CALCULATION AND MEASUREMENT GUIDELINES FOR RAIL TRANSPORT NOISE 1996

TRANSLATION

CHAPTER 0. INTRODUCTION

This document is a non-contextual English translation of the aforementioned Dutch document, for use as a European Interim Method for Noise Mapping.

Content of original (Dutch) Document

1. Categories of railway vehicles to be distinguished
2. Global dB(A) emission value
3. Emission values per octave band
4. Standard calculation method I (SRM I)
5. Standard calculation method II (SRM II)
6. Standard measurement methods
7. Acoustic survey and report
8. Emission register
9. Explanation of calculation and measurement prescriptions

For the use of noise mapping, some modifications to the content had to be made:

- chapters 6 and 7 concerning measurement methods have not been translated, because they are outside the scope of this task;
- chapter 8: reference to the European parameters for noise mapping has been added: L_{den}, L_{day}, L_{night}, $L_{evening}$;
- chapter 9: additional information and application: only parts relevant to the task have been translated; they have been incorporated as introduction to the relevant chapters.

In addition, all references to Dutch legislation and Dutch situations have been removed.

Modifications to the original text are indicated by a yellow background.

CHAPTER 1. CATEGORIES OF RAILWAY VEHICLES TO BE DISTINGUISHED

Prior to the calculation of the *equivalent continuous sound pressure level,* all vehicles that use an identified railway line and follow the appropriate service guidelines are divided into the following railway vehicles categories. These are primarily differentiated based on propulsion system and wheel brake system.

Category 1: Block braked passenger trains

- Exclusively electric passenger trains with cast-iron blocks including the corresponding locomotive, as well as trains from the Dutch 1964 series and passenger trains belonging to Deutsche Bahn (DB);
- Electrical motor mail vehicle.

Category 2: Disc braked and block braked passenger trains

- Electric passenger trains primarily with disc brakes and additional cast-iron blocks, including the corresponding locomotives, as for example the InterCity-Material of the IMC-III, ICR and DDM-1 types,
- Passenger trains belonging to the French Railway Society (SNCF) and the Trans Europe Express (TEE);
- Electric locomotives such as those from the 1100, 1200, 1300, 1500, 1600 and 1700 series of the Belgian Railway Society (B).

Category 3: Disc braked passenger trains

Exclusively passenger trains with disc brakes and engine noise, as for example the regional material (SGM, sprinter).

Category 4: Block braked freight trains

All types of freight trains with cast-iron block brakes.

Category 5: Block braked diesel trains

- Exclusively diesel-electrically driven passenger trains with cast-iron block brakes including the corresponding locomotive as for example the DE I, DE II, DE III types;
- Diesel – electric locomotives as for example the locomotives of the 2200/2300 and 2400/2500 series.

Category 6: Diesel trains with disc brakes

Exclusively diesel–hydraulically driven passenger trains with disc brakes and engine noise.

Category 7: Disc braked urban subway and rapid tram trains

Urban subway and rapid tram trains.

Category 8: Disc braked InterCity and slow trains

- Exclusively electric passenger trains with disc brakes including the corresponding locomotives, as for example InterCities of the ICM-IV, IRM and SM90 types;
- Electric passenger trains with primarily disc brakes and additional sinter and ABEX cast-iron blocks including the corresponding locomotives as for example the InterCities of the ICM-III and DDM-2/3 types.

Category 9: Disc braked and block braked high speed trains

Electric trains with primarily disc brakes and additional cast-iron blocks on the engine car, as for example the TGV-PBA or HLSSouth types.

Category 10: Provisionally reserved for high speed trains of the ICE-3 (M) (HST East) type

Vehicles not mentioned here are allocated to the next appropriate category based on their propulsion system, wheel brake system or maximum speed.

Figure 1.1 shows side views of the various categories and outlines the number of individual units.

One unit of any given category determines the sound emission. In the case of drawn trains, the locomotives and carriages or railway cars act as individual units. In the case of integrated trains, the connected sections should be regarded as one unit.

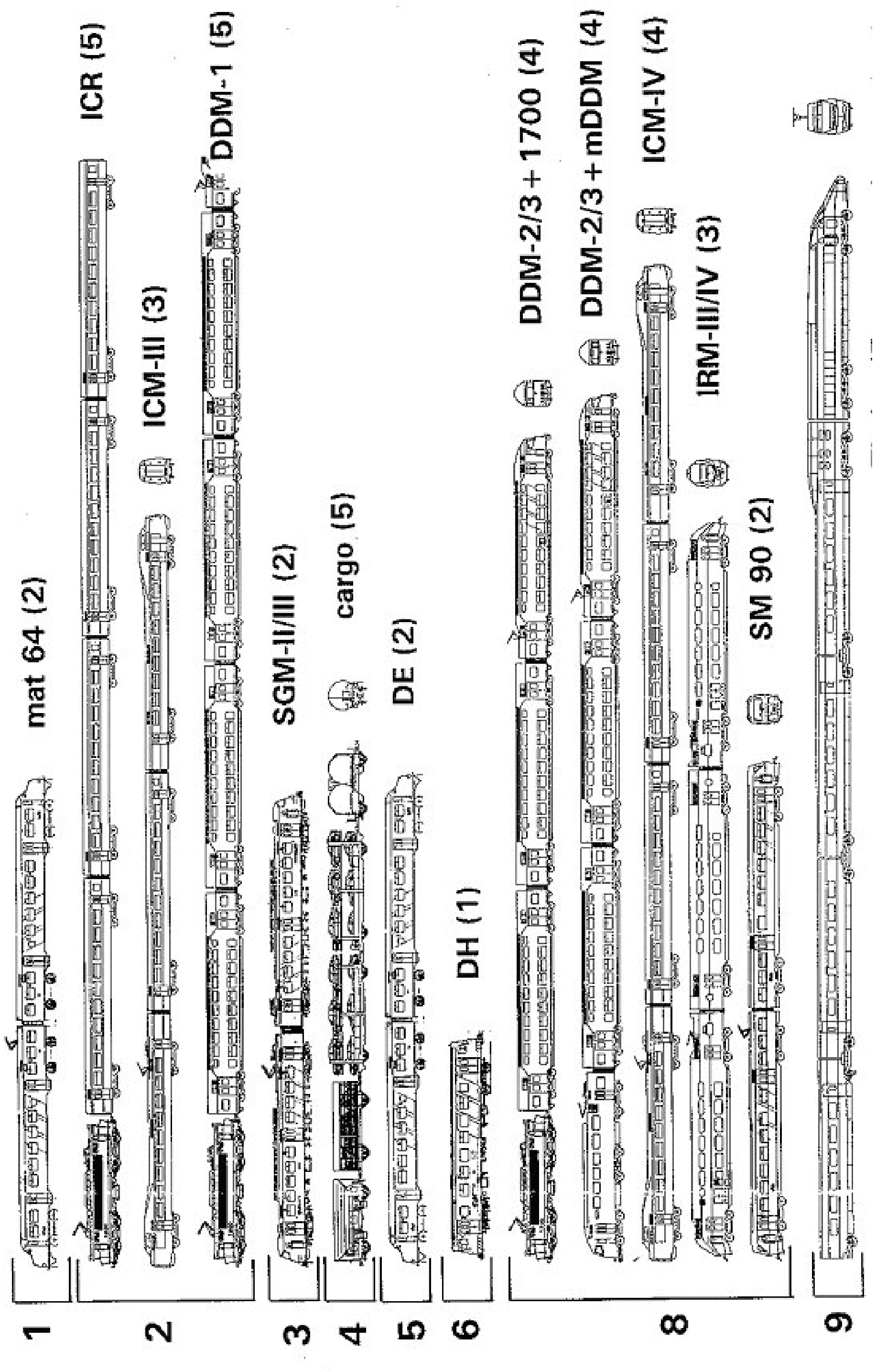

Figure 1.1. **Train categories for the calculation and measurement guidelines for rail transport noise: type (number of units)**

CHAPTER 2. THE GLOBAL dB(A) EMISSION VALUE

2.1. EMISSION VALUE IN DB(A) OF AN EMISSION SECTION

2.1.1. Main formula

$$E = 10\lg\left(\sum_{c=1}^{y} 10^{E_{nr,c}/10} + \sum_{c=1}^{y} 10^{E_{r,c}/10}\right) \qquad 2.1$$

with:
- $E_{nr,c}$ emission term per rail vehicle category for non braking trains;
- $E_{r,c}$ emission term for braking trains;
- c train category
- y total number of categories present

The emission values per rail vehicle category are determined from:

$$E_{nr,c} = a_c + b_c \lg v_c + 10\lg Q_c + C_{b,c} \qquad 2.2a$$

$$E_{r,c} = a_{r,c} + b_{r,c} \lg v_c + 10\lg Q_{r,c} + C_{b,c} \qquad 2.2b$$

The standard emission values a_c, b_c, $a_{r,c}$ & $b_{r,c}$ are given in table 2.1:

category	non-braking trains		braking trains	
	a_c	b_c	$a_{r,c}$	$b_{r,c}$
1	14.9	23.6	16.4	25.3
2	18.8	22.3	19.6	23.9
3	20.5	19.6	20.5	19.6
4	24.3	20.0	23.8	22.4
5	46.0	10.0	47.0	10.0
6	20.5	19.6	20.5	19.6
7	18.0	22.0	18.0	22.0
8	25.7	16.1	25.7	16.1
9	22.0	18.3	22.0	18.3

Table 2.1. Standard emission values as a function of railway category c

2.1.2. Data

To calculate the emission value, the following data are needed:

Q_c	average quantity of non braking trains of the considered rail vehicle category [h^{-1}];
$Q_{r,c}$	average quantity of braking trains of the considered rail vehicle category [h^{-1}];
v_c	average speed of rail cars [km/h^{-1}];
b	track type [-]

Trains are considered "braking" when the brake system is active.

To determine the emission value E, train categories according to the list in § 1.1 are used, distinguishing between braking and non-braking trains.

The following types of tracks are also distinguished:

- Railway tracks with single block or double block (concrete) sleepers, in ballast bed (index code b = 1);
- Railway tracks with wooden or zigzag concrete sleepers, in ballast bed (index code b = 2);
- Railway tracks in ballast with non-welded tracks, tracks with joints or switches (index code b = 3);
- Railway tracks with blocks (index code b = 4);
- Railway tracks with blocks and ballast bed (index code b = 5);
- Railway tracks with adjustable rail fixation (index code b = 6);
- Railway tracks with adjustable rail fixation and ballast (index code b = 7);
- Railway tracks with poured in railway lines (index code b = 8);
- Railway tracks with level crossing.

$C_{b,c}$ indicates the emission difference between a railway car on a track with concrete sleepers and one on another track type under identical circumstances. The value of $C_{b,c}$ is given in table 2.2.

For railway crossings, 2 dB are added to the value in table 2.2 according to the track type before and after the crossing. If these values differ, the construction with the highest values is used.

category	b=1	b=2	b=3	b=4	b=5	b=6[1]	b=7	b=8
1	0	2	4	6	3	-	0	2
2	0	2	5	7	5	-	0	3
3	0	1	3	5	2	-	0	2
4	0	2	5	7	4	-	0	2
5	0	1	2	4	4	-	0	2
6	0	1	3	5	2	-	0	2
7[2]	0	1	-	-	-	-	-	-
8	0	2	4	6	3	-	0	2
9	0	2	4	6	3	-	0	2

Table 2.2. Correction term $C_{b,c}$ as a function of railway category and track type b

1 tracks with b=6 are being further studied

2 tracks of category 7 are also being studied

structure type	track type on structure	index code b (SRM 1)
TT & U-type bridge	adjustable fixtures	4
plate & girder bridge	cross-ties on ballast (either wood or concrete)	1 or 2
	adjustable fixtures	4
	adjustable fixtures filled with ballast	7
steel deck bridge	block type fixation	4
	block type fixation filled with ballast	5
	embedded rails	8

Table 2.3 Correction factor for various types of concrete and steel structures compounds

2.2. MAXIMUM SPEEDS

The emission level for train speeds can be determined using a maximum speed per category as shown in table 2.4.

category	1	2	3	4	5	6	7	8	9	10
maximum calculable speed [km/h]	140	160	140	100	140	120	100	160	300	330

Table 2.4 Maximum calculable speed per category

For vehicles not mentioned in § 1, the maximum speed as specified by the manufacturer applies.

CHAPTER 3. EMISSION VALUES PER OCTAVE BAND

3.1. SOUND SOURCE HEIGHT

The emission values per octave band for categories 1 to 8 are determined for two different sound source heights:

- at the level of the railhead (emission value L_E^{bs});
- 0.5 m above the railhead (emission value L_E^{as}).

For category 9 the emission values per octave band are determined for four different sound source height:

- 0.5 m above the railhead (emission value L_E^{as});
- 2.0 m above the railhead (emission value L_E^{2m});
- 4.0 m above the railhead (emission value L_E^{4m});
- 5.0 m above the railhead (emission value L_E^{5m}).

3.2. TRACK

In order to determine the emission value per sound source level one uses the categories for railway vehicles given in § 2. The emission route is simultaneously standardised, depending on the type of track and condition of the railway tracks, as follows:

- Railway tracks with single block or double block (concrete) sleepers, in ballast bed (index code bb = 1);
- Railway tracks with wooden or zigzag concrete sleepers, in ballast bed (index code bb = 2);
- Railway tracks in ballast bed with non-welded tracks, tracks with joints or switches (index code bb = 3);
- Railway tracks with blocks (index code bb = 4);
- Railway tracks with blocks and ballast bed (index code bb = 5);

- Railway tracks with adjustable rail fixation (index code bb = 6);
- Railway tracks with adjustable rail fixation and ballast bed (index code bb = 7);
- Railway tracks with poured in railway lines (index code bb = 8);
- Railway tracks with level crossing.

When determining the emission values, distinctions are also made, according to how many track disconnections occur on the emission route concerned:

- jointless rails (fully welded tracks) with or without jointless switches or crossings (index code m = 1);
- rails with joints (= tracks with joints) or an isolated switch (m = 2);
- switches and crossings with joints, 2 per 100 meters (m = 3);
- more than 2 switches per 100 meters (m = 4);

3.3. SPECIFICATIONS

The following specifications are necessary to calculate the emission values per octave band:

Q_c	mean number of non-braking trains in the railway vehicle category concerned [h^{-1}]
$Q_{r,c}$	mean number of braking trains in the railway vehicle category concerned [h^{-1}]
v_c	mean speed of passing non-braking railway vehicles [kmh^{-1}]
$v_{r,c}$	mean speed of passing braking railway vehicles [kmh^{-1}]
bb	type of track/condition of the railway tracks [-]
m	estimation of the occurrence of track disconnections [-]
n	number of points or junctions on the emission route concerned [-]
a	length of the emission route in question, at least equivalent to the length of the point or junction [m]

Trains qualify as braking when the brake gear has been activated.

3.4. CALCULATION METHOD

The calculation proceeds as follows[3]:

[3] equations have been modified to correct errors of the RMR1996 method, similar to corrections included in RMR2002.

$$L_{E,i}^{bs} = 10\lg\left(\sum_{c=1}^{8} 10^{E_{bs,nr,i,c}/10} + \sum_{c=1}^{8} 10^{E_{bs,r,i,c}/10}\right) \tag{3.1a}$$

In the calculation model category 9 has no L_E^{bs}:

$$\begin{aligned} L_{E,i}^{as} = 10\lg\Bigg(&\sum_{c=1}^{9} 10^{E_{as,r,i,c}/10} + \sum_{c=1}^{9} 10^{E_{as,nr,i,c}/10} \\ &+ \sum_{c=1}^{9} 10^{E_{brake,i,e}/10} + 10^{E_{motor,i}/10} + 10^{E_{diesel,i}/10}\Bigg) \end{aligned} \tag{3.1b}$$

$$L_{E,i}^{2m} = 10\lg\left(10^{E_{2m,i,c}/10}\right) \tag{3.1c}$$

$$L_{E,i}^{4m} = 10\lg\left(10^{E_{4m,i,c}/10}\right) \tag{3.1d}$$

$$L_{E,i}^{5m} = 10\lg\left(10^{E_{5m,i,c}/10}\right) \tag{3.1e}$$

The following applies for categories 1, 2, 3, 6, 7 & 8:

$E_{bs,nr,i,c} = E_{nr,i,c} - 1$
$E_{bs,r,i,c} = E_{r,i,c} - 1$
$E_{as,nr,i,c} = E_{nr,i,c} - 7$
$E_{as,r,i,c} = E_{r,i,c} - 7$

The following applies for categories 4 & 5:

$E_{bs,nr,i,c} = E_{nr,i,c} - 3$
$E_{bs,r,i,c} = E_{r,i,c} - 3$
$E_{as,nr,i,c} = E_{nr,i,c} - 3$
$E_{as,r,i,c} = E_{r,i,c} - 3$

The following applies for category 9:

$E_{as,nr,i,c} = E_{nr,i,9-as}$
$E_{as,r,i,c} = E_{r,i,9-as}$
$E_{2m,i,c} = E_{i,9-2m}$
$E_{4m,i,c} = E_{i,9-4m}$
$E_{5m,i,c} = E_{i,9-5m}$

with:

$$E_{nr,i,c} = a_{i,c} + b_{i,c} \lg v_c + 10 \lg Q_c + C_{bb,i,m} \qquad 3.2a$$

$$E_{r,i,c} = a_{i,c} + b_{i,c} \lg v_{r,c} + 10 \lg Q_{r,c} + C_{bb,i,m} \qquad 3.2b$$

$$E_{brake,i,c} = a_{i,c} + b_{i,c} \lg v_{r,c} + 10 \lg Q_{r,c} + C_{brake,i,c} \qquad 3.2c$$

for c = 5

$$E_{diesel,i} = 10 \lg \begin{pmatrix} 10^{\left(a_{diesel,i} + b_{diesel,i} \lg v_5 + 10 \lg Q_5\right)/10} \\ + 10^{\left(a_{diesel,i} + b_{diesel,i} \lg v_{r,5} + 10 \lg Q_{r,5}\right)/10} \end{pmatrix} \qquad 3.2d$$

for c = 3 and c = 6

$$E_{motor,i} = 10 \lg \begin{pmatrix} 10^{\left(a_{motor,i} + b_{motor,i} \lg v_c + 10 \lg Q_c\right)/10} \\ + 10^{\left(a_{motor,i,c} + b_{motor,i} \lg vr_{r,c} + 10 \lg Q_{r,c}\right)/10} \end{pmatrix} \qquad 3.2e$$

for c = 9

$$E_{9-2m,i} = 10 \lg \begin{pmatrix} 10^{\left(a_{9-2m,i} + b_{9-2m,i} \lg v_9 + 10 \lg Q_9\right)/10} \\ + 10^{\left(a_{9-2m,i} + b_{9-2m,i} \lg v_{r,9} + 10 \lg Q_{r,9}\right)/10} \end{pmatrix} \qquad 3.2f$$

$$E_{9-4m,i} = 10 \lg \begin{pmatrix} 10^{\left(a_{9-4m,i} + b_{9-4m,i} \lg v_9 + 10 \lg Q_9\right)/10} \\ + 10^{\left(a_{9-4m,i} + b_{9-4m,i} \lg v_{r,9} + 10 \lg Q_{r,9}\right)/10} \end{pmatrix} \qquad 3.2g$$

$$E_{9-5m,i} = 10 \lg \begin{pmatrix} 10^{\left(a_{9-5m,i} + b_{9-5m,i} \lg v_9 + 10 \lg Q_9\right)/10} \\ + 10^{\left(a_{9-5m,i} + b_{9-5m,i} \lg v_{r,9} + 10 \lg Q_{r,9}\right)/10} \end{pmatrix} \qquad 3.2h$$

The values for the emission index codes can be taken from tables 3.1 & 3.2.

category	index code	octave band with centre frequency [Hz]							
		63	125	250	500	1k	2k	4k	8k
		1	2	3	4	5	6	7	8
1	a	20	55	86	86	46	33	40	29
	b	19	8	0	3	26	32	25	24
2	a	51	76	91	84	46	15	24	36
	b	5	0	0	7	26	41	33	20
3	a, v < 60	54	50	66	86	68	68	45	39
	v ≥ 60	36	15	66	68	51	51	27	21
	b, v < 60	0	10	10	0	10	10	20	20
	v ≥ 60	10	30	10	10	20	20	30	30
3 motor	a, v < 60	72	88	85	51	62	54	25	15
	v ≥ 60	72	35	50	68	9	71	7	-3
	b, v < 60	-10	-10	0	20	10	20	30	30
	v ≥ 60	-10	20	20	10	40	10	40	40
4	a	30	74	91	72	49	36	52	52
	b	15	0	0	12	25	31	20	13
5	a, v < 60	41	90	89	76	59	58	51	40
	v ≥ 60	41	72	89	94	76	58	51	40
	b, v < 60	10	-10	0	10	20	20	20	20
	v ≥ 60	10	0	0	0	10	20	20	20
5 diesel	a	88	95	107	113	109	104	98	91
	b	-10	-10	-10	-10	-10	-10	-10	-10
6	a, v < 60	54	50	66	86	68	68	45	39
	v ≥ 60	36	15	66	68	51	51	27	21
	b, v < 60	0	10	10	0	10	10	20	20
	v ≥ 60	10	30	10	10	20	20	30	30
6 motor	a, v < 60	72	88	85	51	62	54	25	15
	v ≥ 60	72	35	50	68	9	71	7	-3
	b, v < 60	-10	-10	0	20	10	20	30	30
	v ≥ 60	-10	20	20	10	40	10	40	40
7	a	56	62	53	57	37	36	41	38
	b	2	7	18	18	31	30	25	23
8	a	31	62	87	81	55	35	39	35
	b	15	5	0	6	19	28	23	19

Table 3.1 Emission index codes a_c and b_c as functions of the railway vehicle category c = 1 to 8 and octave band (i)

category	index code	octave band with centre frequency [Hz]							
		63	125	250	500	1k	2k	4k	8k
		1	2	3	4	5	6	7	8
railcar									
9-as	a	7	14	57	52	57	66	47	71
	b	27	28	12	18	18	15	21	5
9-2m	a	9	10	1	41	8	17	0	23
	b	26	28	36	22	37	34	39	24
9-4m	a	5	11	13	56	-27	-19	-37	-12
	b	27	28	31	15	50	47	53	36
9-5m	a	11	18	28	28	-50	-41	-84	-34
	b	25	26	25	25	59	56	73	45
pushed/pulled units									
9-as	a	3	10	57	50	53	62	43	67
	b	27	28	12	18	18	15	21	5
9-2m	a	3	10	57	46	47	55	37	61
	b	27	28	12	18	18	15	21	5
9-4m	a	1	8	54	40	40	49	30	54
	b	27	28	12	18	18	15	21	5
9-5m	a	3	10	54	0	0	0	0	0
	b	27	28	12	0	0	0	0	0

Table 3.2 **Emission index code a_c and b_c for railcars and pulled/pushed units of railway vehicles of category c = 9 per sound source level and octave band (i)**

Remark: A single Thalys/HST consists of two engine units and eight pulled/pushed units. See also § 8.

$C_{brake,i,c}$ is determined according to table 3.3:

octave band	$C_{brake.i.c}$			
i	c = 1, 4, 5	c = 2	c = 7	c = 3, 6, 8, 9
1	-20	-20	-8	-20
2	-20	-20	-7	-20
3	-20	-20	-20	-20
4	-2	0	-20	-20
5	2	1	-20	-20
6	3	2	-20	-20
7	8	5	-20	-20
8	9	5	-5	-20

Table 3.3 Correction factor $C_{brake.i.c}$ for brake noise as a function of the railway vehicle category (c) and the octave band (i)

The correction for track type $C_{bb,i}$ is given in table 3.6, but the effect of the track roughness has also been integrated in this correction as function of track discontinuities (m).

For m = 1, it yields that $C_{bb,i,m}$ will be calculated for different train categories by:

$$C_{bb,i,m} = C_{bb,i} \qquad 3.3a$$

For m = 2, 3 or 4, it yields:

$$C_{bb,i,m} = C_{3,i} + 10\lg(1 + f_m A_i) \qquad 3.3b$$

with: $C_{bb,i}$ the track correction from table 3.6
f_m table 3.5
A_i table 3.7

The factor f_m can take on the following values, where m does not equal 1:

description	m-type	f_m
track with rail joints	2	1/30
1 isolated switch	2	1/30
2 switches per 100 m	3	6/100
more than 2 switches per 100 m (depot)	4	8/100

Table 3.5

octave band	$C_{bb,i}$							
I	bb = 1	bb = 2	bb = 3	bb = 4	bb = 5	bb = 6	bb = 7	bb = 8
1	0	1	1	6	6	-	6	5
2	0	1	3	8	8	-	1	4
3	0	1	3	7	8	-	0	3
4	0	5	7	10	9	-	0	6
5	0	2	4	8	2	-	0	2
6	0	1	2	5	1	-	0	1
7	0	1	3	4	1	-	0	0
8	0	1	4	0	1	-	0	0

Table 3.6 Correction factor $C_{bb,i}$ as a function of structure compounds/track type (bb) and octave band (i)

The values for A_i can be found in table 3.7.

Octave band i	A_i
1	3
2	40
3	20
4	3
5, 6, 7, 8	0

Table 3.7 Code index for noise emission in the case of impact A_i as a function of the octave band (i).

3.5. EMISSION FROM CONCRETE AND STEEL BRIDGE STRUCTURES

3.5.1. Concrete structures

For concrete structures and the applied track type, the emission of both, the rolling noise and the noise radiation of the structure itself is contained in the track correction table (table 3.2 & 3.6). Therefore, at low frequencies, the effectiveness of screens, mounted on the constructions, is overestimated. This calculation model is consequently only suitable for screens with a maximum height of 2 m above BS. For higher screens, more precise acoustic analysis is necessary.

The correction factor for different track types on various types of concrete structures can be found in table 3.8.

Structure type	track	index code bb
TT & U-type bridge	adjustable fixtures	4
plate & girder bridge	cross-ties on ballast (either wood or concrete)	1 or 2
	adjustable fixtures	4
	adjustable fixtures filled with ballast	7
steel deck bridge	block type fixation	4
	block type fixation filled with ballast	5
	embedded rails	8

Table 3.8 Correction factor for track types on various types of concrete structure. The codes in this table refer back to the index codes in table 3.6

3.5.2. Steel Structures

For steel constructions and the track type constructions installed thereupon, the emission is contained in the corresponding correction factor for tracks as a result of the rolling noise (table 3.2 & 3.6). Sound emissions from the construction itself are incorporated into the final emission level by raising the emission factor E by $\Delta L_{E.bridge}$ i.e. the additional calculation *extra charge* for bridges.

As a result, the effectiveness of screens mounted on the constructions is highly overestimated. The reliability, as far as calculating screens on steel constructions is concerned, is therefore questionable.

In the case of a bridge with screens the additional correction must be determined by measurement.

3.6. MAXIMUM SPEEDS

In this unit the emission level for train speeds can be determined using a maximum speed per category as shown in table 3.9.

category	1	2	3	4	5	6	7	8	9	10
Maximum calculable speed [km/h]	140	160	140	100	140	120	100	160	300	330

Table 3.9 Maximum calculable speed per category

For vehicles not mentioned in § 1, the maximum speed as specified by the manufacturer applies.

CHAPTER 4. STANDARD CALCULATION METHOD I

4.1. SPECIFICATION OF TERMS

Reception Point

The reception point is the point at which the equivalent sound level L_{Aeq} in dB(A) should be determined. When determining the noise pollution at a gable front wall, the reception point can be found at the surface of the front wall concerned.

Source Line

The line at 0.25 m above the centre of the rail which represents the position of noise propagation.

Limiting line

Lines that indicate limitations of the emission sector of the receiving point (figure 4.1).

Height with reference to railhead

The height of the head of the rail with reference to the assessment surface: h_{bs}.

Height of receiver

Height of receiver with reference to the local ground level: h_w.

Distance to source line

Shortest distance between receiver and source line: r.

Horizontal distance to source line

Shortest horizontal distance between receiver and source line: d.

4.2. GEOMETRICAL DEFINITION OF SITUATION

From receiver W a connecting line to the centre of the track is drawn (length of WS = d). At distances 2d from W and parallel to WS we find the limiting line I_1 and I_2. The line through S perpendicular to WS represents the centre of the imaginary rail track (model of the real rail track).

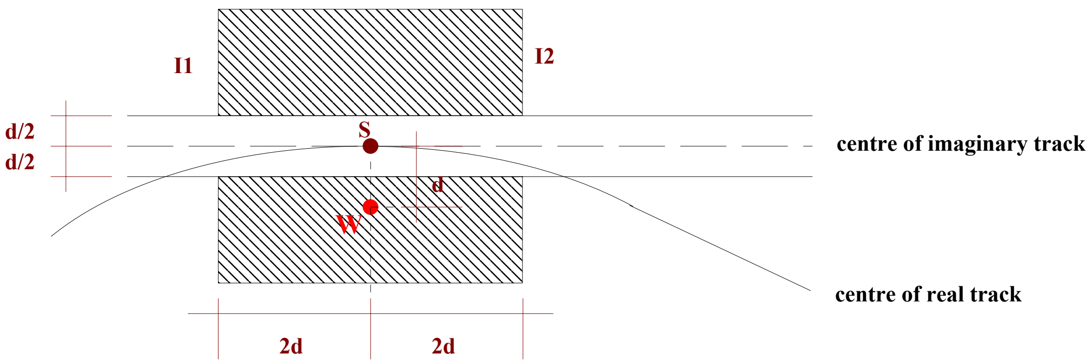

Figure 4.1. Horizontal projection of the considered area, defined to check with the conditions of application

4.3. APPLICATION AREA OF THE METHOD

The A-weighted calculus method is based on a simplification of the situation, allowing -with regard to the application area of the method - to apply following conditions for the considered area between limiting lines I_1 and I_2:

- the centre of the real track may not cross the shaded areas in figure 4.1;
- the view from the receiver may not be inhibited over an angle > 30°;
- if the railway exists of more than one section, the emission values of those sections should not differ by more than 10 dB.
- the distance d from the receiver to the centre of the railway must be at least 1.5 times the distance between the external rails of the railway;
- there should be no structures on the railway within the considered area, and no height differences of more than 3 m relative to the average height.

Screening objects and buildings between the railway and the receiver are not taken into account.

4.4. CALCULATION MODEL

The equivalent noise level L_{Aeq} in dB(A) from railway traffic is calculated with:

$$L_{Aeq} = E_s + C_{reflection} - D_{distance} - D_{air} - D_{soil} - D_{meteo} \qquad 4.1a$$

with:
- $C_{reflection}$ correction value for possible reflections coming from buildings or other vertical surfaces;
- $D_{distance}$ weakening value, depending on the distance;
- D_{air} weakening value, resulting from air absorption;
- D_{soil} weakening value, resulting from soil absorption;
- D_{meteo} correction value for meteorological conditions;
- E_s composed emission value calculated by:

$$E_s = 10\lg \frac{1}{127} \sum_{i=1}^{n} \phi_i 10^{E_i/10} \qquad 4.1b$$

with:
- E_i emission value of the section i as determined in § 2
- ϕ_i angle at which the section i is seen by the receiver
- n number of sections within the considered area

4.5. MODELLING THE SITUATION

4.5.1. Source Lines

To model the geometrical data, the baseline for vertical measurements is the railhead (BS). Horizontal measurements are taken from the centre of the track. The source line in the model is a line at 0.25 m above and along the centre of the track.

4.5.2. Reflections

In order to use the reflection value for surfaces across the track from the receiver, the following conditions must be met:

- they are acoustically reflecting;
- they are vertical and parallel to the track;
- they are higher than the receiver (h_w);

- the horizontal distance (d_r) to the source line is smaller than 100 m and also 4 times smaller than the horizontal distance (d_w) from the receiver to the source line.

4.5.3. Assessment positions

Assessment positions for buildings have to be at a height of 5 m above ground level. For residential buildings with 3 or more floors this position is taken at the top floor level (1 m below the ridge). To determine the exterior climate, an assessment position at 1.5 m above the local ground level is chosen.

4.6. REFLECTION TERM

The reflection term $C_{reflection}$ is calculated by:

$$C_{reflection} = f_{obj} \tag{4.2}$$

with: f_{obj} the object fraction which is - within a distance of $4\left(d_r + d_w\right)$, parallel to the track and symmetric to the receiver- the total length at the other side of the track over which the sound reflecting surfaces extend in relation to this distance of $4\left(d_r + d_w\right)$

d_r horizontal distance between the reflecting object and the source line

d_w horizontal distance between the receiver and the source line

4.7. ATTENUATION BY DISTANCE

The attenuation $D_{distance}$ is calculated by:

$$D_{distance} = 10 \lg r \tag{4.3}$$

with r the shortest distance between the receiver and the source line

4.8. ATTENUATION BY AIR ABSORPTION

The attenuation D_{air} is calculated by:

$$D_{air} = 0.016 r^{0.9} \tag{4.4}$$

with r the shortest distance between the receiver and the source line

4.9. ATTENUATION BY SOIL ABSORPTION

The attenuation D_{soil} is calculated by:

$$D_{soil} = 3B^{0.5}\left(1-e^{-0.03r}\right)\left(1.25e^{-0.75(0.6h_{bs}+0.5)}+e^{-0.9h_w}\right) + 1.6B - 1.8 - 3(1-B)\left(1-e^{\frac{-0.01r}{h_w+h_{bs}+0.4}}\right) \qquad 4.5$$

with B the soil factor: the part of the soil between receiver and source that is not paved

The soil factor is the part of the horizontal projection of the connection line between the receiver and the centre of the track, which lies above a not paved soil. Not paved soil is: ballast, grass, agricultural soil with or without crops, sand plains and soil without vegetation.

4.10. METEOROLOGICAL CORRECTION TERM

The meteorological correction term D_{meteo} is calculated by:

$$D_{meteo} = 3.5\left(1-e^{-0.04\frac{r}{h_w+0.6h_{bs}+0.5}-5}\right) \qquad 4.6$$

If this formula results in a negative value D_{meteo} is considered to be zero.

CHAPTER 5.
NOISE PROPAGATION CALCULATION IN OCTAVE BANDS (SRM II)

5.1. SPECIFICATION OF TERMS

Assessment point

This is the point at which the equivalent sound level should be determined. When determining the noise pollution in a front wall, the assessment point lays in surface of the front wall.

Sector

A volume limited by two vertical surfaces whose borders correspond with the perpendicular through the assessment point.

Sector Surface

The median surface of two limiting surfaces of a sector.

Opening Angle of a Sector

The angle between two limiting surfaces of a sector and the horizontal area.

Total Opening Angle of a Sector

The sum of opening angles from all sectors which are significant in the determination of the equivalent sound level in dB(A).

Viewing Angle

The angle from which an object (front, barrier, street, etc.) is viewed in horizontal projection from the assessment point.

Source Line

The line above the centre of the rail at a particular level above the upper edge of the tracks (BS), which represents the position of noise propagation. Depending on the vehicle type two to four linear noise sources can be differentiated.

Linear Source Segments

The straight line between the intersection points of a line source with the limiting surfaces of a sector.

Point Source

The intersection point of a sector area with a linear source segment.

5.2. BASIC FORMULA

5.2.1. Equivalent sound level L_{Aeq}

The equivalent sound level L_{Aeq} in dB(A) is calculated as follows:

$$L_{Aeq} = 10 \lg \sum_{i=1}^{8} \sum_{j=1}^{J} \sum_{n=1}^{N} 10^{\Delta L_{eq,i,j,n}/10} \qquad 5.1a$$

where $\Delta L_{eq.i.j.n}$ specifies the contribution in an octave band (index code i) of a sector (index code j) and a source point (index code n).

$\Delta L_{eq.i.j.n}$ includes following values:

$$\Delta L_{eq,i,j,n} = L_E + \Delta L_{GU} - \Delta L_{OD} - \Delta L_{SW} - \Delta L_R - 58.6 \qquad 5.1b$$

with
- L_E emission value per source height and octave band according to § 3.4
- ΔL_{GU} attenuation due to distance (§ 5.4)
- ΔL_{OD} attenuation due to propagation (§ 5.5)
- ΔL_{SW} screening effect, if present (§ 5.6)
- ΔL_R attenuation due to reflections, if present (§ 5.7)

5.2.2. Summation

The octave bands with the nominal centre frequencies 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz are used for summation. The classification of sectors must be arranged in such a way, that the geometry in a given sector can be well described in terms of the sector area geometry. In order to achieve a good representation of the noise emission only one emission route per sector is allowed. The maximum opening angle of a sector is set at five degrees. The number of sectors, J, is dependent on the total opening angle of the assessment point and the required sector classification.

The number of source points, N, of a sector depends on how often the source line (segment) intersects the sector area.

5.3. MODELLING THE SITUATION

5.3.1. Source Lines

The starting points for modelling the geometric situations is the railhead (BS) for vertical dimensions, and the middle of the rail for horizontal dimensions. The lines which cross the middle of the track at different levels to BS are represented as source lines in the model. There are two source lines, at 0 cm and at 50 cm above BS, for the material categories 1 to 8. For category 9, there are four source lines at 0.5 m, 2.0 m, 4.0 m and 5.0 m above the BS. The track is preferably divided in emission sections, in steps of no less than 100 m. In order to model important geographic elements it is advisable to work with smaller step sizes, particularly if the above mentioned section is too large, as can occur in the case of curves, screening or in other certain situations.

5.3.2. Composition of the ground

The composition of the land is divided into two groups: acoustically hard and non-hard. The term acoustically hard (B = 0) refers to: pavement, asphalt, concrete, other hardened/sealed ground, water surfaces and related surfaces. The term acoustically non-hard (B = 1) includes: ballast, grass surfaces, agricultural surfaces with or without vegetation, sandy surfaces, ground without vegetation, etc.

5.3.3. Ground Height Differences

The height of the source, object and assessment point are defined in relation to the average terrain height concerned. This average height is determined by the profile in the regarded sector area as an average over a given horizontal distance. The average height of the ground in the source area is therefore applicable for the source and the average height of the ground within a radius of 5 m from the equivalent barrier is applicable for a barrier (figures 5.1 & 5.2).

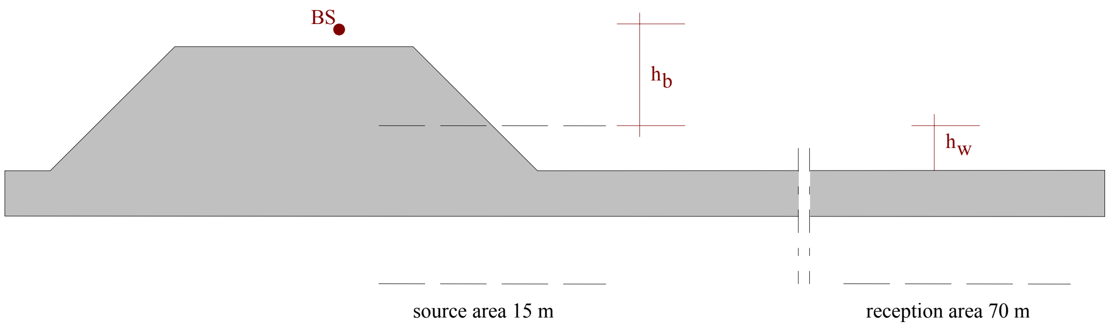

Figure 5.1 **Height in relation to the average terrain level. As a result of the raised tracks the average terrain level is situated in the source area slightly above the upper edge of the terrain, near the embankment.**

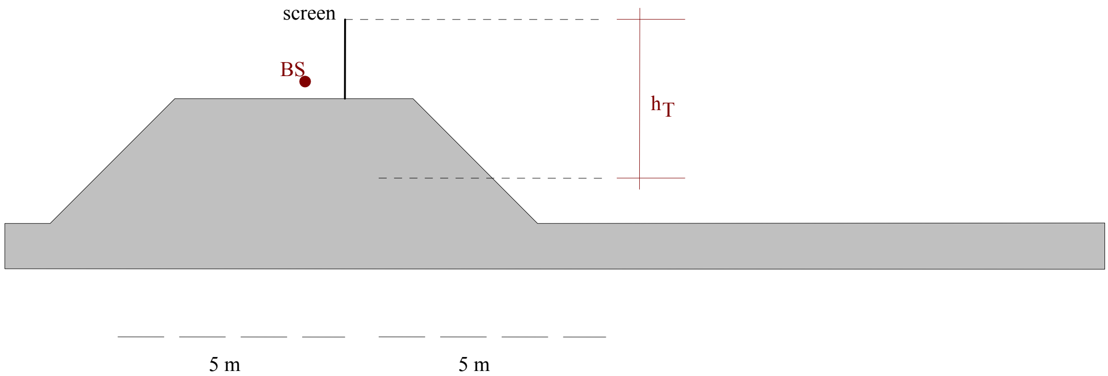

Figure 5.2 **Barrier set upon an embankment; the average terrain level to the left is slightly lower than the upper edge and to the right slightly higher than close to the embankment. The situation to the right is a determining factor for h_T.**

5.3.4. Standard Embankment

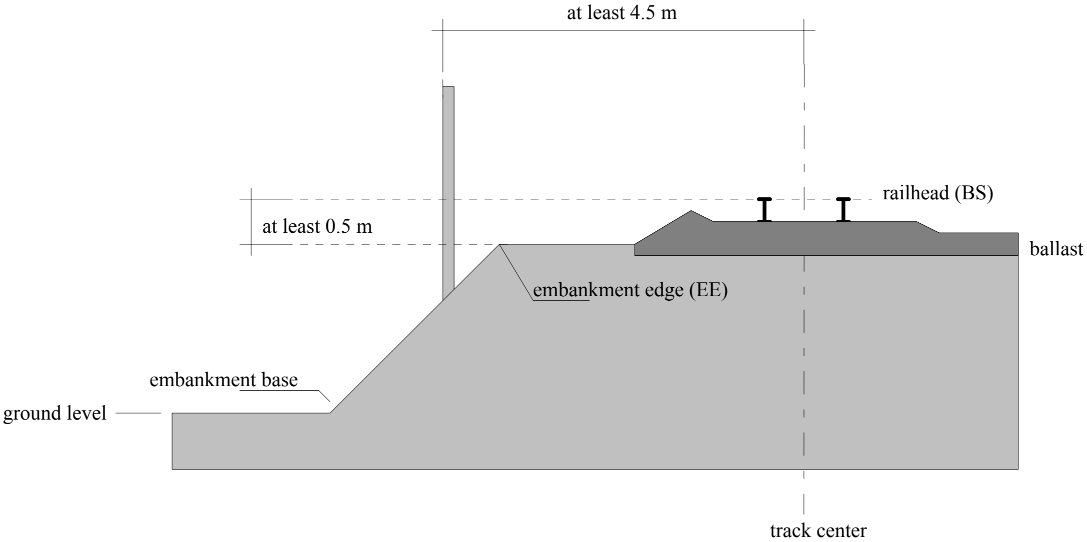

Figure 5.3 **Cross-section of a standard embankment.**

Figure 5.3 shows a cross–section of an actual track embankment. Figure 5.4 shows the corresponding model. The following rules apply when establishing a model:

- the lane is the centre focus of the model; a lane is modelled exactly between the rails for each railway line (the distance between both rails is 1.42 m).
- each lane (A) is modelled at the height of the true railhead (BS) and in the centre of the railway line (between the rails).
- a contour line and a connected obtuse barrier Cp = 2 dB (F) is modelled at a height of 0.2 m below each railway line (the absorbing ballast is situated 0.2 m beneath BS).
- the embankment (EE) is modelled as a contour line along with the connected obtuse barrier (B) at an actual height in relation to BS (b1) and the upper edge of the terrain (b2) and at a distance of 4.5 m to the next lane; if the actual distance between the centre of the tracks and EE deviates from the above mentioned 4.5 m by more than 1 m, then the actual distance concerned is modelled as b3 (in most cases the deviation falls short of 1 m and in most cases EE is situated 0.5 m beneath BS).
- a possible barrier located at the edge of the embankment is modelled as a (acute) barrier (D) with its actual height above BS (d1) and with its actual distance from the centre of the tracks (d2); (in most cases barriers are set 4.5 m from the centre of the tracks).
- the embankment base (c) is modelled as a contour line at the height of the actual upper edge of the terrain above BS (c1) and at the actual distance from the centre of the tracks (c2).
- a ratio of 1:1.5 is used for the gradient of the embankment. The edge of the ground corresponds to the line at which the flat section of the embankment begins to decline; this is to be found, according to definition, 4.5 m from the nearest source line.
- the edge of the ground is an obtuse, absorbing barrier (C_p = 2 dB);
- where ballast is present, the whole horizontal ground surface is absorbing (B = 1) as long as the actual hard sections in the area are not wider than 1 m.

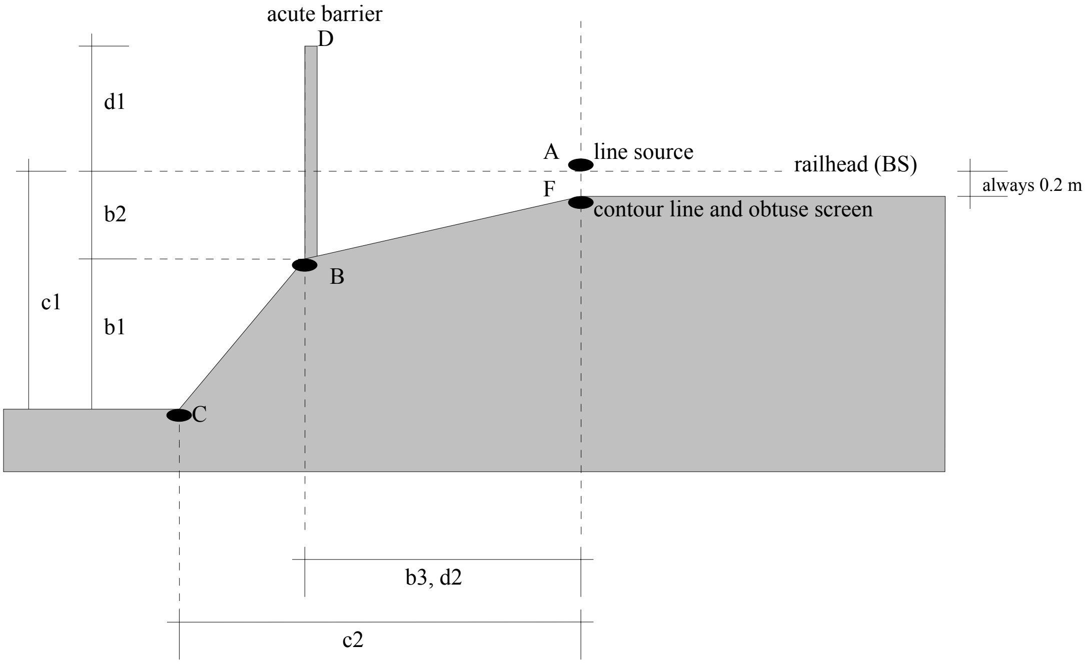

Figure 5.4 Model of a cross-section of a standard embankment

If the actual horizontal embankment dimensions (different embankment width, different gradient) deviate from the standard embankment by more than 0.5 m, the actual distances are used in the usual way.

5.3.5. Level crossing

The section of the railway tracks with a level crossing is modelled with the respective structure above the crossing and hard ground.

5.3.6. Screening slabs (U-type slabs)

The height of the walls of U-type slabs, the local height of the upper edge of the terrain and the distance are modelled corresponding to the actual values. The floor of the screening slabs is modelled at 0.2 m beneath BS. The walls are modelled as absorbing barriers with acute vertex angles (C_p = 0 dB). The correction for the structure above the tunnel depends on the respective construction concerned.

In the case of U-type slabs with absorbing wall lining (see § 5.3.10) the source lines are found at the specified height above BS.

In the case of U-type slabs without absorbing wall lining, source lines which are situated lower than the upper level of the slabs are modelled at the height of the edge or at the height of the train roof. Generally this results in a maximum height of 4.0 m.

No line sources are modelled for the actual tunnel section.

5.3.7. Barriers and screening objects

In order to qualify as a screening object, an object must:

- have complete noise insulation of at least 10 dB higher than the screening effect, in other words, the mass must be at least 40 kg/m² and have no recognisable columns or openings;
- have a viewing angle corresponding at least to the opening angle of the sector in question.

Barriers close to the track should be realised absorbent (at the track side) or have to be inclined at least 15% (see also § 5.3.10).

Reflecting barriers near the track path which show no gradient can be modelled as an absorbing barrier. However, the effective height of the barrier above BS (= $h_{s,eff}$) is calculated as follows:

$$h_{s,eff} = h_s \frac{(1+a)}{2} \qquad 5.2$$

with: a part of the barrier that is absorbent

The lowest half metre of the barrier must be absorbing in all cases.

Noise barriers close to the track path are if possible executed absorbent. § 5.3.10 describes when a barrier is considered absorbent.

In order to calculate the effectiveness of noise barriers which are mounted at the edge of embankments, a 100% absorbing barrier is presumed for octave band calculation methods.

In the case of absorbing barriers the actual height above BS is modelled; in the case of noise reflecting or partially noise reflecting barriers the above-mentioned formula for calculating the effective barrier height can be used. The conditions when a real barrier can be considered absorbing are described in § 5.3.10.

The actual effect of the barrier is probably lower if the barrier being represented is situated less than 4.5 m away from the centre of the tracks or if the barrier is higher than 4.0 m above BS and more than 4.5 m away from the track path.

5.3.8. Platforms

The height of the platform is set at 0.8 m above BS. Platforms are modelled with two absorbing obtuse barriers at each side of the platform and the side facing the tracks is situated 0.2 m from the centre of the tracks. In the case of the barrier near the tracks, the ground under the track (0.2 m below BS) and the relevant height of the upper edge of the terrain apply. The applicable profile dependant correction factor Cp is determined by considering whether an absorbing lining is present or not (see tables 5.4 and 5.3.10). Platforms which are open on both sides (i.e. lack of a side wall on the track side and the outer side) are not modelled as barriers. Platforms which are open on the track side only are to be considered absorbing.

5.3.9. Bridge constructions

In the case of bridge constructions, the actual heights and distances are modelled. The type is defined in accordance with § 3.5. If the construction is not absorbing, the entire bridge floor is modelled as hard. In the case of tracks set on ballast or poured–in tracks with at least 15 cm of ballast the whole bridge flooring is modelled as absorbing ground, unless hard sections of the bridge floor are wider than 1 m. In this case the sections concerned are modelled as hard ground elements. In the case of steel bridges the bridge body is modelled as an absorbing ground element.

In the case of steel girder bridges, T-beam bridges and solid plate web bridge, the bridge is modelled as an absorbing obtuse barrier (see table 5.4 and § 5.3.10).

In the case of U-type bridges and M-type constructions, the border is to be modelled with two absorbing obtuse barriers on both sides of the border. For the barrier near the track, the ground under the tracks (-0.2 m BS) is to be used as the reference ground level.

The profile dependent correction factor Cp is determined by considering whether an absorbing lining is present or not (see table 5.4 and § 5.3.10).

In the case of concrete constructions, barriers can be modelled to a height of 2.0 m according to barrier regulations. For higher barriers, the direct noise reflection of the construction can lead to contributions that cannot be calculated without further information, and a closer acoustic examination must be carried out.

In the case of steel constructions with screening walls, the effect of the screening cannot be calculated. The extra charge for bridges must however be applied.

5.3.10. Noise absorbent construction

Linings or constructions of screening objects, platforms, and tunnel walls are to be considered absorbing if the track specific absorption is larger than or equal to 5 dB(A). This absorption is referred to in further detail in § 5.7.

5.3.11. Reflections

If objects are found inside a sector that complies with the following conditions, L_{Aeq} is also determined by means of reflected noise that reaches the assessment point.

The contribution of reflections to L_{Aeq} is calculated as follows: The sector situated in front of the reflecting surface, when viewed from the assessment point, is substituted with its transposition on the reflecting surface.

In order to qualify as a reflecting surface, the surface must:

- be vertical;
- have a viewing angle that corresponds to the opening angle of the relevant sector;
- be situated at least two metres above the upper edge of the terrain, when the entire sector angle is taken into account;
- have an absorption coefficient of <0,8;
- be so distanced from the track path, that screening and reflection of passing trains do not have to be taken into consideration.

The influence of the reflections on L_{Aeq} has to be more closely examined, if:

- the reflecting surface forms an angle greater than 5 degrees with the vertical;
- the reflecting surfaces have irregularities that are of the same magnitude as the distance between the surface and assessment point or the distance between the surface and the source point.

In the case of multiple reflections, the reflection is taken repeatedly. The contribution of source points, where the noise reaches the assessment point after four or more reflections, is not to be taken into account. In rural areas one reflection is often enough.

5.3.12. Residential buildings and assessment points

The average height of a single storey in a residential building is set at 3 m. An inclined roof is also considered a whole storey. However modelling a sloping roof as a whole storey should not result in unrealistic reflections in the direction of the assessment point.

Assessment points in front of buildings should be selected at the level of the first storey (this corresponds to a height of 5 m above the upper edge of the terrain) and in the case of residential buildings with three or more storeys, at the height of the top storey (i.e. 1 m beneath the roof ridge). An assessment point 1.5 m above the upper edge of the terrain can also be chosen for accessible ground, for rating of outside temperatures and for rating of screening effects.

Assessment points must be modelled so that reflections against the façade in front of an assessment point do not contribute to the sound (pressure) level.

Objects in front of the first building line which are higher than 1 m above BS must be modelled. Small objects such as bays or small sheds do not have to be taken into consideration.

5.4. ATTENUATION BY DISTANCE ΔL_{GU}

5.4.1. Data

In order to calculate the geometric propagation factor the following data is necessary:

r	distance between source and assessment point, measured along the shortest connection line [m];
ν	angle between sector area and section of the source line [in degrees];
ϕ	opening angle of the sector [in degrees].

5.4.2. Calculation

The calculation of ΔL_{GU} is as follows:

$$\Delta L_{GU} = 10 \lg \frac{\phi \sin \nu}{r} \qquad 5.3$$

5.4.3. Conclusion

If the angle ν takes on a value smaller than the opening angle of the sector concerned, further examinations must be carried out to determine ΔL_{GU}.

5.5. ATTENUATION BY PROPAGATION ΔL_{OD}

Losses on the transmission path ΔL_{OD} are composed of the following factors:

$$\Delta L_{OD} = D_L + D_B + C_M \qquad 5.4$$

where

D_L	air attenuation
D_B	ground attenuation
C_M	meteorological correction factor.

5.5.1. Air attenuation D_L

The given values for δ_{air} are derived from the third band spectrum ISO-DIS 3891 at 10°C and relative humidity of 80%. Specifically in the case of the high frequency bands, certain compensations for the intense dispersion character of the absorption have been added.

5.5.1.1 Data

In order to calculate D_L the following data is necessary:

r — the distance between source and assessment point, measured at the shortest connection line [m]

5.5.1.2 Calculation

Calculation is as follows:

$$D_L = r\delta_{air} \tag{5.5}$$

where δ_{air} — air absorption coefficient

The values for δ_{air} can be found in table 5.1.

Octave band index code [-]	Octave band medium frequency [Hz]	δ_{air} [dB/m]
1	63	0
2	125	0
3	250	0.001
4	500	0.002
5	1000	0.004
6	2000	0.010
7	4000	0.023
8	8000	0.058

Table 5.1 Air absorption coefficient δ_{air} as a function of the octave band (i)

5.5.2. Ground attenuation D_B

Subdivision into three ground areas is required due to the fact that, in the model of curved sound radiation, ground reflections near the source and the observer occur and also, if the distance between source and observer is large enough, in the area in between. Each of these areas may present different ground compositions, in which case three different absorption factors are necessary for the calculation.

The term acoustically hard here refers to: pavement, asphalt and other sealed surfaces, water surfaces etc. The term acoustically non-hard refers to: grass surfaces, agricultural ground with or without vegetation, sandy surfaces, ground without vegetation etc.

5.5.2.1 Introduction

When determining the ground attenuation D_B, the horizontally measured distance between source and assessment point (symbol r_o) is divided into three areas: source area, assessment area and middle area. The source area has a length of 15 m and the assessment area a length of 70 m. The remaining section of the distance r_o between the source and assessment point forms the middle area.

If the distance between the source and assessment point is less than 85 m, the length of the middle area is zero.

If the distance r_o is less than 70 m the length of the assessment area is equal the distance r_o.

If the distance r_o is less than 15 m both the length of the source area and the length of the assessment area is equal to the distance r_o.

The (ground) absorption factor is calculated for all three areas. The absorption contribution corresponds to the ratio of the section length of the area concerned, if it is not acoustically hard, divided by the total length of the area concerned. If the length of the middle area is zero, the absorption contribution is one.

5.5.2.2 Data

To calculate ground attenuation the following factors are necessary:

r_o	horizontally measured distance between source and assessment point [m]
h_b	height of the point source above the average terrain level inside the source area [m]
h_w	height of the assessment point above the average terrain height inside the assessment area [m]
B_b	absorption factor in the source area [-]
B_m	absorption factor in the middle area [-]
B_w	absorption factor in the assessment area [-]
S_w	effectiveness of ground attenuation inside the assessment area [-]
S_b	effectiveness of ground attenuation inside the source area [-]

If h_b is less than zero, the value zero is given to h_b, and the same applies for h_w.

If a barrier does not apply to the sector concerned, both S_w and S_b are given a value of one. If a barrier is applicable, S_w and S_b are calculated using equations 5.9a and 5.9b as shown in § 5.6.

5.5.2.3 Calculation

Equation 5.6a to 5.6e are based on the equations in table 5.2.

octave band index [-]	centre frequency [Hz]	soil attenuation [dB]			
1	63		$-3\gamma_o(h_h+h_w,r_o)$		-6
2	125	$[(S_h\gamma_2(h_h,r_o)+1)B_b]$	$-3(1-B_m)\gamma_o(h_h+h_w,r_o)$	$+[(S_w\gamma_2(h_h,r_o)+1)B_w]$	-2
3	250	$[(S_h\gamma_3(h_h,r_o)+1)B_b]$	$-3(1-B_m)\gamma_o(h_h+h_w,r_o)$	$+[(S_w\gamma_3(h_h,r_o)+1)B_w]$	-2
4	500	$[(S_h\gamma_4(h_h,r_o)+1)B_b]$	$-3(1-B_m)\gamma_o(h_h+h_w,r_o)$	$+[(S_w\gamma_4(h_h,r_o)+1)B_w]$	-2
5	1000	$[(S_h\gamma_5(h_h,r_o)+1)B_b]$	$-3(1-B_m)\gamma_o(h_h+h_w,r_o)$	$+[(S_w\gamma_5(h_h,r_o)+1)B_w]$	-2
6	2000	B_b	$-3(1-B_m)\gamma_o(h_h+h_w,r_o)$	$+B_w$	-2
7	4000	B_b	$-3(1-B_m)\gamma_o(h_h+h_w,r_o)$	$+B_w$	-2
8	8000	B_b	$-3(1-B_m)\gamma_o(h_h+h_w,r_o)$	$+B_w$	-2

Table 5.2 **Equation 5.6a to e inclusive for determining ground attenuation D_B as a function of the octave band (i). Symbols printed in italics correspond to the values which must be substituted for variables x and y in γ(x,y).**

The functions γ are defined as follows:

for y ≥ 30x $$\gamma_o(x,y)=1-30\frac{x}{y}$$

for y < 30x $$\gamma_o(x,y)=0$$ 5.6a

$$\gamma_2(x,y)=3.0\left[1-e^{-y/50}\right]\ e^{-0.12(x-5)^2}+5.7\left[1-e^{-2.8\,10^{-6}y^2}\right]\ e^{-0.09x^2} \quad 5.6b$$

$$\gamma_3(x,y)=8.6\left[1-e^{-y/50}\right]\ e^{-0.09x^2} \quad 5.6c$$

$$\gamma_4(x,y)=14.0\left[1-e^{-y/50}\right]\ e^{-0.46x^2} \quad 5.6d$$

$$\gamma_5(x,y)=5.0\left[1-e^{-y/50}\right]\ e^{-0.90x^2} \quad 5.6e$$

The values in brackets following the functions concerned in equation 5.6.a to 5.6.e inclusive (in italic) are used to substitute variables x and y.

5.5.3. Meteorological correction factor C_M

Calculation of ground attenuation (§ 5.5.2) is based on downwind noise propagation. The C_M correction factor corrects to long term average conditions.

5.5.3.1 Data

In order to calculate the meteorological correction factor $C_{M,}$ the following information is necessary:

r_o	horizontally measured distance between source and assessment point [m]
h_b	height of the source point above the average terrain level inside the source area [m]
h_w	height of the assessment point above the average terrain level inside the assessment area [m]

5.5.3.2 Calculation

The calculation is as follows:

for $r_o > 10(h_b + h_w)$: $$C_M = 3{,}5 - 35\frac{h_b + h_w}{r_o} \qquad 5.7a$$

for $r_o \leq 10(h_b + h_w)$ $$C_M = 0 \qquad 5.7b$$

5.6. ATTENUATION FACTOR FOR SCREENING ΔL_{SW}

(including factors S_w and S_b from the ground attenuation equation 5.6.a to 5.6.e inclusive).

5.6.1. Description

If objects found inside a sector have at least a viewing angle that corresponds with the opening angle of the sector concerned and if we can presume that these objects interfere with sound transmission, the attenuation factor ΔL_{SW} is taken into account, along with reduced ground attenuation (expressed in terms of S_w and S_b in accordance with equation 5.5).

The formula for calculating the attenuation contributed by an object of variable shape contains two factors. The first factor describes the screening by an equivalent idealised barrier (a thin, vertical plane). The height of the equivalent barrier corresponds to the height of the obstructing object. The upper edge of the barrier corresponds to the highest edge of the obstacle. If it is possible to place the barrier in various positions, the position at which the highest attenuation occurs is chosen.

The second factor is of importance only if the profile, deviates from that of the idealised barrier. The profile is defined as the cross-section of the sector plane of the attenuating object. The attenuation of the object is equal to the attenuation of the equivalent barrier minus a correction factor C_p depending on the profile.

If several attenuating objects are present in a sector, only the object that - in the absence of the others - would cause the most attenuation is taken into account.

5.6.2. Data

In order to calculate attenuation the following data is necessary:

z_b	height of the source relative to the reference height (= horizontal plane where z = 0) [m]
z_w	height of the assessment point relative to the reference height (= horizontal plane where z = 0) [m]
z_T	height of top of barrier relative to the reference height [m]
h_b	height of the point source above the average terrain level inside the source area [m]
h_w	height of the assessment point above the average terrain level inside the assessment area [m]
h_T	height of the upper edge of the idealised barrier relative to the average terrain level in a 5 m range around the barrier. If the values on both sides of the barrier differ, h_T represents the highest of the two values [m]
r	distance between the source and assessment point measured along the shortest connection line [m]
r_w	horizontally measured distance between the assessment point and the barrier [m]
r_o	horizontally measured distance between the assessment point and the source point [m]
-	profile of the screening object

5.6.3. Calculation

- the reduced ground attenuation expressed by factors S_w and S_b from equation 5.6a to 5.6.e.
- screening effect ΔL_{SW}.

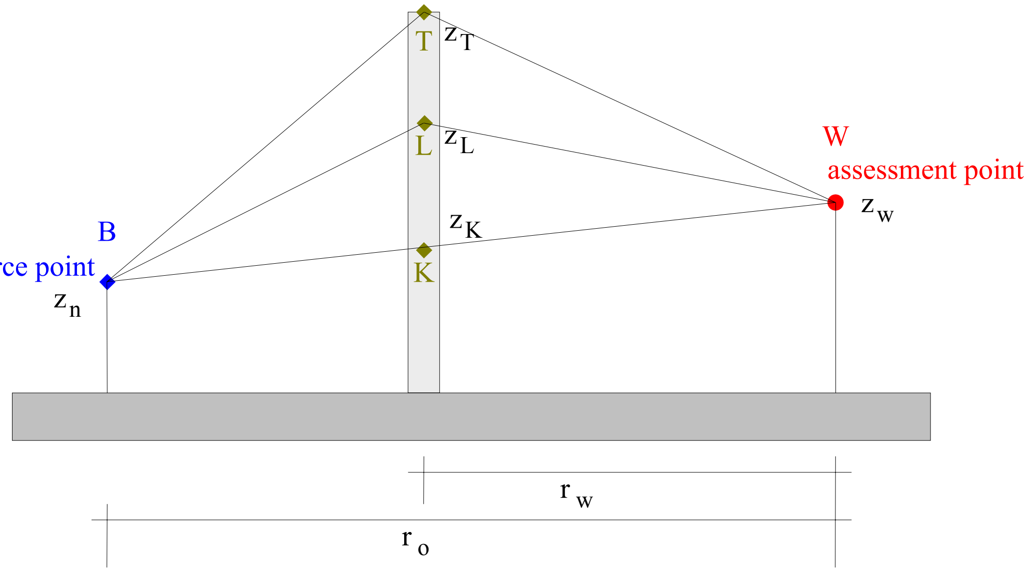

Figure 5.5 **A sector area with an idealised barrier, points K, T and L are shown.**

For the calculation, three points on the barrier are determined (see figure 5.5)

K	intersection point of the barrier and the line of sight (= directly between the source and assessment point)
L	intersection point of the barrier and a curved sound ray, that reaches the assessment point from the source point in downwind conditions
T	upper edge of the barrier

The broken line BLW is a schematic representation of the curved sound ray under downwind conditions.

These three points are to be found at the heights Z_K, Z_L and Z_T respectively above the reference height. The distance between point K and L is calculated as follows:

$$Z_L - Z_K = \frac{r_W(r_o - r_W)}{26 r_o} \qquad 5.8$$

Also:

r_L	is the sum of the partial distances BL and LW
r_T	is the sum of the partial distances BT and TW.

Factors S_w and S_b taken from equation 5.5a to h inclusive are calculated as follows:

$$S_w = 1 - \frac{r_o - r_W}{r_o} \frac{3h_e}{3h_e + h_W + 1} \qquad 5.9a$$

if $h_e < 0$ then $S_w = 1$

$$S_b = 1 - \frac{r_w}{r_o} \frac{3h_e}{3h_e + h_b + 1} \qquad 5.9b$$

if $h_e < 0$ then $S_b = 1$

h_e is the effective barrier height calculated as follows:

$$h_e = Z_t - Z_L \qquad 5.10$$

The attenuation factor ΔL_{SW} is calculated as follows:

$$\Delta L_{SW} = HF(N_f) - C_p \qquad 5.11$$

where H — screening performance
F (N_f) — function with argument N_f (= Fresnel number)
C_p — correction factor depending on the profile

If the attenuation factor ΔL_{SW} as calculated with equation 5.11 is negative, the following applies $\Delta L_{SW} = 0$.

H is determined as follows:

$$H = 0.25 h_T 2^{i-1} \qquad 5.12$$

where i — octave band index

The maximum value of H is 1.

The definition of the function F can be taken from equation 5.13a to f inclusive, as shown in table 5.3. The values for C_p can be found in table 5.4

valid for interval N_f		definition $F(N_f)$
from	to	
-∞	-0.314	0
-0.314	-0.0016	$-3.682 - 9.288 \lg \lvert N_f \rvert - 4.482 \lg^2 \lvert N_f \rvert - 1.170 \lg^3 \lvert N_f \rvert - 0.128 \lg^4 \lvert N_f \rvert$
-0.0016	+0.0016	5
+0.0016	+1.0	$12.909 + 7.495 \lg N_f + 2.612 \lg^2 N_f + 0.073 \lg^3 N_f - 0.184 \lg^4 N_f - 0.032 \lg^5 N_f$
+1.0	+16.1845	$12.909 + 10 \lg N_f$
+16.1845	+∞	25

Table 5.3 Definition of function F with variables N_f for 5 intervals of N_f (equation 5.13a to f inclusive)

C_p	Object (T = top angle in degrees)
0 dB	▪ thin wall with a vertical angle ≤ 20° ▪ Ground elevations where 0° ≤ T ≤ 70° ▪ all ground elevations with thin walls, if the total height is less than twice the wall height ▪ all buildings
2 dB	▪ edge of a filled land site ▪ ground elevation where 70° ≤ T ≤ 165° ▪ all ground elevations with thin walls, if the total height is more than twice the wall height ▪ noise absorbing edge of the railway side of a platform ▪ edge of the platform not facing the railway track ▪ edge of a railway line situated on a viaduct or bridge, except U-type bridge or M-track ▪ noise absorbing edge of a U-type bridge facing the railway line ▪ edge of a U-type bridge not facing the railway line ▪ absorbing edge of a M-track facing the railway line ▪ edge of a M-track not facing the railway line
5 dB	▪ edge (non-absorbing[4]) of the side of a platform facing the railway line ▪ edge (non-absorbing[1]) of the side of a platform facing the railway line U-type bridge ▪ edge (non-absorbing[1]) of the side of the M-track facing the railway line

Table 5.4 Correction factor C_p depending on profile. T is the upper angle of the cross-section of the object.

N_f is determined as:

$$N_f = 0.37\varepsilon 2^{i-1} \qquad 5.13$$

where ε acoustic pathway, defined as follows:

for $z_T \geq z_k$ $$\varepsilon = r_T - r_L \qquad 5.14a$$

for $z_T < z_K$ $$\varepsilon = 2r - r_T - r_L \qquad 5.14b$$

In cases where the profile of the screening object does not correspond to a profile in table 5.4, the attenuation of the object must be determined by means of further examination.

[4] see §5.3.10

5.6.4. Conclusion

If the sound insulation is less than 10 dB above the calculated attenuation $\Delta L_{SW,}$ the complete noise reducing effect of the object must be determined by means of further examination.

5.7. DETERMINING RAILS SPECIFIC ABSORPTION

The absorption coefficients α will be averaged using a weighting factor. As weighting factor the averaged A-weighted 1/3 octave spectrum of the traffic spectrum is used.

Following this, ΔL can be read from all third octave bands by means of equation 5.16 of absorption values, with the weighted average value of α. ΔL is rounded off to the full dB and has a maximum value of 10 dB(A).

Thirds [Hz]	Railway traffic Spectrum [dB]	Spectrum [dB]	Ki [-]
100		-24.0	1
125	-16,2	-21.0	2
160		-19.2	3
200		-17.0	5
250	-10,0	-15.0	8
315		-13.2	12
400		-11.7	17
500	-6,1	-10.8	21
630		-10.4	23
800		-10.0	25
1000	-4,9	-9.7	27
1250		-9.4	29
1600		-9.4	29
2000	-5,0	-9.4	29
2500		-10.6	22
3150		-17.1	5
4000	-15.0	-21.0	2
5000		-24.0	1

Table 5.5 Weighting factors Ki for railway noise to be used in the calculation of a unit value in dB(A) for the absorption value of sound barriers.

Where for railway traffic: Σ Ki = 261

The traffic specific absorption can be expressed in dB(A) with the help of equation 5.15.

$$\Delta L_{A,\alpha,\mathrm{traffic}} = -10\lg\left(\frac{\Sigma(K_i * \alpha_i)}{\Sigma K_i}\right) \qquad 5.15$$

5.8. REDUCTION OF LEVELS AS A RESULT OF REFLECTIONS ΔL_R

5.8.1. Data

In order to calculate level reductions as a result of absorption caused by reflections, the following data is necessary:

N_{ref}	number of reflections (see also § 5.3) between source point and assessment point [-]
-	type of reflecting object

5.8.2. Calculation

The calculation is as follows:

$$\Delta L_R = N_{ref}\,\delta_{ref} \tag{5.16}$$

where δ_{ref} level reduction by means of reflection.

5.8.3. Results

For buildings $\delta_{ref} = 0.8$ is valid for all octave bands. For all other objects $\delta_{ref} = 1$ is valid for all octave bands, unless the object is proven to be sound absorbing. In this case, $\delta_{ref} = 1 - \alpha$ per octave band is valid, where α is the sound absorption factor of the object in the octave band concerned. The highest value for N_{ref} is 3.

5.9. THE OCTAVE BAND SPECTRUM OF THE EQUIVALENT NOISE LEVEL

For a precise determination of the equivalent noise level in residential buildings, it is preferable to have access to the octave band spectrum that is used in the case of noise fields valid for facades. By means of the method described, approximately eight values are obtained for the equivalent noise level in the various octave bands. The A-weighting is already included. In all reports it is necessary to specify the relevant octave spectrum along with the equivalent noise level in dB(A).

The dependent equivalent sound level A in octave band i, symbol $L_{eq.i}$, is calculated as follows:

$$L_{eq,i} = 10 \lg \sum_{j=1}^{J} \sum_{n=1}^{N} 10^{\Delta L_{eq,i,j,n}/10} \qquad 5.17$$

where the definitions of the values and their effects are the same as in equation 5.1a.

CHAPTER 8. EMISSION REGISTER

8.1. CONTENTS

The emission register contains all parameters required for determination of the emission values:

a. a map with indication of the track position for the considered region under management of the emission register manager;
b. a description of the tracks with start and end point, and if present all stations and their position;
c. the track intensity in units per hour, averaged over a year, for day, evening and night period, with a distinction between braking and non braking trains and vehicle category;
d. the average speed per vehicle category per section, and if necessary per period;
e. a description per track of the track construction and if present all bridge constructions, level crossings, switches and/or other particularities;

Considering the fact that these data need to be directly used for acoustical surveys, they need to comply with the minimum requirements for accuracy. With this, the efficiency should not be neglected: collecting and storing data requires a certain amount of effort that can increase exponentially if the requirements become too strict.

For each type of data mentioned above, the minimum requirements are described below.

Map

The map must state a unique link between the gathering of data and the track route. A certain scale level is not imposed as it depends on the complexity. In most cases, a scale of 1/25 000 is sufficient, but in some urban areas 1/10 000 is necessary. A stepless adjustable electronic version must -for each route- provide the link with the data.

Tracks

The start and end of each track must accurately be stated in metres. For a multi track route, the type of track must be stated. For the position of stations, a global indication with an accuracy of 100 m and the name is sufficient.

Vehicle intensity

Use of the track must be stated per track, in units per hour, rounded up to 0.1 unit. The statement is done per vehicle category according to § 1, over day, evening and night period.

Speed profile

Speeds on the route, averaged over a year, are stated per vehicle category, including indication where the vehicles at normal conditions in the service use their brakes. If several speed profiles need to be used, an indication of which part of the vehicles use which profile is necessary (see also intensities). Speeds are to be rounded up to the nearest 5 km/h.

Track

The position – beginning and end – of the constructions described in § 1 are indicated with an accuracy of 1 m. In very complex situations (several switches over distances less than 100 m) an indication of the number of joints over the complex situation is sufficient, depending on the total number of switches.

Barriers (not mandatory)

If the position of barriers is included in the register, the following data should be stated:

a. beginning and end [m];
b. track along which it is placed;
c. indication whether it is placed on the left or the right side of the track;
d. height [dm].

Height (not mandatory)

The height must be given per at least 100 m of track in dm above NAP.

~~9.3.~~8.2. STRATEGIC NOISE MAPPING

8.2.1. Emission values

The calculated noise levels at the assessment points fulfil the criteria for strategic noise mapping if the emission register contains corresponding data:

for L_{day} yearly average of vehicle density during day period for each vehicle category;
for $L_{evening}$ yearly average of vehicle density during evening period for each vehicle category;
for L_{night} yearly average of vehicle density during night period for each vehicle category.

The global evaluation parameter L_{den} is then calculated according to the procedure in EC-document 6660, annex I.

$$L_{den} = 10\lg\frac{1}{24}\left(12*10^{L_{day}/10} + 4*10^{L_{evening}+5/10} + 8*10^{L_{night}+10/10}\right) \qquad 9.1$$

with: L_{day} A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the day periods of a year
$L_{evening}$ A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the evening periods of a year
L_{night} A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year

8.2.2. Meteo

If meteorological conditions similar to the other interim calculation methods have to be applied, following hypotheses should be realised:

- down wind:
  - day period: 50%;
  - evening period: 75%;
  - night period: 100%.

This is only possible in the octave band calculation method: SRMII. In this method, the basic calculation of ground effect is based on downwind curve effects (theory of Maekawa); a meteo correction term C_{meteo} is applied for global overall calculation.

Thus, C_{meteo} = 0, leads to downwind calculation. Combination according to the percentage of downwind and global conditions leads to the required values.

8.2.3. Assessment points

According to END, the assessment points are to be situated:

- height: 4 m;
- distance to façade: 2 m;
- calculation without reflection on the considered façade.

This is possible in the SRM I and SRM II calculation methods: reflection is not taken into account.