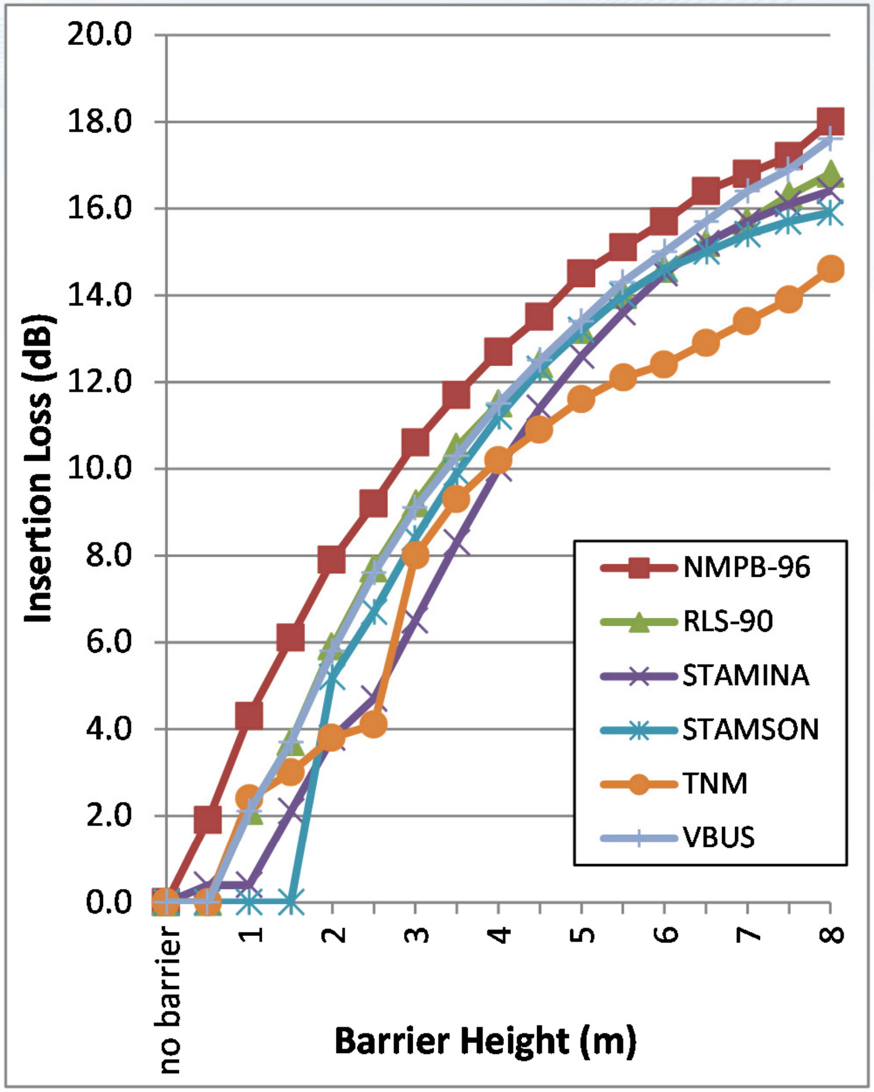
Propagation – Barrier Effectiveness
Arterial Roadways

Ground Level OLA (1.5 m Height)

Predicted Sound Level (L_{eq}(24), dBA)



Barrier Attenuation (IL, dB)



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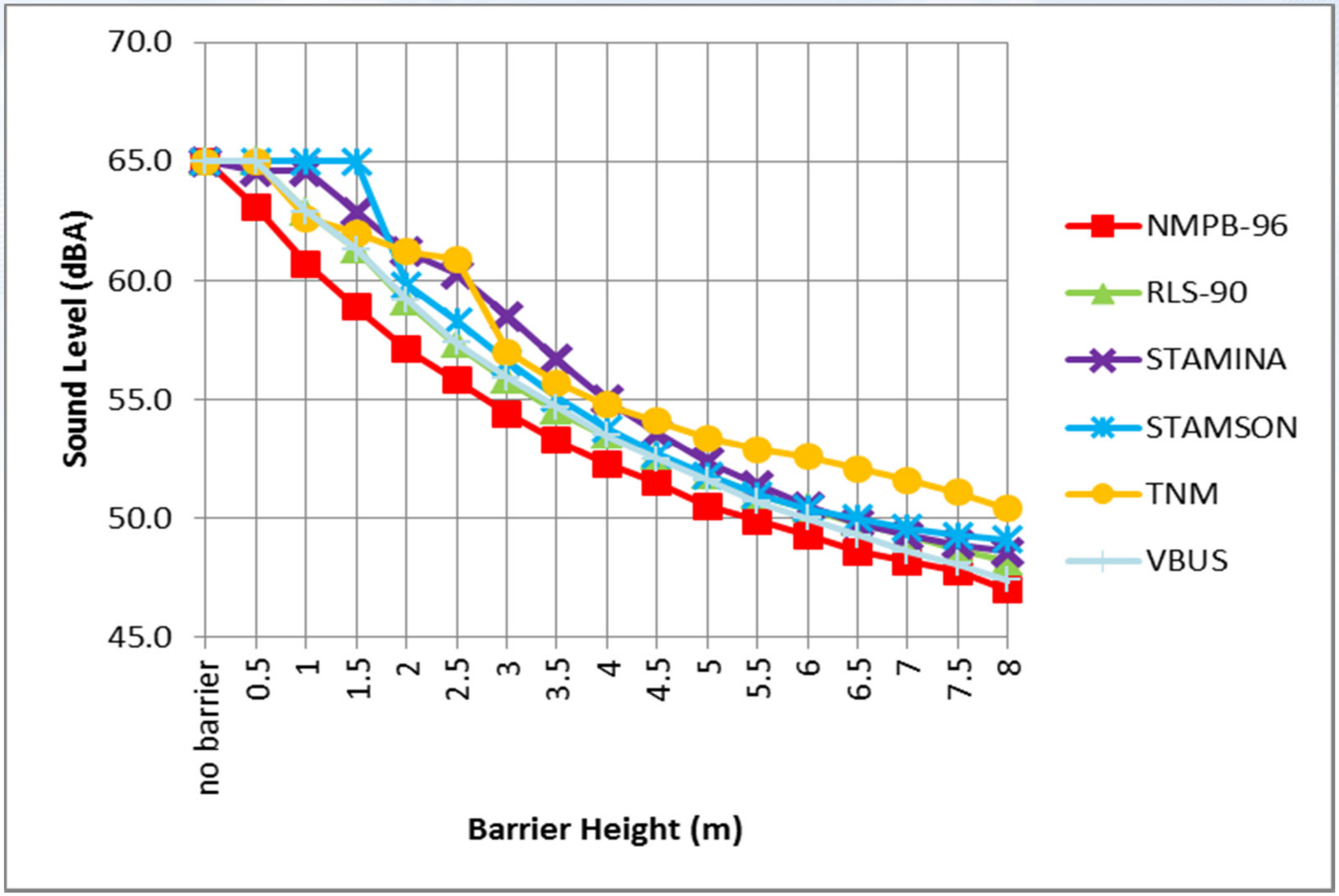
Propagation – Barrier Effectiveness, Arterial Roadways



Sound Level	Required Barrier Height (m)					
	NMPB	RLS-90	VBUS	STAMINA	STAMSON	TNM
Start at 65 dBA	--	--	--	--	--	--
to Reach 60 dBA	1.2	1.8	1.8	2.6	2.0	2.6
to Reach 55 dBA	2.8	3.3	3.4	4.0	3.5	3.9

Noise Emission

- Overall Ranking – Noise Propagation

Modelling Algorithm	Differential Ground Absorption	Meteorology	Distance Propagation – Hard Ground	Distance Propagation – Soft Ground	Speed of Calculation	Overall
ORNAMENT	2	2	2	2	3	4
RD-77-108	2	2	1	2	4	3
TNM	1	2	1	1	**5**	2
NMPB-96	2	1	1	2	2	1
RLS-90	3	2	n/a	2	1	3
VBUS	3	2	n/a	2	1	3

- TNM – Best prediction methodology for ground absorption
- NMPB – Best method for meteorology

Algorithms - Ranking

- Overall Ranking – Algorithms

Modelling Algorithm	Noise Emissions	Noise Propagation	Overall
ORNAMENT	3	4	4
RD-77-108	4	3	4
TNM	1	2	1
NMPB-96	2	1	2
RLS-90	2	3	3
VBUS	2	3	3

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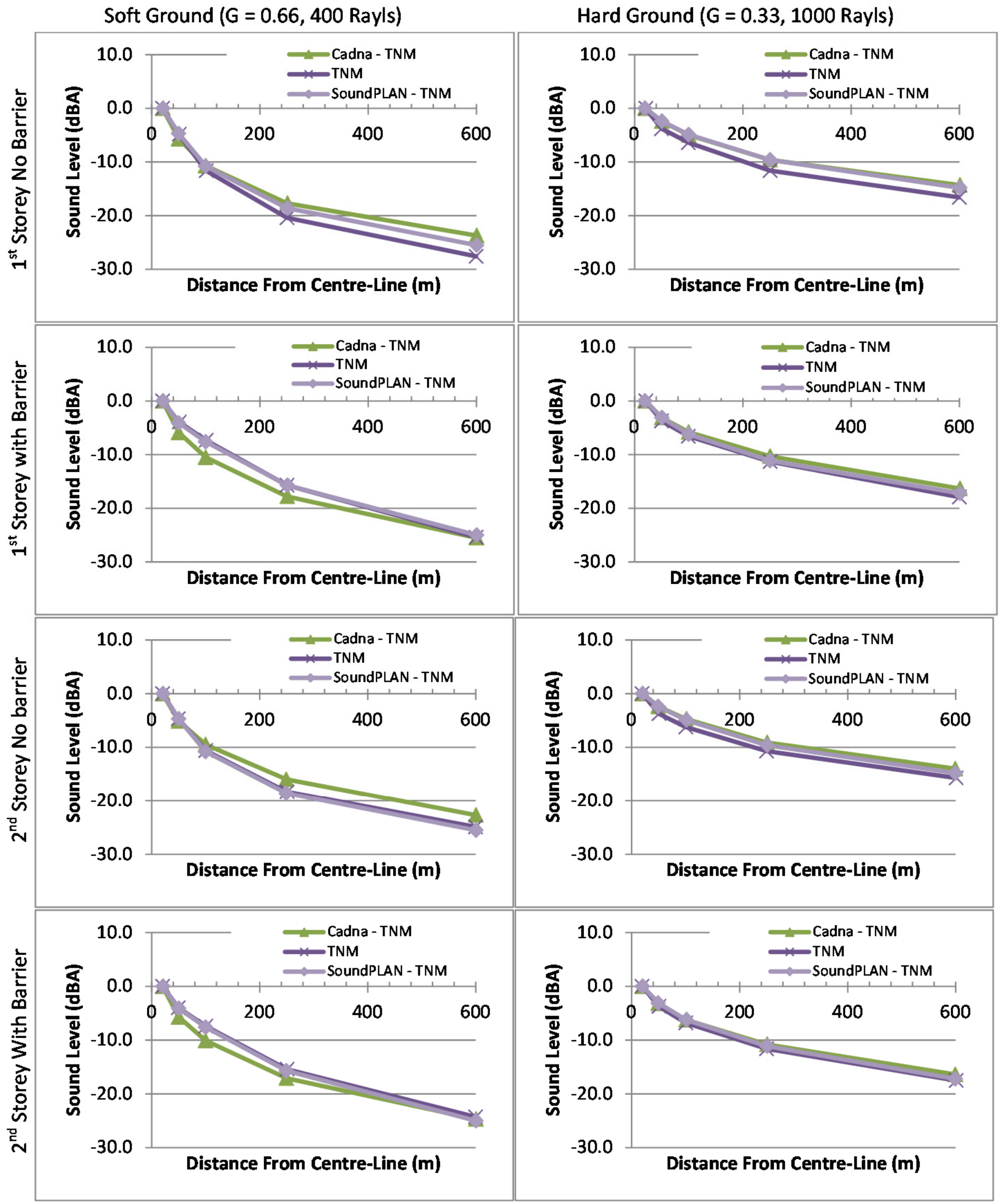
Results - TNM

- Variation within Three TNM implementations



TNM Results

- Comparison Between TNM Implementations – All Geometries

Software	Statistic	Geometry		
		A	C	G
		Sloped, Simple	Flat, Intervening Ditch	Parclo A4
Cadna A	95% Confidence	2.4 dB	2.3 dB	3.3 dB
	Within 1 dB	47% of time	66% of time	64% of time
SoundPLAN	95% Confidence	1.5 dB	3.1 dB	1.3 dB
	Within 1 dB	85.5% if time	53% of time	93% of time

- Comparison Between NMPB Implementations – All Geometries
  - Parclo A4 - 95% Confidence: 1.1 dB

- Comparison Between RLS-90 / VBUS Implementations – All Geometries
  - Parclo A4 - 95% Confidence: 0.1 dB

Interim Technical Findings

Overall

- Existing methods are conservative (~ 2 dB over-prediction)
- TNM as the algorithm
- TNM v2.5 as the software package (v3.0 when it is released)
- Until results have a demonstrable greater degree of consistency, Cadna/A and SoundPLAN are not be desirable for calculation of the FHWA TNM algorithms
- SoundPLAN in limited cases, export to for “official” run

TNM Summary

Pros	Cons
Includes up-to-date NA-based noise emission data	
Includes typical splits used in Ontario noise modelling - cars, medium trucks, heavy trucks	
Includes buses as separate vehicle category - Transit noise impact assessments	
Includes state-of-the art treatments for ground absorption and barrier effects - 1/3-octave, impedance based	"Fresnel" bug is known error in calculations
Graphical user interface - Input and QA checks	Current interface is "clunky"
Reasonable cost - $ 700	
Outputs are sortable by vehicle type	Outputs are NOT sortable by roadway link - Need to do multiple runs to pull out this data
Runs on modern computers and operating systems	Run times are excessively long
Algorithm is published (and in English) - "Simple" spreadsheet version could be developed	Most complex of all road noise algorithms
Examines "worst-case" met conditions	Met conditions are not state-of-the-art and are not fully user specifiable
Can import STAMINA files	
Can import DXF files	Imported as polylines, conversion is difficult, essentially need to redraw, cannot import aerial photography
Theoretically, can calculate contours	TNM V2.5 software warns you that this is too slow to do. - Need to do cluster computing?
Future versions to be released should address all or the majority of the "Cons"	

Thank you!

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