A METHOD TO INCORPORATE METEOROLOGICAL EFFECTS WITHIN A ROAD TRAFFIC MODEL

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Abstract

CoRTN (Calculation of Road Traffic Noise) by the UK Department of Transportation, Welsh Office has been extensively used to model road traffic noise in Australia for many years. The CoRTN model is relatively simple to use manually and, with the use of a computer, to use in complicated road layouts and terrain. This paper proposes a method to incorporate meteorological effects within the framework of the CoRTN model approach. The paper details how to calculate and apply the curved noise path resulting from the local meteorology. The method has been designed to permit hand calculation and relies on existing excess attenuation factors within the CoRTN model. The results of the application of the curved path to CoRTN algorithms are expected to improve predictive accuracy of noise models.

Nomenclature

$u(z)$	Wind velocity (m/s)
z	Height above the ground (m)
u_f	Friction velocity (n/sec)
z_0	Roughness length (m)
d	Zero plane displacement (m)
$c(t)$	Speed of sound (m/s)
T	Temperature (k)
T_0	Temperature at 1 m(C)
c_0	Speed of sound at sea level and 0 C is 331 m/s
R	Radius of curvature (m)

Introduction

The CoRTN method of predicting noise at a reception point from a road scheme consists of five main parts:

(i) divide the road scheme into one or more segments such that the variation of noise within the segment is small;

(ii) calculate the basic noise level at a reference distance of 10 m from the nearside carriageway edge from each segment

(iii) assess for each segment the noise level at the reception point taking into account distance attenuation, ground absorption, and screening of the source line;

(iv) correct the noise levels at the reception point taking into account site layout features including reflections from buildings and facades and the size of the source segment; and

(v) combine the contributions from all segments to give the predicted noise level at the reception point for the whole road scheme.

To account for the influence of meteorology only item (iii) will vary from the current methodology. The methodology will also require reassessment of the segmentation of the road scheme and in many instances it will not be acceptable to only consider one segment.

The CoRTN methodology site geometry requires that a straight noise path be used. However in a diffracting atmosphere it may be more appropriate to consider a curved noise path. Item iii of the CoRTN method becomes

(iii) assess for each segment the noise level at the reception point taking into account distance attenuation, ground absorption, air absorption and screening of the source line associated with the curved noise path.

Curved Noise Path

The formulation of the curved noise path has been documented in Bies & Hansen [1], Tonin [2] and Reynolds [3]. The radius of curvature is a function of both the vertical temperature gradient and the wind gradient.

In Reynolds [3] the vertical wind velocity profile is given by,

$$u(z) = 5.8\ u_f\ \log10((z+d)/z_0). \tag{1}$$

This equation is used for terrains that have tall vegetation and only has meaning if $z \geq z_0+d$. It has found to be accurate in the zone close to the ground.

Differentiating Equation (1) gives the wind gradient at height z,

$$du/dz = 5.8u_f/((\ln 10)*(z+d)). \tag{2}$$

The temperature profile varies according to the time of day and can be very complex. However, for simplicity, it is assumed that the vertical temperature gradient is constant as in Tonin [2]. The speed of sound is given in Equation 3.

$$c=c_0\ (T/273)^{½}\ . \tag{3}$$

Differentiating Equation (3) gives vertical sonic gradient,

$$dc/dz = (dT/dz(10.29/(10dT/dz + T_0 +273)^{½})\ . \tag{4}$$

The radius of curvature for a sound wave is given by the Equation (5) DeJong and Stusnik [4]:

$$R = c_0 / (dc/dz + du/dz). \quad (5)$$

When R is positive the sound rays are curved upwards and when R is negative the sound rays are curved downward.

Meteorology

Vertical Temperature Gradient

It is appropriate to consider Pasquill stability categories as described for example in Manning [5], Refer to Table 1. The wind speed is measured at 10 m.

Table 1. Possible Combinations of Wind Speed and Stability Classes (after Manning 1981)

Wind Speed m/s	Daytime Incoming Solar Radiation (W/cm^2)				1 Hour Before Sunset or After Sunrise	Night-time Cloud Cover (Octas)		
	>60	30-60	< 30	Over-cast		0 to 3	4 to 7	8
≤ 1.5	A	A-B	B	C	D	F-G	F	D
2 – 2.5	A-B	B	C	C	D	F	E	D
3 – 4	B	B-C	C	C	D	E	D	D
5-6	C	C-D	D	D	D	D	D	D
>6	D	D	D	D	D	D	D	D

Typical diurnal solar radiation levels may be obtained from a theoretical approach Bird [6]. Clear sky direct beam solar radiation for the northernmost and southernmost parts of Australia may be seen in Figure 1.

On sunny days with clear skies the incoming solar radiation would be similar to that in Figure 1. If the day were overcast the incoming solar radiation would be zero. To determine the actual solar radiation at any point in time it is necessary to estimate cloud cover and reduce the incoming solar radiation by the fractional amount of cloud cover.

Typical vertical temperature gradients for each Pasquill stability class are given in Table 2. These vertical temperature gradients are relative to the adiabatic lapse rate.

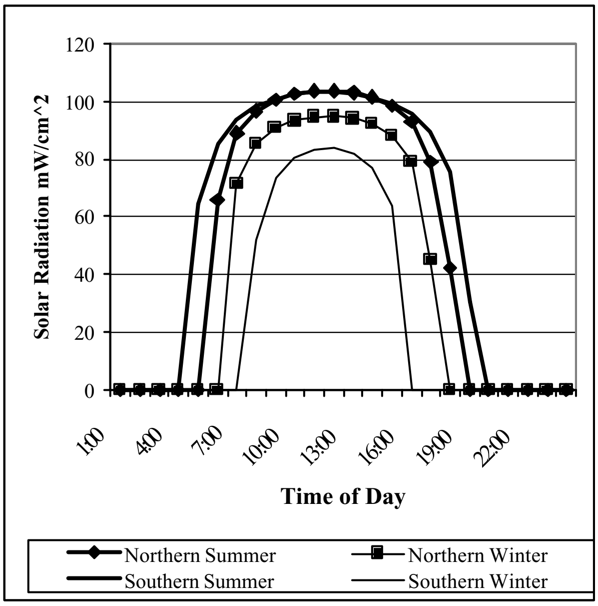

Figure 1: Typical Diurnal Clear Sky Solar Radiation (after Bird 1991)

Table 2. Typical Vertical Temperature Gradients for Pasquill Stability Categories

Pasquill Stability Category	Vertical Temperature Gradient (C/100m)
A	-3.0 to –1.4
B	-1.4 to –1.2
C	-1.2 to –1.0
D	-1.0 to 0
E	0 to 2.0
F	2.0 to 4.0

Wind Gradients

Representative values of the friction velocity coefficient and the roughness length coefficients for natural surfaces for a velocity of 5 m/s at 2.0 m height are shown in Table 3.

In situations where wind speeds have been measured at a known height it is necessary to scale u_f to the measured values and Equation (1) becomes Equation (6),

$$u_f^1 = u(z) / (5.8 \log10((z+d)/z_0)). \quad (6)$$

where u(z) is the measured wind speed at the anemometer height (z).

Table 2. Representative values of Friction Velocity coefficients u_f, Roughness Length Coefficient z_0 for Natural terrain surfaces for a velocity of 5 m/s at 2.0 m height

Surface	z_0 (m)	u_f (m/s)	d (m)
Very Smooth (mud flats, ice)	8.0×10^{-6}	0.16	-
Snow over short grass	1.6×10^{-4}	0.21	-
Swampy plain	3.5×10^{-4}	0.23	-
Sea	5.0×10^{-4}	0.24	-
Lawn grass (1 cm high)	1.0×10^{-3}	0.26	-
Desert	1.3×10^{-3}	0.27	-
Snow Cover	4.0×10^{-3}	0.32	-
Prairie Grass (10 cm high)	6.8×10^{-3}	0.35	0.05
Air field	1.4×10^{-2}	0.40	-
Thick grass (10 cm high)	2.3×10^{-2}	0.45	0.08
Countryside with hedges	2.7×10^{-2}	0.48	0.3
Thin grass (50 cm high)	5.0×10^{-2}	0.57	0.35
Beet field	6.3×10^{-2}	0.62	0.45
Thick grass (50 cm high)	9.0×10^{-2}	0.68	0.34
Grain field	1.4×10^{-1}	0.81	0.38

Typical values for the radius of curvature.

Using equations 4 and 5 the radius of curvature due to vertical temperature gradients is shown in Figure 2.

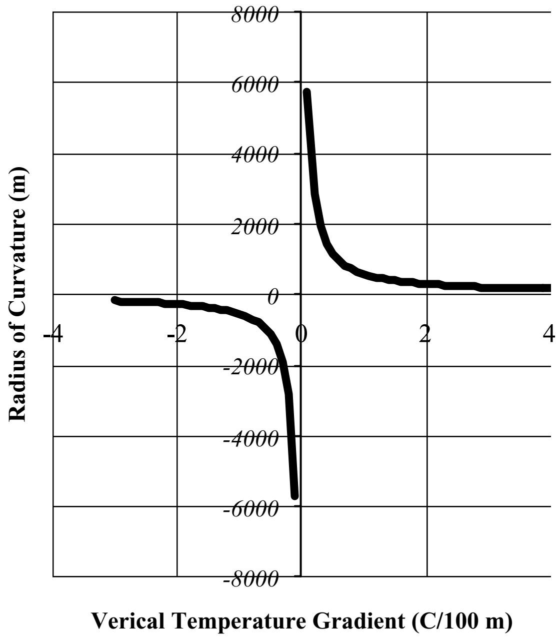

Figure 2 Radius of Curvature for Various Temperature Gradients - No Wind

The radius of curvature due to wind speed alone is shown in Figure 3. The wind speed in this analysis is that part of the resolved wind speed from the source to the receiver.

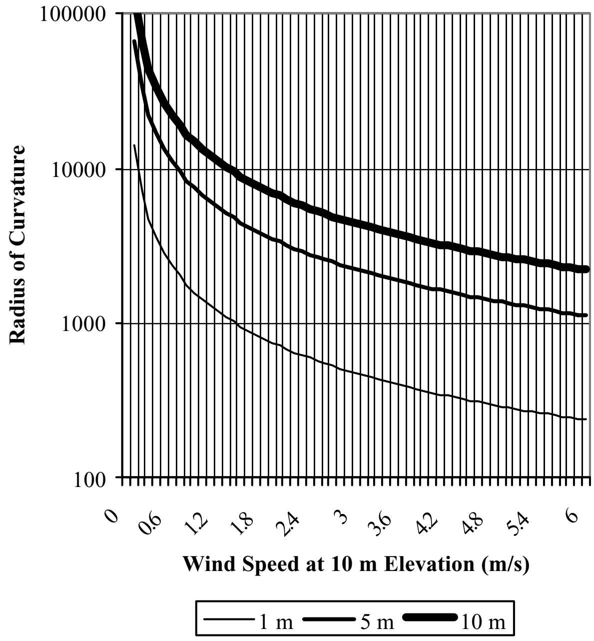

Figure 3: Radius of Curvature at Heights Above the Ground of 1 m, 5m and 10 m for Zero Vertical Temperature Gradient And Various Wind Speeds

For flat ground and assuming an average propagation height of 1 m for the direct path (not influenced by meteorological effects) typical values for the radius of curvature is given in Table 3 for directly upwind conditions and Table 4 for downwind conditions.

Table 3. Radius of Curvature at 1 m over Rough Grass – Upwind Conditions

Wind Speed m/s	Daytime Incoming Solar Radiation (W/cm^2)				1 Hour Before Sunset or After Sunrise	Night-time Cloud Cover (Octas)		
	>60	30-60	< 30	Over-cast		0 to 3	4 to 7	8
≤ 1.5	-200	-240	-300	-340	-530	250	250	-530
2 – 2.5	-160	-190	-200	-200	-260	490	-800	-260
3 – 4	-140	-140	-150	-150	-170	-310	-170	-170
5-6	-110	-120	-120	-120	-120	-120	-120	-120
>6	-90	-90	-90	-90	-90	-90	-90	-90

.

Table 4. Radius of Curvature at 1 m over Rough Grass – Downwind Conditions

Wind Speed m/s	Daytime Incoming Solar Radiation (W/cm^2)				1 Hour Before Sunset or After Sunrise	Night-time Cloud Cover (Octas)		
	>60	30-60	< 30	Over-cast		0 to 3	4 to 7	8
≤ 1.5	-330	-460	-740	-1020	11000	170	170	11K
2 – 2.5	-4360	1610	1010	1010	490	130	220	490
3 – 4	390	360	340	340	350	150	250	250
5-6	190	170	160	160	160	160	160	160
>6	100	100	100	100	100	100	100	100

The above indicates that potentially the noise path can have a significant curvature. For a given noise path the radius of curvature is not constant and varies according to height above the ground, the ground cover and other factors. It cannot be readily solved analytically. Most references simplify the radius of curvature calculation due to wind by applying an average velocity coefficient representative of the region where the sound is propagating; it is assumed to be constant. This has weaknesses where the propagation path is close to the ground (as in the case of road traffic noise). In this region the velocity gradient varies significantly over the relatively short changes in elevation.

If the radius of curvature is negative, that is the sound rays are curved downwards, the average propagation height would be higher than the average propagation height of the direct path (not influenced by meteorological effects). It is proposed to iterate the radius of curvature (based on the average height of the curved path) until the radius of curvature tends to a single value. A computer readily carries out this process. Alternatively for a hand calculation the average of the direct path and first iteration may be used.

If the radius of curvature were positive, that is the sound rays are curved upwards, the average propagation height would be lower than the average propagation height of the direct path (not influenced by meteorological effects). In this case it is not proposed further modify the calculated radius of curvature.

Application of Curved Path to the CoRTN Method

It is proposed to adopt the standard CoRTN ground effect and barrier calculations as contained in CoRTN but assessed for the curved path, rather than the direct path unmodified by meteorological conditions, as is currently the case. In the case of an upwards-curved path it is possible that the receiver will be in the shadow zone. A shadow zone is a region where sound cannot penetrate by virtue of the curved path intercepting the ground between the source and receiver. It is not proposed to introduce a shadow zone excess attenuation; rather it is proposed to utilise the barrier attenuation as a function of path difference to account for the shadow zone.

The following steps would apply:

1. Develop a cross section from the source to the receiver based on the actual terrain details. Figure 4 is an example of a typical cross-section.
2. Calculate (iterate) the radius of curvature using the vertical temperature gradient and the resolved wind speed from source to receptor for the hour in question. Figure 5 is an example of a typical cross-section showing the curved ray.
3. Assume the curved path is a straight line between the source and receiver. Modify the ground height either upwards or downwards in accord with the curved path deflection. Figure 6 is an example of a typical cross-section showing the modified ground heights (to account for the curved ray.).
4. Use standard CoRTN procedures to calculate the noise level, based on the curved ground and straight noise paths. CoRTN requires that the sector be reduced to the projected perpendicular. This is carried out after the curvature calculations and modifications to the ground height.

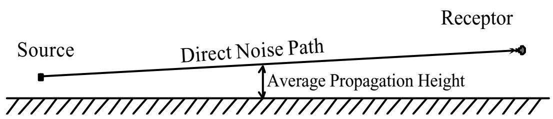

Figure 4: Develop Cross-Section As Recommended in CoRTN

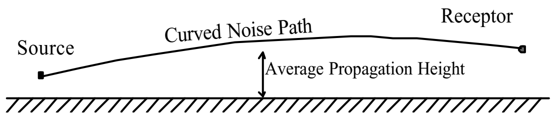

Figure 5: Calculate Curvature Of Noise Path As Per Methods Described

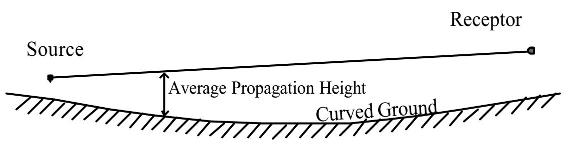

Figure 6: Curved Ground And Direct Noise Path Now Used In All CoRTN Procedures. Any Noise Barriers Placed on the Curved Ground

This approach simplifies the ground and barrier effect calculations since all standard CoRTN calculations now apply and these assume strait noise paths. It is possible for the radius of curvature to be less than the half the distance between source and receiver. In these instances the radius curvature should become equal to half the separation distance.

To obtain the combined correction use Equation (7),

Combined = 10 * log ((i=1,n Σ 10^ (Corr$_i$/10))/n) (7)

Where all segments are equal area and n is the number of segments and Corr$_i$ is the maximum of either the ground effect attenuation or barrier effect attenuation in segment i as required by the CoRTN method.

Worked Example 1

Assume flat terrain and a two-lane road running north south. A receptor is located 50 m from the edge of the nearside carriageway and to the west of the road. The wind speed for a mast height of 10 m is 2.0 m/s from the east, it is overcast and therefore the vertical temperature gradient is zero. The receptor height is 1.5 m and the source height is 0.5 m. It is assumed that the ground beyond the road is rough grass 10 cm high.

All the CoRTN methods apply with the only variation being that for the correction for ground absorption. From Chart 8 of the CoRTN manual [6] the ground absorption is –7.1 dB(A) for the case without any consideration of meteorology.

The ground absorption for the downward curved path is considered for each 5 degree segment from 85 degrees to – 85 degrees in Table 5. Compared with the no wind case a wind perpendicular to the road and towards the receptor would lead to an increase in road traffic noise levels of 0.8 dB(A) (-6.3 - -7.1).

Worked Example 2

This case remains the same as Worked Example 1 except that the wind now blows from the west. In this instance the wind will cause the sound to curve upwards. A shadow zone will be formed for some angles. The ground absorption for the downward curved path is considered for each 5-degree segment from 85 degrees to – 85 degrees in Table 6.

Compared with the no wind case a wind perpendicular to the road and from the receptor would lead to an reduction in road traffic noise levels of 1.1 dB(A) (8.2 -7.1).

Worked Example 3

This case remains the same as Worked Example 1 except that the wind now blows from the north. In this instance the wind will cause the sound to curve downwards for the road north of receptor location and upwards for road south of the receptor location. A shadow zone will be formed for some angles. The ground absorption for the downward curved path is considered for each 5-degree segment from 85 degrees to – 85 degrees in Table 7.

Compared with the no wind case a wind perpendicular to the road and from the receptor would lead to an increase in road traffic noise levels of 0.5 dB(A) (-6.6 - -7.1).

Worked Example 4

This case remains the same as Worked Example 1 except that the wind speed is now zero and there is an F class stability providing a vertical temperature gradient of 3.0 C/100m. In this instance the vertical temperature gradient will cause the sound to curve downwards and the noise levels to increase. The ground absorption for the downward curved path is considered for each 5-degree segment from 85 degrees to – 85 degrees in Table 8.

Compared with the no wind case an F class stability would lead to an increase in road traffic noise levels of 3.4 dB(A) (-3.7 - -7.1). Although increases occur for all angles the greatest increases occur at angles further from the perpendicular.

Worked Example 5

This case remains the same as Worked Example 1 except that the wind speed is now zero and there is an A class stability and a vertical temperature gradient of –2.5 C/100m. In this instance the vertical temperature gradient will cause the sound to curve upwards and the noise levels to decrease. A shadow zone will be formed for some angles. The ground absorption for the downward curved path is considered for each 5-degree segment from 85 degrees to – 85 degrees in Table 9. The radius of curvature was limited to half the distance from source to receiver in some instances.

Compared with the no wind case an A class stability would lead to a reduction in road traffic noise levels of 2.7 dB(A) (-7.1–9.8). Although decreases occur for all angles the greatest decreases occur at angles further from the perpendicular. A shadow zone would occur for angles beyond 25 degrees from the perpendicular.

Table 5. Worked Example 1 Ground Absorption Correction for 2m/s wind and 50m from the Road - Downwind

Angle (deg)	Wind Velocity (m/s)	u_f^1	du/dz	Radius of Curvature (m)	Increase in height (m)	Increase in Area (m^2)	Average increase in height (m)	Average propagation height (m)	Ground absorption correction (dB(A))
85	0.2	0.0	0.04	8180	5.0	1.9k	3.4	2.7	-4.4
80	0.3	0.0	0.08	4106	2.5	484	1.7	1.8	-5.4
75	0.5	0.1	0.12	2755	1.7	218	1.1	1.6	-5.8
70	0.7	0.1	0.16	2085	1.3	124	0.9	1.4	-6.1
65	0.8	0.1	0.20	1687	1.0	81.8	0.7	1.3	-6.2
60	1.0	0.1	0.24	1426	0.9	58.5	0.6	1.3	-6.3
55	1.1	0.1	0.28	1243	0.8	44.4	0.5	1.3	-6.4
50	1.3	0.1	0.31	1109	0.7	35.4	0.5	1.2	-6.5
45	1.4	0.1	0.34	1008	0.6	29.2	0.4	1.2	-6.5
40	1.5	0.2	0.37	931	0.6	24.9	0.4	1.2	-6.6
35	1.6	0.2	0.39	870	0.5	21.8	0.4	1.2	-6.6
30	1.7	0.2	0.42	823	0.5	19.5	0.3	1.2	-6.6
25	1.8	0.2	0.44	787	0.5	17.8	0.3	1.2	-6.6
20	1.9	0.2	0.45	759	0.5	16.6	0.3	1.2	-6.7
15	1.9	0.2	0.46	738	0.5	15.7	0.3	1.2	-6.7
10	2.0	0.2	0.47	724	0.4	15.1	0.3	1.1	-6.7
5	2.0	0.2	0.48	716	0.4	14.7	0.3	1.1	-6.7
0	2.0	0.2	0.48	713	0.4	14.6	0.3	1.1	-6.7
-5	2.0	0.2	0.48	716	0.4	14.7	0.3	1.1	-6.7
-10	2.0	0.2	0.47	724	0.4	15.1	0.3	1.1	-6.7
-15	1.9	0.2	0.46	738	0.5	15.7	0.3	1.2	-6.7
-20	1.9	0.2	0.45	759	0.5	16.6	0.3	1.2	-6.7
-25	1.8	0.2	0.44	787	0.5	17.8	0.3	1.2	-6.6
-30	1.7	0.2	0.42	823	0.5	19.5	0.3	1.2	-6.6
-35	1.6	0.2	0.39	870	0.5	21.8	0.4	1.2	-6.6
-40	1.5	0.2	0.37	931	0.6	24.9	0.4	1.2	-6.6
-45	1.4	0.1	0.34	1008	0.6	29.2	0.4	1.2	-6.5
-50	1.3	0.1	0.31	1109	0.7	35.4	0.5	1.2	-6.5
-55	1.1	0.1	0.28	1243	0.8	44.4	0.5	1.3	-6.4
-60	1.0	0.1	0.24	1426	0.9	58.5	0.6	1.3	-6.3
-65	0.8	0.1	0.20	1687	1.0	81.8	0.7	1.3	-6.2
-70	0.7	0.1	0.16	2085	1.3	124	0.9	1.4	-6.1
-75	0.5	0.1	0.12	2755	1.7	218	1.1	1.6	-5.8
-80	0.3	0.0	0.08	4106	2.5	484	1.7	1.8	-5.4
-85	0.2	0.0	0.04	8180	5.0	1.9k	3.4	2.7	-4.4
Combined									-6.3

Table 6. Worked Example 2 Ground Absorption or Barrier Correction for 2m/s wind and 50m from the Road -Upwind

Angle (deg)	Wind Velocity (m/s)	u_f^1	du/dz	Radius of Curvature (m)	Increase in height (m)	Increase in Area (m^2)	Average decrease in height (m)	Average propagation height (m)	Ground Absorption or Barrier correction dB(A)
85	0.2	0.0	0.04	8180	5.0	1.9k	3.4	-2.35[#1]	-11.9
80	0.3	0.0	0.08	4106	2.5	484	1.7	-0.68[#1]	-8.1
75	0.5	0.1	0.12	2755	1.7	218	1.1	-0.13[#1]	-8.0
70	0.7	0.1	0.16	2085	1.3	124	0.9	0.15	-8.0
65	0.8	0.1	0.20	1687	1.0	81.8	0.7	0.31	-8.0
60	1.0	0.1	0.24	1426	0.9	58.5	0.6	0.42	-8.0
55	1.1	0.1	0.28	1243	0.8	44.4	0.5	0.49	-8.0
50	1.3	0.1	0.31	1109	0.7	35.4	0.5	0.55	-8.0
45	1.4	0.1	0.34	1008	0.6	29.2	0.4	0.59	-8.0
40	1.5	0.2	0.37	931	0.6	24.9	0.4	0.62	-8.0
35	1.6	0.2	0.39	870	0.5	21.8	0.4	0.64	-8.0
30	1.7	0.2	0.42	823	0.5	19.5	0.3	0.66	-8.0
25	1.8	0.2	0.44	787	0.5	17.8	0.3	0.68	-8.0
20	1.9	0.2	0.45	759	0.5	16.6	0.3	0.69	-8.0
15	1.9	0.2	0.46	738	0.5	15.7	0.3	0.70	-8.0
10	2.0	0.2	0.47	724	0.4	15.1	0.3	0.70	-8.0
5	2.0	0.2	0.48	716	0.4	14.7	0.3	0.71	-8.0
0	2.0	0.2	0.48	713	0.4	14.6	0.3	0.71	-8.0
-5	2.0	0.2	0.48	716	0.4	14.7	0.3	0.71	-8.0
-10	2.0	0.2	0.47	724	0.4	15.1	0.3	0.70	-8.0
-15	1.9	0.2	0.46	738	0.5	15.7	0.3	0.70	-8.0
-20	1.9	0.2	0.45	759	0.5	16.6	0.3	0.69	-8.0
-25	1.8	0.2	0.44	787	0.5	17.8	0.3	0.68	-8.0
-30	1.7	0.2	0.42	823	0.5	19.5	0.3	0.66	-8.0
-35	1.6	0.2	0.39	870	0.5	21.8	0.4	0.64	-8.0
-40	1.5	0.2	0.37	931	0.6	24.9	0.4	0.62	-8.0
-45	1.4	0.1	0.34	1008	0.6	29.2	0.4	0.59	-8.0
-50	1.3	0.1	0.31	1109	0.7	35.4	0.5	0.55	-8.0
-55	1.1	0.1	0.28	1243	0.8	44.4	0.5	0.49	-8.0
-60	1.0	0.1	0.24	1426	0.9	58.5	0.6	0.42	-8.0
-65	0.8	0.1	0.20	1687	1.0	81.8	0.7	0.31	-8.0
-70	0.7	0.1	0.16	2085	1.3	124	0.9	0.15	-8.0
-75	0.5	0.1	0.12	2755	1.7	218	1.1	-0.13[#1]	-8.0
-80	0.3	0.0	0.08	4106	2.5	484	1.7	-0.68[#1]	-8.1
-85	0.2	0.0	0.04	8180	5.0	1.9k	3.4	-2.35[#1]	-11.9
Combined									-8.2

Note 1: A negative value implies that the receptor is in the shadow zone and the attenuation is the maximum of either the ground absorption correction or the barrier correction.

Table 7. Worked Example 3 Ground Absorption or Barrier Correction for 2m/s wind and 50m from the Road – Wind Parallel to Road

Angle (deg)	Wind Velocity (m/s)	u_f[1]	du/dz	Radius of Curvature (m)	Increase in height (m)	Increase in Area (m^2)	Average Change in height (m)	Average propagation height (m)	Ground Absorption or Barrier correction dB(A)
85	0.2	0.0	0.04	716	60.0	23k	40.3	21	0.0
80	0.3	0.0	0.08	724	14.5	2.8k	9.7	5.8	-2.5
75	0.5	0.1	0.12	738	6.3	818	4.2	3.1	-4.1
70	0.7	0.1	0.16	759	3.5	344	2.4	2.2	-4.9
65	0.8	0.1	0.20	787	2.2	175	1.5	1.7	-5.5
60	1.0	0.1	0.24	823	1.5	101	1.0	1.5	-5.9
55	1.1	0.1	0.28	870	1.1	63.5	0.7	1.4	-6.2
50	1.3	0.1	0.31	931	0.8	42.2	0.5	1.3	-6.4
45	1.4	0.1	0.34	1008	0.6	29.2	0.4	1.2	-6.5
40	1.5	0.2	0.37	1109	0.5	20.9	0.3	1.2	-6.6
35	1.6	0.2	0.39	1243	0.4	15.2	0.2	1.1	-6.7
30	1.7	0.2	0.42	1426	0.3	11.2	0.2	1.1	-6.8
25	1.8	0.2	0.44	1687	0.2	8.3	0.2	1.1	-6.9
20	1.9	0.2	0.45	2085	0.2	6.0	0.1	1.1	-6.9
15	1.9	0.2	0.46	2755	0.1	4.2	0.1	1.0	-7.0
10	2.0	0.2	0.47	4106	0.1	2.7	0.1	1.0	-7.0
5	2.0	0.2	0.48	8180	0.0	1.3	0.0	1.0	-7.0
0	2.0	0.2	0.48	None	0.0	0.0	0.0	1.0	-7.1
-5	2.0	0.2	0.48	8180	0.0	1.3	-0.0	1.0	-7.2
-10	2.0	0.2	0.47	4106	0.1	2.7	-0.1	0.9	-7.2
-15	1.9	0.2	0.46	2755	0.1	4.2	-0.1	0.9	-7.3
-20	1.9	0.2	0.45	2085	0.2	6.0	-0.1	0.9	-7.5
-25	1.8	0.2	0.44	1687	0.2	8.3	-0.2	0.8	-7.6
-30	1.7	0.2	0.42	1426	0.3	11.2	-0.2	0.8	-7.8
-35	1.6	0.2	0.39	1243	0.4	15.2	-0.2	0.8	-8.0
-40	1.5	0.2	0.37	1109	0.5	20.9	-0.3	0.7	-8.0
-45	1.4	0.1	0.34	1008	0.6	29.2	-0.4	0.6	-8.0
-50	1.3	0.1	0.31	931	0.8	42.2	-0.5	0.5	-8.0
-55	1.1	0.1	0.28	870	1.1	63.5	-0.7	0.3	-8.0
-60	1.0	0.1	0.24	823	1.5	101	-1.0	0.0	-8.0
-65	0.8	0.1	0.20	787	2.2	175	-1.5	-0.5[#1]	-8.0
-70	0.7	0.1	0.16	759	3.5	344	-2.4	-1.4[#1]	-9.7
-75	0.5	0.1	0.12	738	6.3	818	-4.2	-3.2[#1]	-13.4
-80	0.3	0.0	0.08	724	14.5	2.8k	-9.7	-8.7[#1]	-20.8
-85	0.2	0.0	0.04	716	60.0	23k	-40.3	-39[#1]	-30.0
Combined									-6.6

Note 1: A negative value implies that the receptor is in the shadow zone and the attenuation is the maximum of either the ground absorption correction or the barrier correction.

Table 8. Worked Example 4 Ground Absorption Correction for 0m/s wind F Class Stability, 50m from the Road

Angle (deg)	du/dz	Radius of Curvature (m)	½ Separation Dist. (m)	Modified R (m)	Increase in height (m)	Increase in Area (m^2)	Average Increase in height (m)	Average propagation height (m)	Ground Absorption Correction dB(A)
85	1.72	200	287	287	286	96305	167.9	84	0.0
80	1.72	200	144	200	61.3	12185	42.3	22	0.0
75	1.72	200	97	200	24.9	3251	16.8	9.41	-1.4
70	1.72	200	73	200	13.9	1360	9.3	5.65	-2.6
65	1.72	200	59	200	9.0	710.2	6.0	4.00	-3.4
60	1.72	200	50	200	6.4	425.4	4.3	3.13	-4.0
55	1.72	200	44	200	4.8	280.5	3.2	2.61	-4.5
50	1.72	200	39	200	3.8	198.7	2.6	2.28	-4.8
45	1.72	200	35	200	3.2	149.0	2.1	2.05	-5.1
40	1.72	200	33	200	2.7	117.0	1.8	1.90	-5.3
35	1.72	200	31	200	2.3	95.6	1.6	1.78	-5.5
30	1.72	200	29	200	2.1	80.8	1.4	1.70	-5.6
25	1.72	200	28	200	1.9	70.5	1.3	1.64	-5.7
20	1.72	200	27	200	1.8	63.2	1.2	1.59	-5.8
15	1.72	200	26	200	1.7	58.2	1.1	1.56	-5.8
10	1.72	200	25	200	1.6	54.9	1.1	1.54	-5.9
5	1.72	200	25	200	1.6	53.0	1.1	1.53	-5.9
0	1.72	200	25	200	1.6	52.4	1.0	1.52	-5.9
-5	1.72	200	25	200	1.6	53.0	1.1	1.53	-5.9
-10	1.72	200	25	200	1.6	54.9	1.1	1.54	-5.9
-15	1.72	200	26	200	1.7	58.2	1.1	1.56	-5.8
-20	1.72	200	27	200	1.8	63.2	1.2	1.59	-5.8
-25	1.72	200	28	200	1.9	70.5	1.3	1.64	-5.7
-30	1.72	200	29	200	2.1	80.8	1.4	1.70	-5.6
-35	1.72	200	31	200	2.3	95.6	1.6	1.78	-5.5
-40	1.72	200	33	200	2.7	117.0	1.8	1.90	-5.3
-45	1.72	200	35	200	3.2	149.0	2.1	2.05	-5.1
-50	1.72	200	39	200	3.8	198.7	2.6	2.28	-4.8
-55	1.72	200	44	200	4.8	280.5	3.2	2.61	-4.5
-60	1.72	200	50	200	6.4	425.4	4.3	3.13	-4.0
-65	1.72	200	59	200	9.0	710.2	6.0	4.00	-3.4
-70	1.72	200	73	200	13.9	1360.3	9.3	5.65	-2.6
-75	1.72	200	97	200	24.9	3251.2	16.8	9.41	-1.4
-80	1.72	200	144	200	61.3	12185	42.3	22	0.0
-85	1.72	200	287	287	286	96305	167.9	84	0.0
Combined									-3.7

Table 9. Worked Example 5 Ground Absorption Correction for 0m/s wind A Class Stability, 50m from the Road

Angle (deg)	du/dz	Radius of Curvature (m)	½ Separation Dist. (m)	Modified R (m)	Increase in height (m)	Increase in Area (m^2)	Average Increase in height (m)	Average propagation height (m)	Ground absorption or Barrier correction dB(A)
85	1.72	200	287	287	286	111k	195.2	-194#1	-30.0
80	1.72	200	144	200	61.3	9526	33.1	-32#1	-30.0
75	1.72	200	97	200	24.9	2664	13.8	-12#1	-25.0
70	1.72	200	73	200	13.9	1127	7.7	-6.71#1	-18.4
65	1.72	200	59	200	9.0	591.6	5.0	-4.00#1	-14.7
60	1.72	200	50	200	6.4	355.2	3.6	-2.55#1	-12.2
55	1.72	200	44	200	4.8	234.6	2.7	-1.69#1	-10.5
50	1.72	200	39	200	3.8	166.3	2.1	-1.14#1	-9.2
45	1.72	200	35	200	3.2	124.7	1.8	-0.76#1	-8.3
40	1.72	200	33	200	2.7	98.0	1.5	-0.50#1	-8.0
35	1.72	200	31	200	2.3	80.1	1.3	-0.31#1	-8.0
30	1.72	200	29	200	2.1	67.8	1.2	-0.17#1	-8.0
25	1.72	200	28	200	1.9	59.1	1.1	-0.07#1	-8.0
20	1.72	200	27	200	1.8	53.0	1.0	0.00	-8.0
15	1.72	200	26	200	1.7	48.8	0.9	0.06	-8.0
10	1.72	200	25	200	1.6	46.0	0.9	0.09	-8.0
5	1.72	200	25	200	1.6	44.5	0.9	0.11	-8.0
0	1.72	200	25	200	1.6	44.0	0.9	0.12	-8.0
-5	1.72	200	25	200	1.6	44.5	0.9	0.11	-8.0
-10	1.72	200	25	200	1.6	46.0	0.9	0.09	-8.0
-15	1.72	200	26	200	1.7	48.8	0.9	0.06	-8.0
-20	1.72	200	27	200	1.8	53.0	1.0	0.00	-8.0
-25	1.72	200	28	200	1.9	59.1	1.1	-0.07#1	-8.0
-30	1.72	200	29	200	2.1	67.8	1.2	-0.17#1	-8.0
-35	1.72	200	31	200	2.3	80.1	1.3	-0.31#1	-8.0
-40	1.72	200	33	200	2.7	98.0	1.5	-0.50#1	-8.0
-45	1.72	200	35	200	3.2	124.7	1.8	-0.76#1	-8.3
-50	1.72	200	39	200	3.8	166.3	2.1	-1.14#1	-9.2
-55	1.72	200	44	200	4.8	234.6	2.7	-1.69#1	-10.5
-60	1.72	200	50	200	6.4	355.2	3.6	-2.55#1	-12.2
-65	1.72	200	59	200	9.0	591.6	5.0	-4.00#1	-14.7
-70	1.72	200	73	200	13.9	1127	7.7	-6.71#1	-18.4
-75	1.72	200	97	200	24.9	2664	13.8	-12#1	-25.0
-80	1.72	200	144	200	61.3	9526	33.1	-32#1	-30.0
-85	1.72	200	287	287	286	111k	195.2	-194#1	-30.0
Combined									-9.8

Note 1: A negative value implies that the receptor is in the shadow zone and the attenuation is the maximum of either the ground absorption correction or the barrier correction.

Discussion

The meteorological conditions considered in the worked examples would be considered acceptable conditions for carrying out road traffic noise measurements. This analysis suggests that for this simple case at 50 m the likely variation in road traffic noise levels due to wind would be approximately ± 1 dB(A) and for temperature gradients approximately ± 3 dB(A). Potentially this could be a variability of approximately ± 4 dB(A) for both wind and temperature effects.

The calculation of the radius of curvature indicate that the significance of more distant road segments increases for downwind or cool clear night conditions. It is likely that segments of roads that may be obscured by intervening terrain during neutral conditions (i.e. significant barrier attenuation) would become increasing noisy as the curved path travels over the top of barriers without intercepting any terrain. Significant increase in noise levels could occur under these conditions.

The CoRTN method requires that the road scheme be divided into one or more segments such that the variation of noise within the segment is small; the variation within the segment should be less than 2 dB(A). As stated in the CoRTN model it is not possible to provide precise guidance as to the procedure to adopt to determine the segmentation boundaries. The worked examples indicate that greater emphasis will need to be placed on the more distant road segments as the road traffic noise levels from these segments fluctuate the most. For instance at an angle of 85 degrees from the perpendicular the distance from road segment to receptor is approximately 573 m. For the neutral case the ground effect attenuation was –7.1 dB(A). However, the ground effect varied between 0 and –30, ie an increase of +7 and a reduction of 23 dB(A).

The method strictly only applies to the calculation of the L_{10}(1 hour) and the L_{10}(18 hour) would be obtained by averaging the hourly L_{10}'s. By using computer models and annual meteorological statistics it is possible to obtain the statistical variability in the road traffic noise levels at receptor locations.

Conclusions

The method presented here incorporates meteorology into the CoRTN method. It is relatively uncomplicated. It only utilises the CoRTN excess attenuation factors. The method to calculate the curved path is based on recognized methods and is comparatively simple to apply.

The adoption of meteorological effects into the CoRTN methodology would lead to a refinement in the calculated noise levels.

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