Contents

Comparison of Emission Calculation Methods for Rail Traffic
1 Train Categories
   1.1 Location of Source(s)
2 Basic Sound Parameter, Reference Distance, Speed Influence
   2.1 Track Influence
3 Summary and Assessment

Railway Noise (SRM II) - Noise Emission Databases
Description of a method to determine European train and track emissions: Measurement procedures and correction terms.
1 GENERAL COMMENTS ABOUT THE USABILITY OF DUTCH EMISSION METHODS AND DATABASE
2 BRIEF COMMENTS ABOUT OTHER DOCUMENTED METHODS
3 DESCRIPTION OF MEASUREMENT METHODS
4 EUROPEAN DATABASES
   4.1 TRAIN EMISSION DATABASE
   4.2 RAIL ROUGHNESS DATABASE
5 ADAPTATION OF EMISSION CALCULATION METHOD

Revised Noise Emission Data for RMR
1 Existing Rail Vehicle categories
   1.1 Emission Values per Octave Band
      1.1.1 Sound source height
      1.1.2 Track
      1.1.3 Specifications
      1.1.4 Emission from concrete and steel bridge structures
      1.1.5 Maximum Speeds
2 Measurement method
   2.1 Procedure A: Simplified method
      2.1.1 Assignment to an existing train category
      2.1.2 Reporting
   2.2 Procedure B: Comprehensive methods for characterisation of vehicle and track
      2.2.1 Introduction
      2.2.2 Measurement conditions and configuration
      2.2.3 Number and condition of rail vehicles
      2.2.4 Tracks
      2.2.5 Acoustical environment
      2.2.6 Meteorological conditions and background noise level
      2.2.7 Measurement positions and quantities
      2.2.8 Measurement equipment
      2.2.9 Definitions
      2.2.10 Traction noise
      2.2.11 Rolling noise
      2.2.12 Aerodynamic noise
      2.2.13 Braking noise
      2.2.14 Calculation of emission terms
      2.2.15 Test report
   2.3 Measurement methods for determining wheel and rail corrugation
      2.3.1 Relation between vertical railhead vibration and total roughness (for Alternative 2 only)
      2.3.2 L_{r(V,f)} - Roughness as a function of frequency, speed dependent
      2.3.3 Average rail roughness of the national network of the M.S.
      2.3.4 Measurement of track response using a reference vehicle

Project: Wölfel Meßsysteme · Software GmbH & Co (main contractor) - AIB-Vinçotte EcoSafer - AKRON n.v.-s.a. - LABEIN Technological Centre S.L. - Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG - LÄRMKONTOR GmbH
2.4 Procedure C: Measurement method for track characteristics
2.4.1 Introduction
2.4.2 Measurement set-up
2.4.3 Determination of correction values for track characteristics
2.4.4 Reporting

EUROPEAN DATABASES
1 TRAIN EMISSION DATABASE
   1.1 New train emission Database
2 RAIL ROUGHNESS DATABASE
Comparison of Emission Calculation Methods for Rail Traffic

prepared by LÄRMKONTOR GmbH

The emission calculation methods of the following models were included in the comparison:
1. RMR 96 (the Netherlands, interim model for EU),
2. Schall 03 (Germany),
3. ÖN S5011 (Austria),
4. NMT (Nordic countries)

In general, the calculation procedure can be divided into the following parts:
1. train categories,
2. location of source(s),
3. basic sound parameter, reference distance, speed influence
4. track conditions,

1 Train Categories

RMR 96:

IN RMR trains are divided into the following railway vehicles categories. These are primarily differentiated on the basis of drive unit and wheel brake system into the following categories (see Figure 1):

1. Brake-padded passenger trains
   - Exclusively electric passenger trains with brake-pads including the corresponding Locomotive, as well as trains from the 1964 Series and passenger trains belonging to Deutsche Bahn (DB);
   - Electrical motor mail vehicle;
2. Disk-braked and brake-padded passenger trains
   - Electric passenger trains primarily with disk-brakes and additional brake-pads, 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 Europa Express (TEE);
   - Electric locomotives such as those from the 1100, 1200, 1300, 1500, 1600 and 1700 series of the Belgian Railway Society (B)
3. Disk-braked passenger trains
   - Exclusively passenger trains with disk-brakes and engine noise, as for example the municipal material (SGM, sprinter);
4. Brake-padded freight trains
   - All types of freight trains with brake-pads;
5. Brake-padded diesel trains
WP 3.2.2: Railway Noise - Noise emission: databases

- Exclusively diesel-electrically driven passenger trains with brake-pads 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;

6. Diesel trains with disk-brakes
- Exclusively diesel-hydraulically driven passenger trains with disk-brakes and engine noise;

7. Disk-braked urban subway and rapid tram trains
- Urban subway and rapid tram trains;

8. Disk-braked InterCity and slow trains
- Exclusively electric passenger trains with disk – brakes including the corresponding locomotives, as for example InterCities of the ICM-IV, IRM and SM90 types;
- Electric passenger trains with primarily disk – brakes and additional sinter and ABEX brake-pads including the corresponding locomotives as for example the InterCities of the ICM-III and DDM-2/3 types;

9. Disk-braked and brake-padded high speed trains
- Electric trains with primarily disk – brakes and additional brake-pads on the engine car, as for example the TGV-PBA or Thalys (HLSSouth) types;

10. provisionally reserved for high speed trains of the ICE-3(M) (HAST East) type
- Vehicles not mentioned here are allocated to the next appropriate category based on their drive unit, wheel brake system or maximum speed.
Figure 1

Project team: Wölfel Meßsysteme · Software GmbH & Co (main contractor) · AIB-Vinçotte EcoSafer · AKRON n.v.-s.a. · LABEIN Technological Centre S.L. · Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG · LÄRMKONTOR GmbH
WP 3.2.2: Railway Noise - Noise emission: databases

### Table 1: Maximum speeds per category

The max. speed that can be used in the emissions calculation is shown in Table 1. In the case of vehicles not mentioned in Table 1, the maximum speed as specified by the manufacturer applies.

#### SCHALL 03:

In Schall 03 the train categories shown in the following table are considered:

<table>
<thead>
<tr>
<th>No</th>
<th>Train category</th>
<th>v_max in km/h</th>
<th>average train length in m</th>
<th>percentage of wagons with disk brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICE</td>
<td>250</td>
<td>420</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>EC/IC</td>
<td>200</td>
<td>340</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>IR</td>
<td>200</td>
<td>205</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>D/FD-Zug</td>
<td>160</td>
<td>340</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Eilzug</td>
<td>140</td>
<td>205</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Nahverkehrszug</td>
<td>120</td>
<td>150</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>S-Bahn (Triebzug)</td>
<td>120</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>S-Bahn Berlin</td>
<td>100</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>S-Bahn Hamburg</td>
<td>100</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>S-Bahn Rhein-Ruhr</td>
<td>120</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td>Güterzug (Fernv.)</td>
<td>100</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Güterzug (Nahv.)</td>
<td>90</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>U-Bahn</td>
<td>80</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>14</td>
<td>Straßenbahn/Stadtbahn</td>
<td>60</td>
<td>25</td>
<td>100</td>
</tr>
</tbody>
</table>

#### ÖN S5011:

In ÖN S5011 four train categories are considered:

- Intercity trains with
  - Block brakes,
  - Disc brakes,
  - Combinations,
- Railcar fast trains 4010,
- Tandem railcars 4020,
- Goods trains with
- 2 locomotive types (electric, Diesel).

No further specifications of train length or brake types.
NMT:
In NMT typical trains from Norway, Sweden and Finland are considered.

Norway:
- standard passenger train;
- B 65 (passenger);
- B 69 (passenger);
- B 70 (passenger);
- standard goods train
all with electric engines.

Sweden:
- Standard passenger train,
- fast passenger train X2,
- passenger train X10,
- standard goods train,
- standard goods train with Diesel engine,
if nothing specified, with electric engines.

Finland:
- Passenger train Sm,
- Passenger train Sr1,
- standard goods train.

1.1 Location of Source(s)

RMR 96:
In RMR up to four different sources are considered. There are two different sources for train categories 1 to 8:
- At the level of the railhead,
- 0,5 m above railhead.

The source heights for category 9 are as follows:
- 0,5 m above railhead,
- 2,0 m above railhead,
- 4 m above railhead,
- 5 m above railhead.

SCHALL 03:
The source height is assumed to be at the level of the railhead.

ÖN S5011:
The source height is assumed to be 0,3 m at the level of the railhead.
NMT:

Each octave band has its individual source height as shown in the following table.

<table>
<thead>
<tr>
<th>octave band in Hz</th>
<th>source height in m</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>2</td>
</tr>
<tr>
<td>125</td>
<td>1.5</td>
</tr>
<tr>
<td>250</td>
<td>0.8</td>
</tr>
<tr>
<td>500</td>
<td>0.3</td>
</tr>
<tr>
<td>1000</td>
<td>0.4</td>
</tr>
<tr>
<td>2000</td>
<td>0.5</td>
</tr>
<tr>
<td>4000</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 3

2 Basic Sound Parameter, Reference Distance, Speed Influence

RMR 96:

For the RMR 96 the basis of the calculation is the sound power level per meter rail length for each source and each octave band between 63 Hz and 8 kHz as logarithmic function of train speed. For emission measurements the microphone distance is 7.5 m and 1.2 m above railhead. If sources above 0.5 m height have to be considered a second microphone height at 3,5 m must be added. The time signal is registered as an equivalent unweighted octave spectrum and third-octave spectrum, total A-weighted and unweighted levels. The measurement time T is also registered, which is the passage time including the 10 dB-down flanks. For a group of wagons within a train, the buffer-to-buffer time (speed/length) is taken.

The train speed is measured and must be within 5 km/h of the nominal speed for speeds below 100 km/h and 10 km/h for speeds above 100 km/h.

For vehicles with traction or aerodynamic sources at heights of 2 m and above, such as locomotives and high speed trains, additional measurements are carried out at 4 m of the track axis at a height of 1.2 and 4.5 m (±0.2 m); only at one cross-section.

The condition of the track should be as good as possible to minimise their influence.

The emission is calculated from these measurement results for each noise source and each octave band. In this step also the A-weighting is applied. The emission results are then approximated by logarithmic speed functions of the form

\[ E = a + b \times \log(v) \]

The emission represents the sound power of the considered source for one train per hour under reference track conditions. In cases where the deviation of the measurement results are higher than 1 dB, the speed range is split into different ranges and the regression calculation is done for each range separately.

To calculate the emission that is representative for the considered time interval "corrections" for the number of trains, type of locomotive (electric or Diesel), the brake, the rail roughness, the wheel roughness and the type of superstructure have to be applied to the basic speed dependent emissions.

RMR provides also a simplified calculation method for the overall A-weighted emission. The basic formula is as follows:
2.1

\[ E = 10 \log \left( \sum_{c=1}^{y} 10^{E_{nr,c}/10} + \sum_{c=1}^{y} 10^{E_{r,c}/10} \right) \]

with:

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

The emission values per rail vehicle category are determined from:

\[ E_{nr,c} = a_c + b_c \log v_c + 10 \log Q_c + C_{b,c} \] 2.2a

\[ E_{r,c} = a_{r,c} + b_{r,c} \log v_c + 10 \log Q_{r,c} + C_{b,c} \] 2.2b

with:

- \( Q_c \) 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 [-]

The standard regression coefficients are given in Table 4.

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

To determine the emission value \( E \), the defined train categories are used, distinguishing between braking and non-braking trains.

<table>
<thead>
<tr>
<th>Category</th>
<th>Non-braking trains</th>
<th>Braking trains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( a_c )</td>
<td>( b_c )</td>
</tr>
<tr>
<td>1</td>
<td>14.9</td>
<td>23.6</td>
</tr>
<tr>
<td>2</td>
<td>18.8</td>
<td>22.3</td>
</tr>
<tr>
<td>3</td>
<td>20.5</td>
<td>19.6</td>
</tr>
<tr>
<td>4</td>
<td>24.3</td>
<td>20.0</td>
</tr>
<tr>
<td>5</td>
<td>46.0</td>
<td>10.0</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>19.6</td>
</tr>
<tr>
<td>7</td>
<td>18.0</td>
<td>22.0</td>
</tr>
<tr>
<td>8</td>
<td>25.7</td>
<td>16.1</td>
</tr>
<tr>
<td>9</td>
<td>22.0</td>
<td>18.3</td>
</tr>
</tbody>
</table>

Table 4: Standard regression line coefficients as function of railway category \( c \)

To get an overview of the levels for the different train categories the emission contribution of one train to the equivalent sound level at a distance of 25 m and 4 m height is shown Figure 2 as functions of the speed. This distance was chosen for comparison reasons with other methods.
SCHALL 03:

The basic emission value is the equivalent noise level per train per hour at a distance of 25 m and a height of 4 m above railhead. 25 m is also the distance for measurements. To get the equivalent sound level for the reference time intervals (day/night) corrections have to be added to consider different train classes, train length and superstructure. Rail or wheel roughness or brake influence is not taken into account.

The basis emission is given by the following formula:

\[
L_m^{(25)} = 10 \cdot \log(l) + 10 \cdot \log(5 - 4 \cdot p) + 20 \cdot \log(v) - 9
\]

with:

- \(l\) the length of the train in m,
- \(p\) the percentage of wagons with disk brakes in fractions of 1,
- \(v\) train speed in km/h

The superstructure is ballast with wooden sleepers. No spectral calculation is foreseen.

In contradiction to the other calculation methods no individual speed influence is considered. Figure 3 shows the equivalent sound levels for all trains of Table 2 as functions of train speed.
The basic emission parameter is the sound power level per meter rail. As for the RMR method the calculation is executed for octave bands separately using the same frequency range (63Hz to 8kHz).

Measurements are carried out in 7.5 m and 15 m distance from the source (straight line between source and microphone) and 4 different heights.

The emission values are related to a ballast superstructure with wooden or concrete sleepers and rails in good conditions. A correction for rail or wheel roughness is not foreseen.

The approach is similar to the RMR but there is only one source considered and no other influencing parameter.

The NMT is based on the sound power levels per meter track in octave bands between 63 Hz and 4000.

The sound power levels are calculated from measurements of sound exposure (SEL) levels for a given train type and track type. The measurements have to be carried out in different speed intervals and octave bands between 63 and 4000 Hz. The measurement distance is between 7.5 m and 30 m from the track centre line. The full height of both rails must be visible from the measuring position, the elevation angle should be less than 20°.

Figure 4 shows the equivalent noise levels of trains from Nordic countries for a reference time interval of one hour and a train length of 100 m.
Figure 4: Equivalent noise levels for different trains in the Nordic countries. The levels are related to a distance of 25 m, a height of 4 m and a train length of 100 m, no ground effects have been applied. The N indicates Norwegian trains, the S Swedish trains and the F and R Finnish trains.

The measurement results are then normalised to a reference distance of 10 m and a height of 2 m. Corrections for ground effects (in octave bands), train length and A-weighting have to be applied during this normalisation process. The sound power levels per meter track can then be calculated by adding 16 dB to the SEL.

Then approximation functions for the results at different speeds are calculated using logarithmic speed function of the following form:

$$L_w = a + b \log(v/100 \text{ km/h})$$

The a and b coefficients are tabled for each train and each octave band.

Finally $L_w$ will be corrected for track conditions. The 24 h energy equivalent noise level (Leq), which is one of the noise indicators of the NMT is then calculated by summarising the contributions of each train during the 24 h time period and by applying all the corrections necessary to consider the propagation from the source to the receiver.

Besides the equivalent noise level a second noise indicator for the max. noise level at a given receiver is calculated. This indicator is based on the energy average over the maximum range of the instant noise level signal during the passage of a train. This value is then transformed into a power level per meter track in an analogue way as for the equivalent noise level.
2.1 Track Influence

RMR 96:

RMR 96 uses the following track classification:

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

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

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

For jointless rails (\( m = 1 \)) the track correction \( C_{bb,i,m} \) can be taken from the following table:

<table>
<thead>
<tr>
<th>octave band</th>
<th>( bb = 1 )</th>
<th>( bb = 2 )</th>
<th>( bb = 3 )</th>
<th>( bb = 4 )</th>
<th>( bb = 5 )</th>
<th>( bb = 6 )</th>
<th>( bb = 7 )</th>
<th>( bb = 8 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>-</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>8</td>
<td>8</td>
<td>-</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>-</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>9</td>
<td>-</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>2</td>
<td>-</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5: Correction factor \( C_{bb,i} \) as a function of structures above station compounds / railway track condition (bb) and octave band (i)
For the other track disconnection classes the track correction is calculated as follows:

\[ C_{bb,i,m} = C_{3,i} + 10 \times \log(1 + f_m \times A_i) \]

where:
- \( C_{3,i} \) = \( C_{bb,i} \) from Table 5 with \( bb = 3 \),
- \( f_m \) from Table 6,
- \( A_i \) from Table 7

### Table 6

<table>
<thead>
<tr>
<th>Description</th>
<th>Track disconnection</th>
<th>( f_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>rail joint</td>
<td>2</td>
<td>1/30</td>
</tr>
<tr>
<td>1 isolated point</td>
<td>2</td>
<td>1/30</td>
</tr>
<tr>
<td>2 points per 100 m</td>
<td>3</td>
<td>6/100</td>
</tr>
<tr>
<td>more than 2 points per 100 m (Terrain)</td>
<td>4</td>
<td>8/100</td>
</tr>
</tbody>
</table>

### Table 7

\( A_i \) as a function of the octave band \( i \).

<table>
<thead>
<tr>
<th>Octave band i</th>
<th>( A_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5, 6, 7, 8</td>
<td>0</td>
</tr>
</tbody>
</table>

### SCHALL 03:

SCHALL 03 distinguishes between the track classes shown in the following table:

<table>
<thead>
<tr>
<th>No.</th>
<th>Track class</th>
<th>( C_{track} ) in dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>grass covered superstructure</td>
<td>-2</td>
</tr>
<tr>
<td>2</td>
<td>ballast, wooden sleepers</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>ballast, concrete sleepers</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>hard ground (concrete, pavement, asphalt)</td>
<td>5</td>
</tr>
</tbody>
</table>

### ÖN S5011:

ÖN S5011 uses the same track classes and correction values as Schall 03 except class 1:

<table>
<thead>
<tr>
<th>No.</th>
<th>Track class</th>
<th>( C_{track} ) in dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ballast, wooden sleepers</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>ballast, concrete sleepers</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>hard ground (concrete, pavement, asphalt)</td>
<td>5</td>
</tr>
</tbody>
</table>
**AR-INTERIM-CM** (CONTRACT: B4-3040/2001/329750/MAR/C1)  
ADAPTATION AND REVISION OF THE INTERIM NOISE COMPUTATION METHODS FOR THE PURPOSE OF STRATEGIC NOISE MAPPING

WP 3.2.2: Railway Noise - Noise emission: databases

### Table 9

**NMT:**

The correction for track conditions is less specific than for the other methods. The correction is zero for ballasted tracks with continuously welded rails on concrete or wooden sleepers and typical maintenance procedures for the considered country.

If the rail or wheel surface is somewhat rougher than normal +1 to +3 dB should be used as correction. For very rough rails and/or wheels +4 to +6 dB should be used.

For particularly well maintained tracks −1 to −3 dB may be used. When the track and the wheels permanently have very smooth running surfaces larger negative values up to −6 dB may be used. The use of negative values must be based on well documented and appropriate field measurements.

In addition the following corrections have to be applied to consider the influence of joints, switches, crossings or bridges:

1. rails with joints +3 dB,
2. 10 m track length for each unit of switches and crossings +6 dB,
3. partial track length on a bridge without ballast +6 dB,
4. partial track length on a bridge with ballast +3 dB.

### 3 Summary and Assessment

The by far most detailed and specific emission calculation method is provided by RMR, followed by NMT. Compared with these methods the emission modelling of Schall 03 can only be considered as a survey method, whereas the differentiation of this method is lower than that of the simplified option (dB(A)-option) of the RMR. The ÖN S5011 is ranked between the NMT and Schall 03. In detail the differences between the emission calculation of the 4 models are summarised in Table 10.
## WP 3.2.2: Railway Noise - Noise emission: databases

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic noise parameter</td>
<td></td>
</tr>
<tr>
<td>octave band sound power level, calculated from measurements at different distances and heights, the emission is a function of train category and speed, locomotive and brake influences are considered separately</td>
<td>( L_{Aeq} ) at reference distance 25 m and 4 m height, based on measurements, the emission is a function of train category, length, percentage of disc wheels and speed</td>
</tr>
<tr>
<td>frequency range</td>
<td>from 63 Hz to 8000 Hz</td>
</tr>
<tr>
<td>location of source</td>
<td>up to 4 sources with different heights, at railhead, 0,5 m, 2 m, 4 m, 5 m above railhead, representing different mechanisms</td>
</tr>
<tr>
<td>speed dependency</td>
<td>for each octave band and source</td>
</tr>
<tr>
<td>Track influence</td>
<td>9 different classes, corrections are frequency dependent</td>
</tr>
<tr>
<td>Influence of joints, switches, crossings and bridges</td>
<td>correction table, corrections are frequency dependent</td>
</tr>
<tr>
<td>specific parameter</td>
<td>local rail and wheel roughness consideration</td>
</tr>
</tbody>
</table>

Table 10
Railway Noise (SRM II) - Noise Emission Databases

Description of a method to determine European train and track emissions: Measurement procedures and correction terms.
prepared by Labein Technological Centre S.L.

1 GENERAL COMMENTS ABOUT THE USABILITY OF DUTCH EMISSION METHODS AND DATABASE

Some general characteristics of the Dutch emission method could be remarked because their significance in the usability of the method at European level.

...Existing train category database is quite wide, as it already contains trains from different European countries: Belgian, Deutsche, Dutch and French. There is also a simple database of wheel roughness according to the type of brake system.

Besides, this train category database could grow by adding new train categories completely characterised by measurement procedure, even with more detail than the existing ones.

In that sense, the emission measurement procedure separates vehicle and track as noise sources, as it is recommended in current research projects dealing with railway noise (STAIRRS1 and HARMONISE2), in order to set priorities for noise reduction programs and to set policy responsibilities.

Noise caused by trains is characterised by rail and wheel roughness and vehicle and track transfer function. Therefore rail roughness influences on emission level. Dutch method refers train emission characterisation to Dutch national average rail roughness. The method should be adapted to avoid this dependence and to allow using other rail roughness, related to other railway systems. All this rail roughness data documented with its use will become a database.

The emission measurement procedure also allows to assign a particular train emission to an existing category. This is a much more simplified way to define train emission level...

The methods are consistent with the new draft type testing standard for railway noise prEN ISO 3095:20013. This issue is explained below.

Finally, we could bear in mind that the Dutch emission method is defined to get input data for Dutch railway calculation method, and therefore it fulfils SRM specifications: emission levels at different heights and different emission level for braking and no braking conditions, meanwhile other official European methods do not take into account these aspects when defining the emission as it is shown later.

2 http://www.harmonoise.org
2 BRIEF COMMENTS ABOUT OTHER DOCUMENTED METHODS

In the following the Dutch measurement method is referred to other documented methods for describing railway noise emission. Firstly it is mentioned the prEN ISO 3095. Different official railway calculation methods used in Europe states are also analysed. And finally there is a reference to the European project STAIRRS, funded by the European Commission's Transport and Energy Directorate and related to railway noise creation research.


The scope of pr EN ISO 3095:2001 is to specify the conditions for obtaining reproducible and comparable measurement results of levels and spectra of noise emitted by all kinds of vehicle operating on fixed tracks (except track maintenance vehicles). Data obtained using the ISO procedure could be used either for type testing, to prove that vehicle derived by manufacturers complies with noise specifications, or to check that noise emitted by one or more vehicles is within prescribed limits. Therefore obtained final result is sound pressure level emitted by these vehicles.

On the Dutch measurement method, also railway vehicle’s sound pressure level is measured in order to get input for Dutch railways calculation method. Nevertheless, last scope of this method is to derive their emission sound power level.

Anyway, there is a relationship between them, and this is that the Dutch measurement method is based on the European standard in two main matters:

- Measuring conditions and configuration are referred to pr EN ISO:3095: microphone positions (excluding positions for source heights), vehicle conditions, measurement time, and test site and meteorological conditions.
- Dutch method also refers to pr EN ISO 3095:2001 roughness measurements procedure to carry out of rail and wheel roughness.

So, although the last objective of the two methods are different, the European standard is the reference method over which the Dutch measurement method is built.

Official railway calculation method used at Europe states

Railways noise official calculation method used nowadays in Europe are the followings: CRN at United Kingdom and Ireland; NMPB/XPS 31-133 at France; Schall 03 at Germany and Luxembourg; ONORM S5011 at Austria; and Temanord 524 at Scandinavian Countries. Besides these methods, it is known that at Netherlands SRM II is used.

The comparison of the calculation method with SRM II is shown in other chapter of this railway noise emission analysis.

Here some brief comments are made about how the specific characteristics of Dutch emission database are fulfilled by other railway methods.

- In general, it can be concluded that other official methods do not separate vehicle and track as noise sources in the characterisation of railway noise emission. In that sense there is no clear quantitative reference to rail roughness influence. In most of the methods there is a general correction scheme for different track conditions (ballast, sleepers, joints and so on), but not specially reference to rail roughness. It can be mentioned that Scandinavian method considers that rail or wheel roughness can affect largely to noise emission levels (from –6 dB to +6 dB) and French method refers to a possible variance in ± 5 dB with rolling material and rail track maintenance.
- Those methods do not consider different train emissions for braking and no braking conditions as the Dutch method does. And sound emission is allocated at one single height above the rail head.
According to train emission database, logically each method contains data from the most used train categories running on each national track system. Scandinavian method describes each train category emission level by the coefficients that defines speed dependence \( a + b \log V \), in that sense is similar Dutch method. On the other hand French and British methods define a fixed general relationship with train speed \( 20 \log V \) and \( 30 \log V \), respectively, and train category databases contain an adding coefficient to emission level.

**European STAIRRS project.**

The main objectives of the project are:

1. By how much and at what cost can railway noise be reduced?
2. How can railway noise creation be classified to take into account the separation of vehicle and track contributions?

On that project new measurement techniques will be developed to describe different types of railway track and vehicles separately. And also an appropriate classification system for trains and track types will be proposed.

The partners of the project are European Rail Research Institute, Swiss, French Dutch and German National Railways Institutes, and some Technological Centres from Austria, Italy, United Kingdom, Belgium and Netherlands. The project will be finished at the end of 2002.

Although up to now there is not so much public information about the results of STAIRRS project, as far as we know from it\(^4\), some comments could be done:

Although STAIRRS project will probably propose a train emission characterisation procedure different from the Dutch one, there seems to be some similarities on their principles. STAIRRS refers to same previous documents: prEN ISO 3095 and measurement procedures defined by TNO \(^3\). And the method proposed by STAIRRS to separate vehicle and track contributions is based on four spectra: wheel and rail roughness, and vehicle and track transfer function from total roughness to noise. This global idea is similar to Dutch emission procedure.

On the other hand as a result of STAIRRS there will be a train and track database from data collection campaign carried out at four European countries.

STAIRRS project will provide information to HARMONISE project \(^2\), where new harmonised computation methods will be proposed.

To conclude it can be said that it could be necessary in the future to analyse needs and solutions to adapt STAIRRS project results to interim calculation method for railway noise.

### 3 DESCRIPTION OF MEASUREMENT METHODS

Measurement methods for determining railway noise emission defined in the Dutch method have been adapted in order to allow their use for non-Dutch rolling stock on non-Dutch tracks.

Most of the changes have been caused by the reference to Dutch national average rail roughness and to standard track values used to convert contact filter from rail roughness to rail vibration. Alternative procedures have been proposed to permit the characterisation of train emission running on non-Dutch rails.

This proposal assumes that emission correction values for track type \( C_{b,c} \) and \( C_{b,i} \) and for structures are valid for non-Dutch rails, as their descriptions are quite general and therefore useable all over Europe.

---

\(^4\) British method, CRTN, defines a specific speed dependence for noise emission of diesel locomotive on power. This relation is \(-10 \log V\).
Besides this, some hints and comments have been included to help the practical use of the methods. At the end of the methods description document there are two Flow Charts (A and B) to illustrate the different measurements needed and their purpose. These charts include numerical reference to the text description for measurement conditions and for the used formulas.

Proposed procedures are included as an Annex 1. It becomes an independent document to replace the existing one (Annex B). The changes made can be easily seen as their are marked: both new text and previous one appears in different colours (blue and yellow, respectively).

In the methods description there are also some notes about translation names proposed that concerns the work made by AKRON at this task. These notes are marked in red font.

4 EUROPEAN DATABASES

4.1 TRAIN EMISSION DATABASE

The Current Train Emission Database is composed of all Dutch vehicles and other European vehicles circulating on Dutch tracks. In order to use these categories in another type of track, a correction factor for the difference on the rail roughness should be calculated.

- Category 1: Block braked passenger trains
- Category 2: Disc braked and block braked passenger trains
- Category 3: Disc braked passenger trains
- Category 4: Block braked freight trains
- Category 5: Block braked diesel trains
- Category 6: Diesel trains with disc brakes
- Category 7: Disc braked urban subway and rapid tram trains
- Category 8: Disc braked InterCity and slow trains
- Category 9: Disc braked and block braked high speed trains
- Category 10: Provisionally reserved for high speed trains of the ICE-3 (M) (HST East)

New train emission Database

When a new train category is added to the "European Train Emission Database", the information required is the following:

- If the emission of the train is given in Global dB(A), the emission index codes for braking and non-braking conditions related to the general equation. \( E = a + b \log V \) are required. (Table 1).
- If the emission values are defined per octave band, emission index codes for each source height, for braking and non braking conditions (passage conditions) and for all octave bands; related to the general equation \( E = a + b \log V \) are required. (Table 2).
- Correction term \( C_{b,c} \) as a function of vehicle category and track type. (Only for emission in Global dB(A)) (Table 3).
- The average vehicle wheel roughness as a function of wavelength. (Only for emission in octave bands) (Table 4).
- Maximum speed per train category (Table 5)
- Number of individual units of the train, if relevant. (Table 6).
- Optionally, it can be included a side view of the train category.
## Table 1: Emission value in dB(A): emission index codes as functions of train category, and passage conditions (braking or constant speed).

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>non-braking trains</th>
<th>braking trains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$a_c$</td>
<td>$b_c$</td>
</tr>
<tr>
<td></td>
<td>$a_{br,c}$</td>
<td>$b_{br,c}$</td>
</tr>
<tr>
<td>New category</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Table 2: Emission value per octave band: emission index codes as functions of train category, source height, passage conditions (braking or non-braking) and octave band.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Train category</th>
<th>Source height (m)</th>
<th>Passage conditions</th>
<th>Emission index codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>0</td>
<td>Both</td>
<td></td>
<td>$a_{bs} i,c$</td>
</tr>
<tr>
<td>125</td>
<td>0</td>
<td>Both</td>
<td></td>
<td>$b_{bs} i,c$</td>
</tr>
<tr>
<td>250</td>
<td>0.5</td>
<td>Both</td>
<td></td>
<td>$a_{nb,i,c}$</td>
</tr>
<tr>
<td>500</td>
<td>0.5</td>
<td>No braking</td>
<td></td>
<td>$b_{nb,i,c}$</td>
</tr>
<tr>
<td>1000</td>
<td>0.5</td>
<td>Braking</td>
<td></td>
<td>$a_{br,i,c}$</td>
</tr>
<tr>
<td>2000</td>
<td>0.5</td>
<td>Braking</td>
<td></td>
<td>$b_{br,i,c}$</td>
</tr>
<tr>
<td>4000</td>
<td>2</td>
<td>Both</td>
<td></td>
<td>$a_{2m,i,c}$</td>
</tr>
<tr>
<td>8000</td>
<td>2</td>
<td>Both</td>
<td></td>
<td>$b_{2m,i,c}$</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Both</td>
<td></td>
<td>$a_{4m,i,c}$</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Both</td>
<td></td>
<td>$b_{4m,i,c}$</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Both</td>
<td></td>
<td>$a_{5m,i,c}$</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Both</td>
<td></td>
<td>$b_{5m,i,c}$</td>
</tr>
</tbody>
</table>

**Hint:** Emission index codes at each source height, are independent of the passage conditions except for 0.5 m source height, where they could be different.

## Table 3: Correction term $C_{b,c}$ as a function of railway category and track type $b$.

<table>
<thead>
<tr>
<th>category</th>
<th>$b=1$</th>
<th>$b=2$</th>
<th>$b=3$</th>
<th>$b=4$</th>
<th>$b=5$</th>
<th>$b=6$</th>
<th>$b=7$</th>
<th>$b=8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>New category</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For a new train category the emission difference between a railway vehicle on a track with concrete sleepers ($b=1$) and one on another track type ($b \neq 1$) must be calculated. For description of the different track types see § 2.2.1.2.
WP 3.2.2: Railway Noise - Noise emission: databases

Table 4: Average vehicle wheel roughness as a function of wavelength.

<table>
<thead>
<tr>
<th>Wavelength (cm)</th>
<th>Wheel roughness $L_{veh}(\lambda)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.2</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>

Wheel roughness can be directly measured as a function of wavelength or calculated from formula B.6 after measured as a function of frequency.

It is recommendable to update periodically wheel roughness data.

Table 5: Maximum speed per train category.

<table>
<thead>
<tr>
<th>New category</th>
<th>$n^\circ_1$</th>
<th>$n^\circ_2$</th>
<th>$n^\circ_3$</th>
<th>$n^\circ_4$</th>
</tr>
</thead>
</table>

Table 6: Number of individual units of the train, if relevant.

<table>
<thead>
<tr>
<th>New category</th>
<th>$n^\circ_1$</th>
<th>$n^\circ_2$</th>
<th>$n^\circ_3$</th>
<th>$n^\circ_4$</th>
</tr>
</thead>
</table>

4.2 RAIL ROUGHNESS DATABASE

As it has been exposed before, rail roughness is an important factor on railway emission calculation. Adapted Dutch calculation method allows the calculation of any train emission running on non-Dutch rails. However, when rolling noise is relevant and there are no junctions on the track, the method will need data of rail roughness to be compared with the reference rail roughness.

Therefore a rail roughness database has to be built. Rail roughness data should be measured in third octaves according to procedure in prEN ISO 3095:2001. If the roughness data is obtained by any other procedure, it should be documented that the results are comparable with the data from prEN ISO 3095:2001.

After doing some search of existing rail roughness data at different European countries, very few data has been found. Actually, neither Germany, Austria, Spain, nor Belgium have statistical relevant roughness data. There is data available of Dutch national average rail roughness.
Rail roughness database will contain local rail roughness expressed as a function of wavelength $L_{\text{tr,loc}}(\lambda)$, where $\lambda$ is in cm and the roughness is a level referred to 1 micrometer.

To allow calculation related to roughness in the frequency domain, it has to be converted as explained in Annex B.3.2 and it depends on train speed. With varying speed, the roughness spectrum curve retains its shape, but shifts in horizontal direction.

The structure of the roughness database is as described on following table.

<table>
<thead>
<tr>
<th>wave length [cm]</th>
<th>$L_{\text{tr,loc}}(\lambda)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>0.315</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

It is recommendable to update periodically rail roughness data.

5 ADAPTATION OF EMISSION CALCULATION METHOD

The changes made on the measurement methods cause some changes on the calculation of emission values defined in Dutch method. It only affects to chapter 2 of the Method.

The Global dB(A) Emission Values calculation, explained at chapter 2.2, is not affected, unless a reference to new train categories correction track data, as this correction depends on train category.

On the other hand, the calculation of Emission Values per Octave Band, described at chapter 2.3, is affected on the following aspects:

- General formulas to calculate the emission of new train categories at different heights.
- Calculation method of track type and track roughness correction.

Project team: Wölfel Meßsysteme · Software GmbH & Co (main contractor) - AIB-Vinçotte EcoSafer - AKRON n.v.-s.a. - LABEIN Technological Centre S.L. - Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG - LÄRMKONTOR GmbH
Proposed changes are included as Annex 2. It becomes an independent document to replace the existing Chapter 2 of the calculation method. The changes made can be easily seen as their are marked: both new text and previous one appears in different colours (blue and yellow, respectively).

In the text there are some notes that concerns the work made by AKRON at this task. These notes are marked in red font.

ANNEX 1: MEASUREMENT METHODS FOR DETERMINING NOISE EMISSION (to replace Annex B of existing document. This documents has itself annexed the two Flow Charts A and B. This last one should be printed in A3 paper size)

ANNEX 2: EMISSION VALUES (to replace Chapter 2 of existing document)
Revised Noise Emission Data for RMR

prepared by Wölfel Meßsysteme · Software GmbH & Co
AKRON n.v.-s.a.
LABEIN Technological Centre S.L.

The Dutch railway noise computation method has its own emission model described in Chapter 2 of the original Dutch text. In the following both, the original emission model and the measurement method outlined in the original Dutch text are explained and where necessary amended for use outside The Netherlands. It must be noted that the revisions and adaptations are minor in nature. The emission model does in fact remain unchanged. The measurement method is the recommended way to produce new emission data for the emission method to compensate for the lack of emission data of non Dutch rolling stock on non Dutch rails. Proper use of the detailed measurement method allows any M.S. to produce its own input data.

1 Existing Rail Vehicle categories

In 2, measurement methods are proposed to add additional railway vehicles to this database:

- to add vehicles to the existing (10) categories;
- to add additional categories.

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 by 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 municipal 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 Thalys (HST) 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 drive unit, wheel brake system or maximum speed.

Figure 5 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 5-Train categories for the calculation and measurement guidelines for rail transport noise: type (number of units)
1.1 Emission Values per Octave Band

1.1.1 Sound source height

The emission values per octave band are determined for five different sound source heights:

- at the level of the railhead (emission value $L_{E_{bs}}$);
- 0.5 m above the railhead (emission value $L_{E_{as}}$);
- 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 $L_{E_{5m}}$);

Not all train categories have dominant emission at all heights. More specifically, high speed trains have important source levels at higher heights. For vehicles designed for lower speed, the emission values at higher heights can be set to zero.

1.1.2 Track

In order to determine the emission value per sound source level one uses the categories for railway vehicles given in 1. 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);

1.1.3 Specifications

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

- $Q_c$ the mean number of non-braking trains in the railway vehicle category concerned [h\(^{-1}\)]
- $Q_{br,c}$ the mean number of braking trains in the railway vehicle category concerned [h\(^{-1}\)]
WP 3.2.2: Railway Noise - Noise emission: databases

\( v_c \)  
the mean speed of passing non-braking railway vehicles [kmh\(^{-1}\)]

\( v_{br,c} \)  
the 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.

Calculation method

The calculation proceeds as follows:

\[
L_{E,i}^{bs} = 10 \lg \left( \sum_{c=1}^{8} 10^{E_{bs,nr,i,c} / 10} + \sum_{c=1}^{8} 10^{E_{bs,r,i,c} / 10} \right) \quad 2.3a
\]

In the calculation model category 9 has no \( L_{E}^{bs} \)

\[
L_{E,i}^{as} = 10 \lg \left( \sum_{c=1}^{9} 10^{E_{as,r,i,c} / 10} + \sum_{c=1}^{9} 10^{E_{as,nr,i,c} / 10} \right)
+ \sum_{c=1}^{9} 10^{E_{brake,i,c} / 10} + 10^{E_{motor,i} / 10} + 10^{E_{diesel,i} / 10} \quad 2.3b
\]

\[
L_{E,i}^{2m} = 10 \lg \left( 10^{E_{2m,i,c} / 10} \right) \quad 2.3c
\]

\[
L_{E,i}^{4m} = 10 \lg \left( 10^{E_{4m,i,c} / 10} \right) \quad 2.3d
\]

\[
L_{E,i}^{5m} = 10 \lg \left( 10^{E_{5m,i,c} / 10} \right) \quad 2.3e
\]

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:

\[
E_{bs,nr,i,c} = E_{nr,i,c} - 3
\]

\[
E_{bs,r,i,c} = E_{r,i,c} - 3
\]

\[
E_{as,nr,i,c} = E_{nr,i,c} - 3
\]
The following applies for category 9:

\[ E_{as,r,i,c} = E_{r,i,c} - 3 \]

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

with:

\[ E_{nr,i,c} = a_{i,c} + b_{i,c} \log v_c + 10 \log Q_c + C_{bb,i,m} \]
\[ E_{r,i,c} = a_{i,c} + b_{i,c} \log v_r + 10 \log Q_r + C_{bb,i,m} \]
\[ E_{\text{brake},i,c} = a_{i,c} + b_{i,c} \log v_r + 10 \log Q_{r,c} + C_{\text{brake},i,c} \]

for \( c = 5 \)

\[ E_{\text{diesel},i} = 10 \log \left( \frac{10^{a_{\text{diesel},i} + b_{\text{diesel},i} \log v_5 + 10 \log Q_5}}{10^{a_{\text{diesel},i} + b_{\text{diesel},i} \log v_{r,5} + 10 \log Q_{r,5}}} \right) \]

for \( c = 3 \) and \( c = 6 \)

\[ E_{\text{motor},i} = 10 \log \left( \frac{10^{a_{\text{motor},i} + b_{\text{motor},i} \log v_c + 10 \log Q_c}}{10^{a_{\text{motor},i} + b_{\text{motor},i} \log v_{r,c} + 10 \log Q_{r,c}}} \right) \]

for \( c = 9 \)

\[ E_{9-2m,i} = 10 \log \left( \frac{10^{a_{9-2m,i} + b_{9-2m,i} \log v_9 + 10 \log Q_9}}{10^{a_{9-2m,i} + b_{9-2m,i} \log v_{r,9} + 10 \log Q_{r,9}}} \right) \]
\[ E_{9-4m,i} = 10 \log \left( \frac{10^{a_{9-4m,i} + b_{9-4m,i} \log v_9 + 10 \log Q_9}}{10^{a_{9-4m,i} + b_{9-4m,i} \log v_{r,9} + 10 \log Q_{r,9}}} \right) \]
\[ E_{9-5m,i} = 10 \log \left( \frac{10^{a_{9-5m,i} + b_{9-5m,i} \log v_9 + 10 \log Q_9}}{10^{a_{9-5m,i} + b_{9-5m,i} \log v_{r,9} + 10 \log Q_{r,9}}} \right) \]

The values for the emission index codes can be taken from tables 2.5 & 2.6.
Table 11- Emission index codes \(a_c\) and \(b_c\) as functions of the railway vehicle category \(c = 1\) to \(8\) inclusive in octave band \((i)\)

<table>
<thead>
<tr>
<th>category</th>
<th>index code</th>
<th>octave band with centre frequency [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>1</td>
<td>a</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>a</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>a, (v &lt; 60)</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>b, (v &lt; 60)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>motor</td>
<td>a, (v &lt; 60)</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>b, (v &lt; 60)</td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>-10</td>
</tr>
<tr>
<td>4</td>
<td>a</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>a, (v &lt; 60)</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>b, (v &lt; 60)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>diesel</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>-10</td>
</tr>
<tr>
<td>6</td>
<td>a, (v &lt; 60)</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>b, (v &lt; 60)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>motor</td>
<td>a, (v &lt; 60)</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>b, (v &lt; 60)</td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td>(v \geq 60)</td>
<td>-10</td>
</tr>
<tr>
<td>7</td>
<td>a</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>a</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>15</td>
</tr>
</tbody>
</table>
Table 12 – 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)

<table>
<thead>
<tr>
<th>Category</th>
<th>Index code</th>
<th>Octave band with centre frequency [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Railcar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-as</td>
<td>a</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>27</td>
</tr>
<tr>
<td>9-2m</td>
<td>a</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>26</td>
</tr>
<tr>
<td>9-4m</td>
<td>a</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>27</td>
</tr>
<tr>
<td>9-5m</td>
<td>a</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>25</td>
</tr>
<tr>
<td>Pushed/Pushed units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-as</td>
<td>a</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>27</td>
</tr>
<tr>
<td>9-2m</td>
<td>a</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>27</td>
</tr>
<tr>
<td>9-4m</td>
<td>a</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>27</td>
</tr>
<tr>
<td>9-5m</td>
<td>a</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 13 – Correction factor $C_{rem.i,c}$ for brake noise as a function of the railway vehicle category (c) and the octave band (i)

<table>
<thead>
<tr>
<th>Octave band</th>
<th>$C_{rem.i,c}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i$</td>
<td>$c = 1, 4, 5$</td>
</tr>
<tr>
<td>1</td>
<td>-20</td>
</tr>
<tr>
<td>2</td>
<td>-20</td>
</tr>
<tr>
<td>3</td>
<td>-20</td>
</tr>
<tr>
<td>4</td>
<td>-2</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

The extra noise emission of a rough track or the noise reduction of a smoother track will be included for existing categories by integration of the difference in the energetic sum of wheel and track roughness in the correction for the track characteristics.

This methodology is only correct for a jointless track ($m = 1$). This parameter is therefore dependent on speed ($v$) and train category ($c$).
For $m=1$, it yields that $C_{c,bb,i,m}$ will be calculated for different train categories by:

$$C_{c,bb,i} = C_{c,bb,i} - \left[ L_{i,rtr,rrl} (\lambda_i) \oplus L_{i,rveh,c} (\lambda_i) \right] + \left[ L_{i,rtr,loc} (\lambda_i) \oplus L_{i,rveh,c} (\lambda_i) \right]$$

2.5a

with:

- $C_{bb,i}$ the track correction from Table 16
- $L_{i,rtr,rrl} (\lambda_i)$ reference rail roughness, according to 25
- $L_{i,rtr,loc} (\lambda_i)$ local rail roughness of the track on which the calculation are being carried out
- $L_{i,rveh,c} (\lambda_i)$ wheel roughness of different train categories, according to Table 14

$\oplus$ energetic summation

To determine the local wheel roughness, measurements have to be carried out according to 2.3.2. The measured rail roughness of the local situation is measured at representative locations and integrated in the model. These locations have to be selected from the total length of the track that will be included in the model. These locations have to be specified in the measurement report.

If calculations are carried out with a lower than average rail roughness, the track exploitation company has to guarantee that the low rail roughness level can be maintained by monitoring and additional grinding.

The deciding factor for this is that the differences in rail roughness, averaged over the considered part of the track and the calculated total noise emission per train category, (sum of all source heights and octave bands) remain equal to the value of the original calculation, and that the local increase per train category remains limited to maximum 1 dB(A).

Table 14-Data to determine rail roughness, according to the type of brake system in function of the wavelength

<table>
<thead>
<tr>
<th>wavelength [cm]</th>
<th>disc brake + blocks</th>
<th>wheel roughness as a function of brake system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>only disc brakes</td>
<td>cast-iron block brake</td>
</tr>
<tr>
<td></td>
<td></td>
<td>disc brake + added cast-iron block brake</td>
</tr>
<tr>
<td>20.2</td>
<td>-3</td>
<td>8</td>
</tr>
<tr>
<td>16</td>
<td>-4</td>
<td>7</td>
</tr>
<tr>
<td>12.7</td>
<td>-3</td>
<td>7</td>
</tr>
<tr>
<td>10.1</td>
<td>-2</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>-1</td>
<td>6</td>
</tr>
<tr>
<td>6.3</td>
<td>-2</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td>3.2</td>
<td>-2</td>
<td>-2</td>
</tr>
<tr>
<td>2.5</td>
<td>-3</td>
<td>-3</td>
</tr>
<tr>
<td>2</td>
<td>-3</td>
<td>-3</td>
</tr>
<tr>
<td>1.6</td>
<td>-3</td>
<td>-4</td>
</tr>
<tr>
<td>1.3</td>
<td>-4</td>
<td>-4</td>
</tr>
<tr>
<td>1</td>
<td>-5</td>
<td>-5</td>
</tr>
<tr>
<td>0.8</td>
<td>-7</td>
<td>-7</td>
</tr>
</tbody>
</table>

Project team: Wölfel Meßsysteme · Software GmbH & Co (main contractor) - AIB-Vinçotte EcoSafer - AKRON n.v.s.a. - LABEIN Technological Centre S.L. - Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG - LÄRMKONTOR GmbH
AR-INTERIM-CM (CONTRACT: B4-3040/2001/329750/MAR/C1)
ADAPTATION AND REVISION OF THE INTERIM NOISE COMPUTATION METHODS FOR THE PURPOSE OF STRATEGIC NOISE MAPPING

WP 3.2.2: Railway Noise - Noise emission: databases

For the nine categories in this standard the following relation between brake system and train category applies:

- categories 1, 4, 5, 7 & 9: pushed units: cast-iron block brake;
- category 2: disc brake + added block brake;
- categories 3, 6, 8 & 9: pulled units: disc brake.

For new train categories that are being measured in accordance to 2, the average wheel roughness is determined by measurements.

The disc brake system with added block brakes is currently unavailable in the Netherlands, but its introduction is always possible.

If wheel and rail roughness are expressed in 1/3 octave bands, they are transposed to octave bands by equation B.16.

For other track types \( m = 2, 3 \) or 4, the correction factor for track types is based on:

\[
C_{bb,i,m} = C_{3,i} + 10 \log(1 + f_m A_i)
\]

with:

- \( C_{bb,i} \) the track correction from Table 16
- \( f_m \) Table 15
- \( A_i \) Table 17

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

<table>
<thead>
<tr>
<th>description</th>
<th>( m ) type</th>
<th>( f_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>track with rail joints</td>
<td>2</td>
<td>1/30</td>
</tr>
<tr>
<td>1 switch</td>
<td>2</td>
<td>1/30</td>
</tr>
<tr>
<td>2 switches per 100 m</td>
<td>3</td>
<td>6/100</td>
</tr>
<tr>
<td>more than 2 switches per 100 m (depot)</td>
<td>4</td>
<td>8/100</td>
</tr>
</tbody>
</table>

Table 16- Correction factor \( C_{bb,i} \) as a function of structures above station compounds/railway track condition (bb) and octave band (i)

<table>
<thead>
<tr>
<th>octave band</th>
<th>( bb = 1 )</th>
<th>( bb = 2 )</th>
<th>( bb = 3 )</th>
<th>( bb = 4 )</th>
<th>( bb = 5 )</th>
<th>( bb = 6 )</th>
<th>( bb = 7 )</th>
<th>( bb = 8 )</th>
</tr>
</thead>
</table>
| 1           | \( \begin{array}{cccccccc} 0 & 1 & 1 & 6 & 6 & - & 6 & 5 \\
                              & 0 & 1 & 3 & 8 & 8 & - & 1 & 4 \\
                              & 0 & 1 & 3 & 7 & 8 & - & 0 & 3 \\
                              & 0 & 1 & 3 & 10 & 9 & - & 0 & 6 \\
                              & 0 & 1 & 4 & 8 & 2 & - & 0 & 2 \\
                              & 0 & 1 & 5 & 2 & 1 & - & 0 & 1 \\
                              & 0 & 1 & 4 & 1 & 1 & - & 0 & 0 \\
                              & 0 & 1 & 4 & 0 & 1 & - & 0 & 0 \end{array} \) |

The values for \( A_i \) can be found in Table 17.
Table 17 - Code index for noise emission in the case of impact A_i as a function of the octave band (i).

<table>
<thead>
<tr>
<th>Octave band i</th>
<th>A_i</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5, 6, 7, 8</td>
<td>0</td>
</tr>
</tbody>
</table>

1.1.4 Emission from concrete and steel bridge structures

1.1.4.1 Concrete structures

For concrete structures and the applied tracks, the emission of both, the rolling noise and the noise radiation from the structure itself, is contained in the track correction table (Table 15 & Table 16). Therefore, in the case of 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 accurate acoustic analysis is necessary.

The correction factor for different track types on various types of concrete structures can be found in Table 18.

Table 18 - Track types on various types of concrete structure. The codes in this table refer back to the index codes in Table 16

<table>
<thead>
<tr>
<th>Structure type</th>
<th>track</th>
<th>index code</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>bb (SRM II)</td>
</tr>
<tr>
<td>TT &amp; U-type bridge</td>
<td>adjustable fixtures</td>
<td>4</td>
</tr>
<tr>
<td>plate &amp; girder bridge</td>
<td>cross-ties on ballast (either wood or concrete)</td>
<td>1 or 2</td>
</tr>
<tr>
<td></td>
<td>adjustable fixtures</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>adjustable fixtures filled with ballast</td>
<td>7</td>
</tr>
<tr>
<td>steel deck bridge</td>
<td>block type fixation</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>block type fixation filled with ballast</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>embedded rails</td>
<td>8</td>
</tr>
</tbody>
</table>

1.1.4.2 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 12 & Table 16). Sound emissions from the construction itself are incorporated into the final emission level by raising the emission factor E by \( \Delta L_E.\text{bridge} \) 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 calculation for bridges must be determined separately or by following the method described in 2.2.11.

1.1.5 Maximum Speeds

In this unit the emission level for train speeds can be determined using a maximum speed per category as shown in Table 19.
Table 19-Maximum calculable speed per category

<table>
<thead>
<tr>
<th>category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum calculable speed [km/h]</td>
<td>140</td>
<td>160</td>
<td>140</td>
<td>100</td>
<td>140</td>
<td>120</td>
<td>100</td>
<td>160</td>
<td>300</td>
<td>330</td>
</tr>
</tbody>
</table>

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

2 Measurement method

The emission characteristics of a railway vehicle or a track are to be determined by measurement. These characteristics are already available for:

- railway vehicles: all Dutch vehicles and other European vehicles circulating on Dutch tracks;
- tracks: typical characteristics of Dutch tracks.

Two procedures are given hereafter to determine the characteristics of new train categories or non-Dutch rolling stock on non-Dutch tracks:

- procedure A: a simplified procedure to determine if a railway vehicle belongs to a category for which the characteristics already exist;
- procedure B: a more elaborate method to determine the emission characteristics directly.

An additional procedure C has been added to determine acoustical characteristics of track construction (sleepers, ballast bed, …).

2.1 Procedure A: Simplified method

The use of simplified methods with reference to existing categories provides a fast allocation method. This method can also be used for new (to be constructed) vehicles on which it is impossible to carry out measurements. This can be done mainly based on the type of propulsion system (diesel, electric, hydraulic) and the brake system (disc or block).

A flow chart illustrating the two different measurement methods described in this chapter and their purpose is provided in ANNEX 3.

2.1.1 Assignment to an existing train category

The track type for procedure A is specified as UIC 54 rails on mono block or duo block concrete sleepers with rail pads with static stiffness of 300-500 kN/mm at 60 kN preload (e.g. 4.5 mm cork rubber pads).

The measurement equipment required is a sound level meter with octave spectrum analysis and a rail roughness measuring device (unless the site roughness is already known) according to the procedure described in pr EN ISO 3095, January 2001. In the following the term “reference rail” or “reference rail roughness” and any similar term or indices is used in accordance with the aforementioned ISO standard. The standard is used and referenced for two reasons: on the one hand the Dutch standard measurement method accompanying the Dutch RMR computation model is relatively close to the ISO standard. On the other hand a study [9] produced by TNO TPD on behalf of DG Environment comes to the conclusion that the ISO standard sufficient although some limitations are formulated. The replacement of the current EN ISO 3095 by a more recent method (like STAIRRS level 2) should be investigated once better methods become available. In the meantime, while EN ISO 3095 is used, the limitations explained in the TNO report should be taken into account.

The condition of the railway vehicle should fulfil the description of 2.2.3. The measurement location, measurement conditions and measurement equipment should fulfil the description of 2.2.2.
ADAPTATION AND REVISION OF THE INTERIM NOISE COMPUTATION METHODS FOR THE PURPOSE OF STRATEGIC NOISE MAPPING

WP 3.2.2: Railway Noise - Noise emission: databases

The A-weighted equivalent sound pressure level in octave bands $L_{pAeq,tot,i}$ is measured at one cross-section, at 7.5 m for the track centre line and 1.2 m above the rail surface. A number of passages is performed as indicated in Table 20.

Table 20- Passage speeds for procedure A1.

<table>
<thead>
<tr>
<th>subject</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powered vehicles with traction noise</td>
<td>20, 40, 60, 100 km/h and if applicable 140, 250 km/h and maximum speed</td>
</tr>
<tr>
<td>Unpowered rolling stock</td>
<td>100 km/h and if applicable 140, 250 km/h and maximum speed</td>
</tr>
</tbody>
</table>

The measured noise level $L_{pAtotij}$ will be increased by $L_{diff}$, with:

$$L_{diff} = 1 + Y$$  \hspace{0.5cm} B.1

where $Y$ is a roughness correction determined as follows:

- determine the frequency $f_{pmax}$ at which the octave spectrum of the A-weighted sound pressure level at 100 km/h is highest;
- determine the corresponding wavelength $\lambda_{fpmax}$ at 100 km/h (27.8 m/s):

$$\lambda_{fpmax} = \frac{27.8}{f_{pmax}}$$  \hspace{0.5cm} B.2

- determine the correction term $Y$ from the difference between the measured rail roughness $L_{r,tr}(\lambda_k)$ and the reference rail roughness, averaging over 4 third-octave bands either side of $\lambda_{fpmax}$:

$$Y = \frac{1}{9} \sum_{k=4}^{0} \left( L_{r,tr,ref} (\lambda_k) - L_{r,tr} (\lambda_k) \right)$$  \hspace{0.5cm} B.3

where $k$ third octave band index for the rail roughness $L_r$, and $k = 0$ for $\lambda_k = \lambda_{fpmax}$.

$$L_{diff} = 1$$  \hspace{0.5cm} B.4

- for speeds at which traction noise or aerodynamic noise predominate;
- for speeds at which rolling noise is predominant and the vehicles have cast-iron brake blocks that work on the wheel surface.

The sound level $L_{pAeq,tot,i}$ is compared per octave band with the curves predicted by the calculation scheme for corresponding conditions. The vehicle type may be assigned to a train category if the measured curve incremented by $L_{diff}$ is below the predicted curve in all octave bands and at all speeds.

Small isolated peaks above the level per octave band are acceptable, as long as the dB(A) noise level at a distance of 25 m and a height of 3.5 m above BS, corrected according to the octave band noise propagation calculation method, is not higher than the calculated noise level on location.

2.1.2 Reporting

The reporting consists of the items in 2.2.15 except for items 6, 15, 16 & 17. The measured sound pressure level in octaves for all measured speeds will be presented and compared with the spectral data of the category into which the material will be assigned. The rail roughness addition $L_{diff}$ is stated, along with a reason for the choice of $L_{diff}$.
2.2 Procedure B: Comprehensive methods for characterisation of vehicle and track

2.2.1 Introduction

This procedure describes methods of obtaining emission data for rail vehicles that do not necessarily fit into an existing train category. A so-called ‘free category’ is introduced to which any vehicle type can be assigned, if its noise emission is determined according to this procedure. The data obtained in this manner take into account the separation of vehicle, the track sound radiation and the wheel and track roughness. Also the type of source – traction, rolling and aerodynamic noise – and source heights are taken into account.

2.2.2 Measurement conditions and configuration

The measurements are carried out as outlined in § 2.3 in accordance with pr EN ISO 3095, with the following additions and exceptions.

2.2.3 Number and condition of rail vehicles

The vehicles selected for the test must satisfy the following. For unpowered vehicles, at least four vehicles are used in the test. For powered vehicles and units, at least two units are tested. If the vehicles are part of a train with other rolling stock, the effect of adjacent vehicles must be taken into account and avoided if possible. The vehicles must have run at least 1 000 km under normal operating conditions, with the braking system in operation. Wheels must be free of damage such as flats. The vehicles should be empty and all doors and windows must be closed. Powered vehicles should have a characteristic traction load. Auxiliary equipment must be in operation during the measurements.

2.2.4 Tracks

A test track is selected that is not only smooth, but also radiates as little noise as possible for a given roughness excitation (low response). Such a track may be specially built over a limited length of about 100 m and could be any of the following alternatives.

Continuous concrete slab track of at least 20 cm thick, without sleepers, with ballast or other absorbent covering material and:

- rails cast into the concrete (rail foot on one side of the rail);
- continuously supported rails with a small rail cross-section and stiff embedding material;
- discrete supports with stiff railpads;
- discrete supports with soft railpads and rail dampers that are effective below 1 kHz.

A less effective, but economic alternative is ballasted track with concrete sleepers, rail dampers that are effective below 1 kHz and optimised railpads.

It is advisable to select the quietest track currently available. Track response can be characterised using the method given in 2.3. The best track will have a low track response function $L_{Hpv,tr}$.

The consequence of using a normal track is that the vehicle noise contribution can be overestimated below about 1 kHz. This however is acceptable if the measurement data is used for emission predictions on tracks that are noisier than the test track.

The condition of the track should be good over the whole test length plus 25 m at each end: there should be no rail joints, welds, rail damage, loose sleepers or rail attachments which can all cause impact noise.
2.2.5 Acoustical environment

The measurement site must offer free field conditions. The soil must be free of obstacles and there must be no reflecting objects such as walls, building, slopes or bridges nearby. The track must be in a flat environment. There should not be any obstacles near the microphones that may distort the noise field, e.g. persons. The observer must not influence the noise measurement by his position. The soil between track and measurement microphone must - as far as possible - be free of strongly absorbing surfaces such as snow, high grass, other tracks or strongly reflecting surfaces such as water. A ballast layer of 10 cm or more is allowed. The soil is described in the measurement report.

2.2.6 Meteorological conditions and background noise level

Measurements must only be carried out at wind speeds below 5 m/s and without precipitation (rain, snow, ...). The track must be dry and free of snow or ice. Temperature, humidity, air pressure, wind speed and wind direction should be registered during the measurements and stated in the report.

Background noise that might influence the measurements must be reduced to a minimum. The measured sound pressure level must be at least 10 dB above the background level in all octave and 1/3 octave bands.

2.2.7 Measurement positions and quantities

The microphone is positioned at M1, which is at a distance of 7.5 m and height of 1.2 m as indicated in figure B.2. If sources above axle height (0.5 m) are present, the microphone is positioned at a height of 3.5 m, at M2. Measurements are performed preferably at three cross-sections about 10-25 m apart; the results will be averaged, or at one cross-section with three averages. The time signal is registered as an equivalent unweighted octave spectrum and third-octave spectrum, total A-weighted and un-weighted levels. The measurement time T is also registered, which is the passage time including the 10 dB-down flanks. For a group of wagons within a train, the buffer-to-buffer time (speed/length) is taken.

Besides sound pressure, railhead vertical vibration is also measured by attaching an accelerometer to the centre of the railfoot, or underneath the railhead. This is done at the same three cross-sections, close to a sleeper. The vibration is registered as a time signal, and as an unweighted third octave equivalent level spectrum $L_{veq}$ during measurement time T. Vibration levels should be checked on both rails to determine differences. If the difference in overall rail vibration level of both rails is less than 2 dB, it is sufficient to measure the rail vibration on the rail on the side of the microphone. Otherwise, the signals from both rails are averaged. Special care must be taken to avoid signal distortion and cutoff as high vibration levels of up to 10-100 m/s$^2$ can occur. Accelerometers must be firmly attached and should not be sensitive to moisture.

The train speed is measured and must be within 5 km/h of the nominal speed for speeds below 100 km/h and 10 km/h for speeds above 100 km/h.

For vehicles with traction or aerodynamic sources at heights of 2 m and above, such as locomotives and high speed trains, additional measurements are carried out at 4 m from the track axis at a height of 1.2 and 4.5 m ($\pm$0.2 m) only at one cross-section.
Figure 6-Microphone positions for passage measurements as in pr EN ISO 3095, with additional positions for source height measurement at 4 m distance.

### 2.2.8 Measurement equipment

Equipment required for the measurements consists of microphones, vibration recorders with measurement chain, together with a multi-channel 1/3 octave and octave analyser and multi-channel recorder. The vibration recorders should be moisture proof and need to be firmly attached. The measurement chains need to be well adjusted with regard to possible overload of the measured signal.

All equipment, including analysers, cables and recorders must satisfy the requirements for "type I" equipment according to EN 61260. Microphones must be calibrated with nearly flat frequency characteristic in the free field. The 1/3 octave filters and octave filters must satisfy EN 61260. The microphones must be equipped with a windshield. Before and after every measurement session, the measurement chains of microphones and vibration recorders are calibrated using calibrators with an accuracy of at least ±0.3 dB (class I according to HD 556 S1), at one or more frequencies in the relevant frequency domain. Measurement results must be rejected if there is a difference of more than 0.5 dB in the calibration. The frequency domain lies between 20 and 10 000 Hz. The calibrators must be checked at least twice a year according to HD 556 S1. The instrumentation must be checked at least twice a year according to EN 61260. The date of the last calibration is stated in the report.

### 2.2.9 Definitions

- $V$: Train speed [m/s]
- $f$: Frequency [Hz]
- $L(f)$: Level in 1/3-octave band with frequency $f$, according to EN ISO 266
- $L_i$: Level in octave band $i$ where $i = 1, 2, \ldots, 8$ with band frequencies 63, 125, 250, 500, 1k, 2k, 4k, 8kHz
- $L_{ptot}$: Total sound pressure level of a passage [dB re $2 \times 10^{-5}$ Pa]
- $L_{pveh}$: Sound pressure level of a passage, vehicle contribution [dB re $2 \times 10^{-5}$ Pa]
- $L_{pveh1}$: Sound pressure level of a passage due to vehicle traction noise (incl. auxiliary equipment) [dB re $2 \times 10^{-5}$ Pa]
- $L_{pveh2}$: Sound pressure level of a passage due to vehicle rolling noise [dB re $2 \times 10^{-5}$ Pa]
- $L_{pveh3}$: Sound pressure level of a passage due to vehicle aerodynamic noise [dB re $2 \times 10^{-5}$ Pa]
2.2.10 Traction noise

If the vehicles concerned are powered, e.g. locomotives, EMU’s or DMU’s, the traction noise is measured separately at low speeds. Traction noise also includes the noise from auxiliary equipment.

For locomotives, measurements are performed at full acceleration from standstill to 60 km/h. Other types of powered vehicle are measured at constant speed at 20, 40 and 60 km/h. It should be verified that traction noise is indeed greater than rolling noise at the mentioned speeds. If this is not the case, this should be reported and the data at the speeds concerned should be eliminated.

Locomotives are measured at two track cross-sections, at 5 m and 20 m ahead of the starting position (front buffers). The speed at the passing of the two cross-sections is registered. The measurement time lasts from the start until the rear of the vehicle has passed the second cross-section by 20 m.

Other types of powered vehicle are measured at a single cross-section.

The equivalent sound pressure level in octave bands due to traction, \( L_{pveh1,i} \), is measured at a distance of 7.5 m and a height of 1.2 m. The measurements are averaged over the passages at each speed. A spectrum as a function of train speed is derived by interpolation or a regression line between the measurement points:
where:

\[ L_{pveh1,i} \]  equivalent sound pressure level at 7.5 m due to traction, in octave band \( i \);

\( x_1(i) \) & \( y_1(i) \)  constants per octave band number describing the linear relation between \( \log V \) and the sound pressure level.

This spectrum for traction noise may be extrapolated to higher speeds, as long as rolling noise and/or aerodynamic noise are not included. It is permissible to use a higher order approximation for the curve if necessary.

### 2.2.10.1 Source height determination

Traction noise sources are allocated to heights 0.5 m, 2 m or 4 m above the rail surface.

Traction sources at axle level height are allocated to 0.5 m. Vehicle traction sources above floor level are allocated to 2 m or 4 m.

The source height can be determined by detecting the highest octave band level of the two microphones at 4 m or closer (M4 and M5 in Figure 6). Antenna or alternative techniques may be applied to obtain more detailed information.

The traction noise level can be given a single source height or distributed over several source heights, depending on the information available. The energy sum of all of the sources must correspond to the overall traction noise \( L_{pveh1,i} \).

For example, a diesel locomotive with a roof exhaust as the major source could result in:

- \( L_{pveh1,i} \) (4 m) = \( L_{pveh1,i} \)
- \( L_{pveh1,i} \) (2 m) = 0
- \( L_{pveh1,i} \) (0.5 m) = 0

and an EMU with powered bogies could result in:

- \( L_{pveh1,i} \) (4 m) = 0
- \( L_{pveh1,i} \) (2 m) = 0
- \( L_{pveh1,i} \) (0.5 m) = \( L_{pveh1,i} \)

### 2.2.11 Rolling noise

#### 2.2.11.1 Measurement conditions

For the determination of the total rolling noise, the following four parameters are required:

- wheel roughness;
- transmission of wheel to noise;
- rail roughness;
- transmission of rail via track (sleepers and ballast bed).

This is described in 2.2.11.2 to 2.2.11.5.

Measurements are carried out at speeds of 20, 40, 60, 100, 140, 200 & 250 km/h and the maximum speed of the considered vehicle. Measurements are carried out at 7.5 m off axis and at a height of 1.2±0.2 m.
If traction noise or other sources are dominating, the test should also be performed with traction switched off, either by pulling the vehicles or by switching off the engine during the passage.

### 2.2.11.2 Rail roughness (measurement or existing data)

Rail roughness L_{r,tt} at the measurement site is either measured in third octaves according to the procedure in pr EN ISO 3095: 2001 or is already known from a measurement taken no longer than 6 months earlier. Rail roughness is measured as a function of wavelength. This can be converted to a function of frequency and train speed according to 2.3.2.

### 2.2.11.3 Vehicle wheel roughness and total roughness

Two alternatives are proposed to carry out the next step.

- **Alternative 1:** avoids the procedure described in 2.3.1 whenever there is no need to use terms defined only for a standard Dutch track. Moreover, with the use of this alternative, vehicle wheel roughness is directly measured as a function of wavelength and can be easily introduced into the wheel roughness database (Table 4 of the noise emission database).

- **Alternative 2:** it is difficult to use outside The Netherlands as some input values needed for calculations according to 2.3.1 are only defined for standard Dutch tracks. Nevertheless, these values can be calculated for other track types using the method outlined in 2.3.1.

### 2.2.11.4 Alternative 1 - Vehicle wheel roughness (measurement)

The average vehicle wheel roughness in third octaves wavelength L_{r,veh}(\lambda) is directly measured using similar techniques as for rail roughness measurement, i.e. contact transducers on parallel lines. At least three wheels per vehicle are measured, each on three parallel lines on the wheel surface, one in the middle and one at 10 mm on either side. Averaging is done over three wheel revolutions. All these roughness data are averaged as roughness spectra to obtain an average for the whole vehicle.

Wheel roughness has to be converted to a function of frequency according to 2.3.2 and using the passage speeds defined in 2.2.11.2.

**Note:** Wheel roughness is an important characteristic of the train category and will be introduced as a function of wavelength on Table 4 of the Noise Emission Database.

#### Total roughness (calculation)

The total roughness L_{r,tot}(\lambda) is derived from both measured roughnesses, vehicle wheel roughness L_{r,veh}(\lambda) and rail roughness L_{r,tt}(\lambda) as follows:

\[
L_{r,tot}(\lambda) = 10 \log \left( 10^{L_{r,veh}(\lambda)/10} + 10^{L_{r,tt}(\lambda)/10} \right)
\]  

Total roughness has to be converted to a function of frequency according to 2.3.2 and using the passage speeds determined in 2.2.11.2.

#### Alternative 2 - Total roughness (measurement)

The total roughness L_{r,tot} is derived from the vertical railhead vibration L_v(f) in third octaves at the train speeds described in both 2.2.11.2 and 2.3.1. An accelerometer is attached vertically underneath the centre of the rail foot or underneath the railhead, close to a sleeper (2.2.7).

#### Vehicle wheel roughness (calculation)

The average vehicle wheel roughness in third octaves L_{r,veh} is derived from the total roughness L_{r,tot}, and the measured rail roughness L_{r,tt}:

\[
L_{r,veh}(f) = 10 \log \left( 10^{L_{r,tot}(f)/10} - 10^{L_{r,tt}(f)/10} \right)
\]
Note: Rail roughness is transformed into a frequency function at the speeds defined in 2.2.11.2.

If $L_{\text{rtot}}(f) - L_{\text{rr}}(f) < 1$, per frequency band, then the wheel roughness is set at:

$$L_{\text{rveh}}(f) = L_{\text{rr}}(f) - 5$$  \(B.7\)

Note:

1. the vehicle wheel roughness is overestimated if the site rail roughness exceeds the pr EN ISO 3095 limit curve.

2. Wheel roughness as a function of wavelength will be introduced on Table 4 of the Train Emission Database. Convert wheel roughness from a function of frequency to a function of wavelength according to 2.3.2 and using passage speeds determined in 2.2.11.2.

**Total roughness on a reference track (calculation)**

The total roughness (energy sum of wheel and rail roughness) on a reference track $L_{\text{rtot,ref}}$ is determined from the reference rail roughness $L_{\text{rr,ref}}(f)$ and the wheel roughness of the test vehicles $L_{\text{rveh}}(f)$:

$$L_{\text{rtot,ref}} = L_{\text{rr,ref}}(f) \oplus L_{\text{rveh}}(f)$$  \(B.8\)

with:

$$\oplus \quad \text{energy summation.}$$

The reference rail roughness $L_{\text{rr,ref}}(f)$ is shown in 2.3.3. This reference rail roughness is defined to homogenize the effect of differences in rail roughness on rolling noise. This reference roughness is the Dutch average rail roughness, since it is used on the national Dutch measurement method.

**Track and vehicle contributions to rolling noise (measurement and calculation)**

The track vibration response function $L_{\text{Hpv, tr}}$ in third octaves is determined according to 2.3.4. The procedure consists of measuring sound pressure and railhead vibration during the passage of a reference vehicle. A silent reference vehicle has a low vehicle response, i.e. the contribution from the sound radiation of the silent vehicle is much lower than that of the track. The track noise level $L_{\text{ptr}}$ is calculated from the track vibration response and from the rail vibration due to the test vehicle:

$$L_{\text{ptr}}(f) = L_{\text{Hpv, tr}}(f) + L_{r}(f)$$  \(B.9\)

(all in third octaves and unweighted).

Measurement of $L_{r}(f)$ is carried out according to 2.2.7 and on the speed range defined in 2.2.11.2.

The vehicle noise $L_{\text{veh}}$ is calculated from the energy difference between the total sound pressure level (measured according to 2.2.11.2) and the track noise level:

$$L_{\text{veh}}(f) = 10\log\left(10^{L_{\text{tot}}(f)/10} - 10^{L_{\text{ptr}}(f)/10}\right)$$  \(B.10\)

and if $L_{\text{ptr}}(f) - L_{r}(f) < 1$, per frequency band,

$$L_{\text{veh}}(f) = L_{\text{ptr}}(f) - 5$$  \(B.11\)

**Track response and vehicle response functions (calculation)**

The track response function $L_{\text{Hpr, tr}}$ (due to roughness) is calculated from:

$$L_{\text{Hpr, tr}}(f) = L_{\text{ptr}}(f) - L_{\text{tot}}(f)$$  \(B.12\)
And the vehicle response function $L_{Hpr,veh}$ (due to roughness) is calculated from:

$$L_{Hpr,veh}(f) = L_{pveh}(f) - L_{rot}(f).$$  \(B.13\)

(all in third octaves and unweighted).

### Sound radiation of vehicle and track (calculation)

The rolling noise emission of the vehicle results from:

$$L_{pveh2,ref}(f) = L_{Hpr,veh}(f) + L_{rot,ref}(f)$$  \(B.14\)

and from the track:

$$L_{ptr,ref}(f) = L_{Hpr,tr}(f) + L_{rot,ref}(f)$$  \(B.15\)

Note: these two equations depend on the train speed, as the total roughness is expressed as a function of frequency. This is explained in 2.3.1.

Both of these spectra are converted from third octave bands to octave bands with

$$L(f_c) = L(f-) \oplus L(f+)$$  \(B.16\)

where:

- $f_c$ : octave band frequencies
- $f_-$, $f_+$ : adjacent third octave band frequencies
- $\oplus$ : energy summation

An octave spectrum as a function of train speed is derived by interpolation or by a regression line between considered speeds:

$$L_{ptr,ref,i} = x_{tr,i} + y_{tr,i} \log V$$  \(B.17a\)

$$L_{pveh2,ref,i} = x_{veh,i} + y_{veh,i} \log V$$  \(B.17b\)

For the rolling noise octave spectra this results in $L_{pveh2,i}$ and $L_{ptr,i}$. The vehicle rolling noise is allocated to source height 0.5 m, the track noise to height 0 m.

### 2.2.12 Aerodynamic noise

#### 2.2.12.1 Measurement conditions

If the vehicle(s) under test:

- have a maximum speed of more than 200 km/h,
- or
- produce aerodynamic noise noticeably higher (more than 1 dB(A)) than the combined rolling noise and traction noise at high speeds,

then the aerodynamic noise is measured.

The second point can be checked as follows. The traction noise and rolling noise are extrapolated from the data obtained in 2.2.10 & 2.2.11 as unweighted octave spectra. If the measured sound pressure (of all sources) at high speeds (above 200 km/h) exceeds the combined traction and rolling noise by more than 1 dB, aerodynamic noise is to be measured.

Aerodynamic noise is measured at two or more speeds at which it is known to be dominant, and preferably with a difference of at least 50 km/h, e.g. 250 km/h and 300 km/h.

The equivalent sound pressure level in octave bands due to aerodynamic sources, $L_{pveh3,i}$ is measured at a distance of 7.5 m and a height of 0.5 m. The measurements are averaged over the passages at
each speed. A spectrum as a function of train speed is derived by fitting an interpolation or a regression on the measurement points:

\[ L_{p\text{veh3},i} = x_3(i) + y_3(i) \lg V \]  

where:

- \( L_{p\text{veh3},i} \): equivalent sound pressure level at 7.5 m due to aerodynamic sources, in octave band \( i \);
- \( x_3(i), y_3(i) \): constants per octave band describing the linear relation between \( \lg V \) and the sound pressure level.

This spectrum for aerodynamic noise may be extrapolated to lower speeds. A higher order approximation for the curve can be used if necessary.

### 2.2.1.2 Source height determination

The aerodynamic noise level can be given a source height or be distributed over several source heights, depending on the information available. The energy sum of all the sources must correspond to the overall traction noise \( L_{p\text{veh3},i} \).

Aerodynamic noise sources are allocated to heights 0.5 m, 2 m, 4 m or 5 m above the rail surface. The source height can be determined by detecting the highest octave band level of the two microphones at a distance of 4 m or closer (M4 and M5 in figure B.2):

- \( L_{p\text{n}12,i} \): 1.2 m above BS and 4 m from the centre line;
- \( L_{p\text{n}45,i} \): 4.5 m above BS and 4 m from the centre line.

Some additional rules are given here for determining source height using the two microphones M4 and M5 with levels \( L_{p\text{n}12,i} \) and \( L_{p\text{n}45,i} \):

- If \( L_{p\text{n}45,i} > L_{p\text{n}12,i} + 1 \), the source height is:
  - \( h = 5 \) m if the vehicle has an extra high structure, e.g. a high cabin;
  - \( h = 5 \) m if a pantograph is present and if the level at 4.5 m reduces by more than 1 dB when the pantograph is retracted;
  - \( h = 4 \) m if a pantograph is present and if the level at 4.5 m reduces by less than 1 dB when the pantograph is retracted;
  - \( h = 4 \) m if no pantograph is present.

- If \( L_{p\text{n}45,i} \leq L_{p\text{n}12,i} + 1 \) the source height is:
  - \( h = 2 \) m.

These rules provide a ‘worst case’ source height, as for example the bogies may be dominant aerodynamic sources. This would require further research by antenna or alternative techniques. Such techniques may be applied if available.

If the pantograph noise were dominant, the result would be:

- \( L_{p\text{veh3},i} (5 \text{ m}) = L_{p\text{veh3},i} \)
- \( L_{p\text{veh3},i} (4 \text{ m}) = 0 \)
- \( L_{p\text{veh3},i} (2 \text{ m}) = 0 \)
- \( L_{p\text{veh3},i} (0.5 \text{ m}) = 0 \).
AR-INTERIM-CM (CONTRACT: B4-3040/2001/329750/MAR/C1)
ADAPTATION AND REVISION OF THE INTERIM NOISE COMPUTATION METHODS FOR THE PURPOSE OF STRATEGIC NOISE MAPPING

WP 3.2.2: Railway Noise - Noise emission: databases

If the aerodynamic noise sources were equally distributed over the source heights, the result would be:

- \( L_{\text{veh3},i} (5 \text{ m}) = L_{\text{veh3},i} - 6 \)
- \( L_{\text{veh3},i} (4 \text{ m}) = L_{\text{veh3},i} - 6 \)
- \( L_{\text{veh3},i} (2 \text{ m}) = L_{\text{veh3},i} - 6 \)
- \( L_{\text{veh3},i} (0.5 \text{ m}) = L_{\text{veh3},i} - 6 \).

2.2.13 Braking noise

Braking noise \( L_{\text{br},i} \) is determined by measuring the equivalent sound pressure level in octaves during a braking passage of the vehicle(s). This is performed at four speeds, if applicable: 25, 50, 100 km/h and the maximum speed, each with one passage at a single cross-section. The speed measured may not differ more than 20% from the speeds defined above. The microphone position is at a distance of 7.5 m and height of 1.2 m above the rail surface.

If the measured levels do not exceed the levels at constant speed by more than 1 dB, then braking noise is neglected:

\[ L_{\text{br},i} = 0 \]

Otherwise, the braking noise is determined as follows.

Least squares regression lines are determined describing the braking noise spectrum as a function of train speed:

\[ L_{\text{br},i} = x_{\text{br}}(i) + y_{\text{br}}(i) \lg V \]  \( B.19 \)

where:

- \( L_{\text{br},i} \) sound pressure level at 7.5 m due to braking noise (equivalent octave spectrum);
- \( i \) octave band number;
- \( x_{\text{br}}(i) \) & \( y_{\text{br}}(i) \) constants per octave band describing the linear relation between the sound level and \( \lg V \). This may also be defined piecewise.

Braking noise is allocated to source height \( h = 0.5 \text{ m} \).

2.2.14 Calculation of emission terms

2.2.14.1 Emission characteristics in octave bands

The noise emission terms for the ‘free category’, indexed with \( x \) are derived from sound pressure contributions of the various sources in octave bands \( L_{\text{ptr,ref},i} \), \( L_{\text{veh1},i} \), \( L_{\text{veh2,ref},i} \), \( L_{\text{veh3},i} \) at the relevant source heights as derived in both 2.2.10.1 and 2.2.12.2. These are all a function of train speed.

For non braking conditions, the emission terms are derived as:

- \( E_{\text{nb},i,c} (0 \text{ m}) = L_{\text{ptr,ref},i} + L_{\text{m},i} \)  \( B.26 \)
- \( E_{\text{nb},i,c} (0.5 \text{ m}) = L_{\text{veh1},i}(0.5 \text{ m}) \oplus L_{\text{veh3},i}(0.5 \text{ m}) \oplus L_{\text{veh2,ref},i} + L_{\text{m},i} \)  \( B.27 \)
- \( E_{\text{nb},i,c} (2 \text{ m}) = L_{\text{veh1},i}(2 \text{ m}) \oplus L_{\text{veh3},i}(2 \text{ m}) + L_{\text{m},i} \)  \( B.28 \)
- \( E_{\text{nb},i,c} (4 \text{ m}) = L_{\text{veh1},i}(4 \text{ m}) \oplus L_{\text{veh3},i}(4 \text{ m}) + L_{\text{m},i} \)  \( B.29 \)
- \( E_{\text{nb},i,c} (5 \text{ m}) = L_{\text{veh3},i}(5 \text{ m}) + L_{\text{m},i} \)  \( B.30 \)

For braking conditions, the emission terms are:

- \( E_{\text{br},i,c} (0 \text{ m}) = L_{\text{ptr,ref},i} + L_{\text{m},i} \)  \( B.31 \)

Project: Wölfel Messtechnik · Software GmbH & Co (main contractor) · AIB-Vinçotte EcoSafer · AKRON n.v.-s.a. · team: LABEIN Technological Centre S.L. · Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG · LÄRMKONTOR GmbH

Page 47 of 60
AR-INTERIM-CM (CONTRACT: B4-3040/2001/329750/MAR/C1)
ADAPTATION AND REVISION OF THE INTERIM NOISE COMPUTATION METHODS FOR THE PURPOSE OF STRATEGIC NOISE MAPPING

WP 3.2.2: Railway Noise - Noise emission: databases

\[
E_{br,i,c}^{(h)} = \max\{L_{pveh1,i}^{(h)}(0.5 \text{ m}) \oplus L_{pveh2,ref,i}^{(h)}(0.5 \text{ m}) + L_{m,i}\} + L_{m,i}
\]

\[
E_{br,i,c}^{(2 \text{ m})} = L_{pveh1,i}^{(2 \text{ m})} \oplus L_{pveh3,i}^{(2 \text{ m})} + L_{m,i}
\]

\[
E_{br,i,c}^{(4 \text{ m})} = L_{pveh1,i}^{(4 \text{ m})} \oplus L_{pveh3,i}^{(4 \text{ m})} + L_{m,i}
\]

\[
E_{br,i,c}^{(5 \text{ m})} = L_{pveh3,i}^{(5 \text{ m})} + L_{m,i}
\]

Comment: Note that the only difference between the emission terms for braking and non braking conditions is at \(h=0.5 \text{ m}\). At this height the emission terms might be different.

with:

\[
E_{nm,i,c}^{(h)} = \text{emission term in octave bands at source height } h, \text{ non braking conditions [dB(A)]};
\]

\[
E_{br,i,c}^{(h)} = \text{emission term in octave bands at source height } h, \text{ for braking conditions [dB(A)]};
\]

\(\oplus\) = symbol for energy summation;

\(L_{m,i}\) = conversion term from passage sound pressure to emission term [dB] :

\[
L_{m,i} = 10 \log \left( \frac{T}{3600} \right) - 10 \log n - \Delta L_1 + L_{fA,i}
\]

\(T\) Passage time of the train or group of vehicles [s] (including –10 dB points, or buffer to buffer time for a group of wagons within a train);

\(n\) number of vehicles or wagons;

\(r\) distance from the track centreline to the microphone [m];

\(\Delta L_1\) sound transmission attenuation [dB];

\(L_{fA,i}\) A-weighting filter in octave bands [dB];

\[
\Delta L_1 = 10 \log \left( \frac{1}{25} \sum_{k=-12}^{12} \left( \Delta L_{k,i} - \Delta L_{GU} (\phi_k) \right) / 10 \right) + 5.86
\]

with:

\(\phi_k = k \times 5^\circ\)

A total view angle (from the microphone to the source) of 125\(^\circ\) is taken for measurements at 7.5 m from the track.

The geometrical sound attenuation is:

\[
\Delta L_G = 10 \log \frac{\phi \sin \nu}{r}
\]

with:

\(\phi\) view angle of the sector [degrees]

\(\nu\) angle between sector plane and source line segment [degrees]

\(r\) distance between source and measurement point [m]

The attenuation term \(\sum \Delta L_{k,i}\) consists of:

\[
\sum \Delta L_{k,i} = D_{A,i} + D_{G,i} + C_{M,i}
\]
with:

\[ D_{A,i} \ ] \text{ attenuation due to absorption in the air [dB]} \]

\[ D_{G,i} \ ] \text{ attenuation due to ground effects [dB]} \]

\[ C_{M,i} \ ] \text{ meteorological correction term = 0 dB at 7.5 m distance} \]

\( D_A \) and \( D_G \) can be calculated according to the Dutch railway noise computation scheme. \( D_A \) is less than 0.5 dB in the 8 kHz octave band, less than 0.2 dB in the 4 kHz band and less than 0.1 dB in all lower bands. The ground effect \( D_G \) is the most important at 7.5 m.

Alternatively, the attenuation term \( \sum \Delta L_{k,i} \) can be measured at a site as follows:

1. measure the sound pressure of a broadband artificial sound source in free field conditions (e.g. anechoic chamber or in the open), in octave bands, \( L_{\text{free},i} \) at 7.5 m distance and at source height (conversion to other distances can be made; the free field should be checked by 6 dB level drop per doubling of distance);

2. measure at the site at microphone position 7.5 m, 1.2 m height, the sound pressure level \( L_{p,j,i} \) of the same sound source at 0.5 m above the rail surface and at the track centreline, at the following positions along the track:

\[ x(j) = -28 \text{ m}, -9 \text{ m}, -3.5 \text{ m}, 0 \text{ m}, 3.5 \text{ m}, 9 \text{ m} \text{ and } 28 \text{ m}, \text{ with } j = 1, 2...7; \]

3. determine \( D_{k,j,i} \) from:

\[ D_{k,j,i} = L_{\text{free},i}(r_j) - L_{p,j,i}(r_j) \] \[ \text{ B.40} \]

with:

\[ r_j = \sqrt{7.5^2 + x(j)^2} \]

\( \sum \Delta L_{k,i} \) is calculated from:

\[ \sum \Delta L_{k,i} = 10 \log \left( \frac{1}{7} \sum_{j=1}^{7} 10^{-D_{k,j,i}/10} \right) \] \[ \text{ B.41} \]

The emission terms for non-braking and braking material are calculated for the total speed domain relevant to the material. These values are then fitted to the following linear relation, using the method of smallest quadrants:

\[ E_{nb,i,c} = a_{i,c} + b_{i,c} \log V \] \[ \text{ B.42} \]

\[ E_{br,i,c} = a_{br,i,c} + b_{br,i,c} \log V \] \[ \text{ B.43} \]

Values \( a_{i,c} \) & \( b_{i,c} \), are then used to determine the emission number using Table 11 to Table 13 and the Database of new Train Categories for braking as well as non-braking tests and for each octave band.

The linear fitting against speed may cause deviations of the measured values. If these deviations are larger than 1 dB(A), the speed domain needs to be split up. For every partial domain the values \( a_{i,c} \), \( b_{i,c} \), \( a_{br,i,c} \) and \( b_{br,i,c} \) are defined.

Note: The data needed to completely determine a new train category are:

- \( a_{i,c} \) & \( b_{i,c} \) and \( a_{br,i,c} \) & \( b_{br,i,c} \) (at braking conditions for h= 0.5 m), which are introduced on the train emission database (Table 2 of the Train Emission Database) at each source height and for each octave band,
- Wheel roughness (Table 4 of the Train Emission Database)
- the maximum speed of the train (Table 5 of the Train Emission Database)
WP 3.2.2: Railway Noise - Noise emission: databases

and the number of individual units of the train, if relevant. (Table 6 of the Train Emission Database).

The calculated emission value implies that the train is running on a track with reference rail roughness (that is the Dutch average rail roughness). If this is not the case, the effect of this different roughness must be checked by calculating the correction factor \( C_{rr,i,c} \) (§ 2.3.4.3). This correction is only applied at heights where rolling noise is allocated, i.e. 0 m and 0.5 m.

2.2.15 Test report
The following items are reported for measurement procedure B.

1. The nature of the tests.
2. Name and address of the organisation and staff performing the measurements.
3. Date and location of the measurements.
4. Description of the track: track type, fastener system, rail pad thickness, material, static stiffness, clip type, sleeper type, rail type, rail roughness according to pr EN ISO 3095.
5. Description of the site: surroundings, ground and vegetation, ambient temperature, air humidity, air pressure, wind speed and direction.
6. The track roughness response function \( L_{Hpr,ir}(f) \) and/or the track vibration response function \( L_{Hpv,ir}(f) \).
7. A list of the used measuring equipment and type and serial number of microphones and accelerometers, with the most recent calibration date.
8. The background noise level of the sound pressure as an octave spectrum and the A-weighted total Level.
9. Description of the vehicle(s) including the type and serial numbers used in the measurements; a statement that the measured vehicles are fully representative for all corresponding vehicles in service.
10. The running speeds and operating conditions during the measurements.
11. Description of any auxiliary equipment and its operating conditions during the measurements.
12. The positions of transducers such as microphones, accelerometers and triggering devices.
13. The measured sound pressure levels and vibration levels as overall levels and as third octave or octave spectra at the various positions and speeds.
14. The time history of the A-weighted sound pressure level and of the unweighted railhead velocity level.
15. As a function of train speed and in octave bands: the derived contributions for traction noise, rolling noise from the track, rolling noise from the vehicle, aerodynamic noise and the braking noise. The rolling noise is normalised to the reference rail roughness.
16. The derived wheel roughness and vehicle roughness response function \( L_{Hpr,veh}(f) \) in third octaves.
17. The emission terms in octave bands and as a function of the train speed for the different source heights, if relevant.
2.3 Measurement methods for determining wheel and rail corrugation

2.3.1 Relation between vertical railhead vibration and total roughness (for Alternative 2 only)

The total roughness, the energy sum of wheel and rail roughness, can be calculated from vertical railhead vibration using the following equation:

\[
L_{r_{\text{tot}}}(f) = L_{v_{\text{eq}}}(f) + 10 \log \left( \frac{VTD(f)}{8.68} \right) + C_{23}(f) - 10 \log(2\pi f)
\]

\[
= L_{v_{\text{max}}}(f) + C_{23}(f) - 10 \log(2\pi f)
\]

where:

- \( L_{r_{\text{tot}}}(f) \) = total roughness spectrum in third octaves [dB re 10^-6 m];
- \( L_{v_{\text{eq}}}(f) \) = equivalent vibration velocity spectrum in third octaves [dB re 10^-6 m/s];
- \( L_{v_{\text{max}}}(f) \) = maximum vibration velocity spectrum in third octaves [dB re 10^-6 m/s];
- \( V \) = train speed [m/s];
- \( T \) = passage time [s];
- \( D_s(f) \) = spectrum of the vertical spatial decay of the track [dB/m];
- \( C_{23}(f) \) = conversion spectrum for the contact filter and from roughness to contact point vibration\(^{1}\).

The spectrum \( C_{23}(f) \) can be determined with the following expression:

\[
C_{23}(f) = 10 \log \left( \left[ \frac{-f^2}{f_1^2} + 1 + jfD_1 \right] \left[ \frac{-f^2}{f_2^2} + 1 + jf \right] \left[ \frac{-f^2}{V^2f_3^2} + 1 + j\sqrt{2f} \right] \right)
\]

\[
D_1 = \frac{\Delta f}{f_1} \sqrt{10^{R/10}}
\]

\[
D_2 = \frac{\Delta f}{f_1^2} \frac{1}{\sqrt{10^{R/10}}}
\]

with the following input values can be used for a standard Dutch track:

\( R = -5.5 \) dB
\( \Delta f = 500 \) Hz

2.3.2 \( L_r(V,f) \) - Roughness as a function of frequency, speed dependent

Roughness is usually given as a function of wavelength, \( L_r(\lambda) \), independent of the train speed. This roughness is converted to a function of frequency \( L_r(f) \), to allow for calculations in the frequency domain. It is then also a function of train speed. The roughness curve retains its shape, but shifts in horizontal direction with varying train speed.

The location of this curve is calculated using:

\[
L_r(V,f) = L_r(\lambda),
\]

where:

\[
f = \frac{V}{\lambda}
\]

so for example, \( L_r(\lambda=0.01\text{m}) = L_r(V=90\text{ km/h}, f = 2500\text{ Hz}) \)

For calculation, speed (v) is expressed in m/s.

2.3.3 Average rail roughness of the national network of the M.S.

For calculation purposes, the reference rail roughness of the whole national network of the M.S. is used. The reference rail roughness is designated \( L_{rtr,nat}(\lambda) \), where \( \lambda \) is the wavelength in cm, and is equal to the Dutch average rail roughness.

Table 21 - Example of conversion of a roughness spectrum from wavelength to frequency domain.

<table>
<thead>
<tr>
<th>wave length [cm]</th>
<th>REFERENCE [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>7.0</td>
</tr>
<tr>
<td>12.5</td>
<td>6.0</td>
</tr>
<tr>
<td>10</td>
<td>5.0</td>
</tr>
<tr>
<td>8</td>
<td>4.0</td>
</tr>
<tr>
<td>6.3</td>
<td>3.0</td>
</tr>
<tr>
<td>5</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>3.15</td>
<td>0.0</td>
</tr>
<tr>
<td>2.5</td>
<td>-1.0</td>
</tr>
<tr>
<td>2</td>
<td>-2.0</td>
</tr>
<tr>
<td>1.6</td>
<td>-3.0</td>
</tr>
<tr>
<td>1.25</td>
<td>-4.0</td>
</tr>
<tr>
<td>1</td>
<td>-5.0</td>
</tr>
<tr>
<td>0.8</td>
<td>-6.0</td>
</tr>
<tr>
<td>0.63</td>
<td>-7.0</td>
</tr>
</tbody>
</table>
**WP 3.2.2: Railway Noise - Noise emission: databases**

<table>
<thead>
<tr>
<th>wavelength [cm]</th>
<th>REFERENCE [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>-8.0</td>
</tr>
<tr>
<td>0.4</td>
<td>-9.0</td>
</tr>
<tr>
<td>0.315</td>
<td>-10.0</td>
</tr>
<tr>
<td>0.25</td>
<td>-11.0</td>
</tr>
<tr>
<td>0.2</td>
<td>-12.0</td>
</tr>
<tr>
<td>0.16</td>
<td>-13.0</td>
</tr>
<tr>
<td>0.13</td>
<td>-14.0</td>
</tr>
<tr>
<td>0.1</td>
<td>-15.0</td>
</tr>
</tbody>
</table>

ISO and NL Average rail roughness

![Graph showing ISO and NL Average rail roughness.](image)

**Figure 7** - Average rail roughness of the Dutch rail network and the pr EN ISO 3095 limit curve for rail roughness at a test site.

**2.3.4 Measurement of track response using a reference vehicle**

The track vibration response $L_{HPV,TR}(f)$ in third octaves is measured with 3-4 so-called reference vehicles. The main property of these vehicles is that they radiate substantially less sound (10-20 dB) than the track. Wagons with small massive wheels with 40 cm diameter or less and massive webs are suitable. The ‘Rolling Highway’ wagons (RoLa Truck transport wagons) used in the EU are an example. The wheels do not have to be very smooth but should be free of flats and excessive wear.

During the passage, the vertical railhead vibration and the sound pressure at 7.5 m are measured. The track vibration response $L_{HPV,TR}(f)$ is the transfer function between the sound pressure and railhead vibration during the passage of the reference vehicles:

$$L_{HPV,TR}(f) = L_{PV,ref}(f) - L_{v,ref}(f)$$

---

**Project** | Wölfel Meßsysteme · Software GmbH & Co (main contractor) - AIB-Vinçotte EcoSafer - AKRON n.v.-s.a. - LabeIN Technological Centre S.L. - Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG - LÄRMKONTOR GmbH

**Team** | LabeIN Technological Centre S.L. - Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG - LÄRMKONTOR GmbH

**Page 53 of 60**
where:

\[ L_{Hpv,tr}(f) \]  track vibration response in third octaves from vertical railhead vibration to sound pressure at 7.5 m [dB re 20 Pa/m/s];

\[ L_{ptr,ref}(f) \]  equivalent sound pressure level in third octaves at 7.5 m during passage of reference vehicles [dB re 2.10^{-5} Pa];

\[ L_{v,ref}(f) \]  equivalent railhead vibration velocity level in third octaves during passage of reference vehicles [dB re 10^{-6} m/s].

This measurement must be performed at three cross-sections and at three speeds, over which an average is taken. The wheel and rail roughnesses are not relevant for this measurement, although extremely high roughness should be avoided.

Using the track vibration response, the sound radiation from the track can now be derived for any other test vehicle from the railhead vibration:

\[
B.48 \quad L(f) = L_{Hpv,tr}(f) + L_{v}(f)
\]

(all in third octaves and unweighted)

where:

\[ L_{ptr}(f) \]  equivalent sound pressure level due to track radiation in third octaves at 7.5 m during passage of test vehicle(s) [dB re 2.10^{-5} Pa];

\[ L_{v}(f) \]  equivalent railhead vibration velocity level in third octaves during passage of test vehicle(s) [dB re 10^{-6} m/s]. It is measured according to 2.2.7 on the speed range defined in 2.2.11.2.

### 2.4 Procedure C: Measurement method for track characteristics

#### 2.4.1 Introduction

This procedure aims to determine the track characteristics for new, renewed or different types of tracks.

The noise calculation method is based on the fact that the track characteristics, in octave bands, are independent of the type of vehicle or of the speed of the vehicle. To verify this, it is necessary to perform measurements at one location at two additional speeds (difference > 20, respectively 30%). The differences in the calculated track characteristics should be below 3dB in each of the octave bands.

If the correction is dependent on speed, additional research has to be carried out that may lead to speed dependent characteristics.

#### 2.4.2 Measurement set-up

##### 2.4.2.1 Number and test tracks condition

To determine the correction terms for the track type, measurements are carried out on at least two sections of test tracks, equipped with the new track type, each of at least 100 m long. The construction of the test tracks is identical over this length. Adjacent to the test tracks lies a reference track of at least 100 m with a track consisting of jointless rails on concrete mono block sleepers in ballast. The construction of this reference track must be representative of the construction on which this recommendation is based, with track type correction terms equal to \( C_{bb,i} \) (Table 16), with \( bb=1 \).

For each location, the measurements are carried out on three cross-sections of the test track and on two cross-sections of the reference track. The results of these measurements are averaged over the cross-sections for both the test and reference track. The environment between assessment point and reference and test track allows no difference in noise transmission. This means that soil properties,
realisation of embankment, height line, ... are identical. They may however differ for the several locations.

The rail roughness of the test and reference tracks is preferably lower than the ISO maximum graphic (pr EN ISO 3095). If this is not possible, the measurements can be made with a higher rail roughness. In this case, the total roughness should be determined: this is the sum of the rail roughness and the wheel roughness. The total roughness should be as similar as possible at both the reference and test location. Some deviations in the levels per octave band are allowed but they may not lead to a difference higher than 0.5 dB(A) in the A-weighted track type correction.

Both test and reference track are horizontal and straight. In order to prevent contact noises, no rail joints, welding joints, damaged paved areas or loose sleepers are allowed within a distance of 25 m from each side of the measurement cross sections. Connecting constructions between reference, test and other tracks are at least 25 m from the cross-sections.

2.4.2.2 Number and condition of the rail vehicles
To determine the track type correction terms, in each of the assessment points at least five passages of railway equipment with cast-iron block brakes and relative high rail roughness are measured. The rolling noise of the passing railway equipment has to be dominant with no other noise sources affecting the measurements. The passing railway equipment must comply with the conditions in § B.2.2.1. The condition of the passing railway equipment is recorded, stating at least the train type, train number and the number of passing railway carriages. The number of passages to be measured on each of both assessment points may differ by 20%.

The railway equipment must pass all assessment points with a constant speed (±5%) between 100 and 160 km/h and with the brakes deactivated.

2.4.2.3 Acoustic environment
The measurement environment must comply with the conditions in 2.2.5.

2.4.2.4 Meteorological conditions and background noise
The meteorological conditions and background noise must comply with the conditions in 2.2.6.

2.4.2.5 Quantities to be measured and assessment point
The A-weighted equivalent sound pressure level in octave bands $L_{pAeq,i}$ is measured at the cross-sections at a distance of 7.5 m from the centre of the track and at a height of 1.2 m above BS. Furthermore, the measurement arrangement in 2.2.7 must be used. Vibration measurements do not need to be executed, unless they are needed to determine the rail transmission (e.g. to use the measured track type to determine the properties of new railway equipment.) Also, the rail roughness is measured according to the method in 2.2.11.1 for both the reference and the test track.

2.4.2.6 Measurement equipment
The measurement equipment should comply, as much as possible, with the aforementioned conditions.

2.4.3 Determination of correction values for track characteristics
2.4.3.1 Octave band methods (SRM II)
The track type correction terms of the test track in octave bands $C_{bb,test,i}$ equal:
2.4.3.2 **Global dB(A) method (ARM 1)**

The track type correction terms for ARM-1 depend on the material category and are calculated as follows:

- Make a model according to SRM II of a simple situation with a single track on soft soil and a standard embankment of 1 m high;
- Calculate with this model the sound pressure at an assessment point, 25 m from the centre of the track and at a height of 2.5 m above BS;
- Use the correction term $C_{bb}$ from table 3.5 with $bb=1$ and the SRM II correction terms for the test track;
- Execute this calculation for each of the vehicle categories. For vehicle categories with a maximum speed of 140 km/h or higher, use following speeds: 80, 100 & 140 km/h. For those with a lower maximum speed, use following speeds: 60, 80 & 100 km/h. A regular train frequency is assumed, e.g. 10 carriages per hour.

The results from these calculations are used to determine the track type correction terms for ARM-1 as follows:

$$
C_{bb, \text{test}, i} = \frac{1}{n} \sum_{j=1}^{n} \left( L_{\text{Aeq, test}, i, j} - L_{\text{Aeq, ref}, i, j} \right)
$$

with:

- $L_{\text{Aeq, test}, i, j}$: equivalent noise level during passage of train $j$ in octave band $i$ over test tracks, energetically averaged over the cross-sections
- $L_{\text{Aeq, ref}, i, j}$: equivalent noise level during passage of train $j$ in octave band $i$ over reference tracks, energetically averaged over the cross-sections
- $n$: number of measured passages

### 2.4.4 Reporting

The reporting consists of the items in 2.2.15, with the exception of items 6 and 15. Item 4 is recorded for both reference and test track. In addition to this, the calculated track type correction terms in octave bands are reported, including the intermediate results of the calculations on which they are based.
EUROPEAN DATABASES

prepared by LABEIN Technological Centre S.L.

1 TRAIN EMISSION DATABASE

The current Train Emission Database is composed of all Dutch vehicles and other European vehicles circulating on Dutch tracks. In order to use these categories in another type of track, a correction factor for the difference on the rail roughness should be calculated.

Category 1: Block braked passenger trains
Category 2: Disc braked and block braked passenger trains
Category 3: Disc braked passenger trains
Category 4: Block braked freight trains
Category 5: Block braked diesel trains
Category 6: Diesel trains with disc brakes
Category 7: Disc braked urban subway and rapid tram trains
Category 8: Disc braked InterCity and slow trains
Category 9: Disc braked and block braked high speed trains
Category 10: Provisionally reserved for high speed trains of the ICE-3 (M) (HST East)

1.1 New train emission Database

When a new train category is added to the "European Train Emission Database", the information required is the following:

- If the emission of the train is given in Global dB(A), the emission index codes for braking and non-braking conditions related to the general equation $E = a + b \log V$ are required. (Table 1).
- If the emission values are defined per octave band, emission index codes for each source height, for braking and non braking conditions (passage conditions) and for all octave bands; related to the general equation $E = a + b \log V$ are required. (Table 2).
- Correction term $C_{b,c}$ as a function of vehicle category and track type. (Only for emission in Global dB(A)) (Table 3).
- The average vehicle wheel roughness as a function of wavelength. (Only for emission in octave bands) (Table 4).
- Maximum speed per train category (Table 5).
- Number of individual units of the train, if relevant. (Table 6).
- Optionally, it can be included a side view of the train category.

Table 1: Emission value in dB(A): emission index codes as functions of train category, and passage conditions (braking or constant speed).

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>non-braking trains</th>
<th>braking trains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$a_c$</td>
<td>$b_c$</td>
</tr>
<tr>
<td>New category</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Project: Wölfel Meßsysteme · Software GmbH & Co (main contractor) - AIB-Vinciotte EcoSafer - AKRON n.v.-s.a. - LABEIN Technological Centre S.L. - Honorar-Professor Dipl.-Ing. Dr. techn. Judith LANG - LÄRMKONTOR GmbH
Table 2: Emission value per octave band: emission index codes as functions of train category, source height, passage conditions (braking or non-braking) and octave band.

<table>
<thead>
<tr>
<th>Train category</th>
<th>Source height(m)</th>
<th>Passage conditions</th>
<th>Emission index codes</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>New category</td>
<td>0</td>
<td>Both</td>
<td>a^{bi,lc}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>No braking</td>
<td>a^{nb,bi,lc}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Braking</td>
<td>a^{br,bi,lc}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Both</td>
<td>a^{2m,bi,lc}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Both</td>
<td>a^{4m,bi,lc}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Both</td>
<td>a^{5m,bi,lc}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hint: Emission index codes at each source height, are independent of the passage conditions except for 0.5 m source height, where they could be different.

Table 3: Correction term C_{b,c} as a function of railway category and track type b.

<table>
<thead>
<tr>
<th>category</th>
<th>b=1</th>
<th>b=2</th>
<th>b=3</th>
<th>b=4</th>
<th>b=5</th>
<th>b=6</th>
<th>b=7</th>
<th>b=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>New category</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For a new train category the emission difference between a railway vehicle on a track with concrete sleepers (b=1) and one on another track type (b\neq 1) must be calculated. For description of the different track types see § 2.2.1.2.

Table 4: Average vehicle wheel roughness as a function of wavelength.

<table>
<thead>
<tr>
<th>Wavelength (cm)</th>
<th>Wheel roughness L_{veh}(\lambda)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.2</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>
Wheel roughness can be directly measured as a function of wavelength or calculated from formula B.6 after measured as a function of frequency. It is recommendable to update periodically wheel roughness data.

Table 5: Maximum speed per train category.

<table>
<thead>
<tr>
<th>New category</th>
<th>n°</th>
<th>n°</th>
<th>n°</th>
<th>n°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum speed (km/h)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Number of individual units of the train, if relevant.

<table>
<thead>
<tr>
<th>New category</th>
<th>n°</th>
<th>n°</th>
<th>n°</th>
<th>n°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of units</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 RAIL ROUGHNESS DATABASE

As it has been exposed before, rail roughness is an important factor on railway emission calculation. Adapted Dutch calculation method allows the calculation of any train emission running on non-Dutch rails. However, when rolling noise is relevant and there are no junctions on the track, the method will need data of rail roughness to be compared with the reference rail roughness.

Therefore a rail roughness database has to be built. Rail roughness data should be measured in third octaves according to procedure in prEN ISO 3095: 2001. If the roughness data is obtained by any other procedure, it should be documented that the results are comparable with the data from prEN ISO 3095:2001.

After doing some search of existing rail roughness data at different European countries, very few data has been found. Actually, neither Germany, Austria, Spain, nor Belgium have statistical relevant roughness data. There is data available of Dutch national average rail roughness.

Rail roughness database will contain local rail roughness expressed as a function of wavelength $L_{tr,loc}(\lambda)$, where $\lambda$ is in cm and the roughness is a level referred to 1 micrometer.

To allow calculation related to roughness in the frequency domain, it has to be converted as explained in Annex B.3.2 and it depends on train speed. With varying speed, the roughness spectrum curve retains its shape, but shifts in horizontal direction.

The structure of the roughness database is as described on following table.
WP 3.2.2: Railway Noise - Noise emission: databases

<table>
<thead>
<tr>
<th>wave length [cm]</th>
<th>$L_{nr,loc}(\lambda)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>0.315</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

It is recommendable to update periodically rail roughness data.