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Harmonised Accurate and Reliable Methods for the EU Directive on the assessment and management Of environmental NOISE

WP1.2 Rail Sources
Railway source model and user manual of the database
(D13p1)

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Contents

1. Introduction

The purpose of HARMONOISE is to provide an engineering model for the propagation of road and rail traffic with the following requirements:

- The engineering model will provide Lden values that could be used for noise mapping, for the assessment of annoyed people and effect of action plans (application of END Directive)
- This model should eliminate inconsistencies of previous models
- A high scientific quality as well as a good acceptance of the model is required (as accurate as possible, as simple as possible!)
- The distinction between source output and propagation should be made

In that context, the purpose of work package WP1.2 is to provide the emission data for railway sources to be implemented in the engineering model for the propagation (developed in work package WP3).

1.1 End user calculation process

The Figure 1 presents the end user process for propagation calculations using the WP3 model and WP1.2 railway emission data.

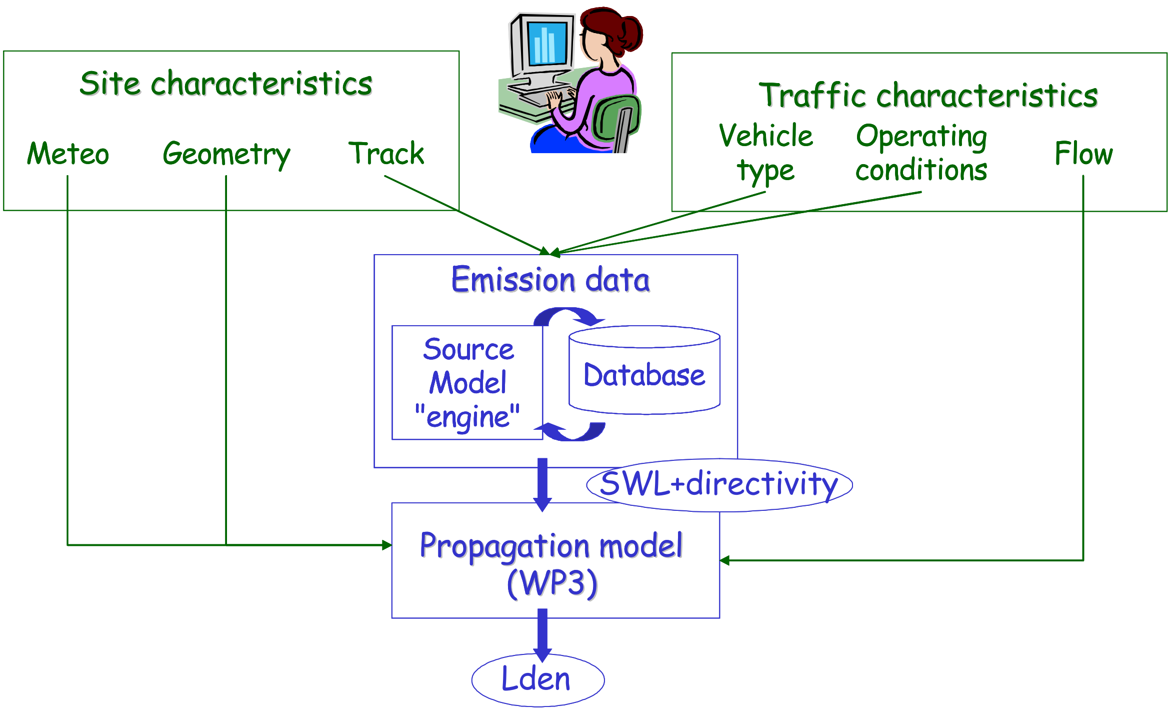

Figure 1: End user calculation process

1.2 Input Data

The two boxes on the top of the Figure 1 illustrate the input data that should be known by the end user. Some of this data will be used directly in the propagation calculation (as meteorological conditions, geometry of flow traffic), some of them will be useful to choose the appropriate values of the emission data (as the track characteristics, the vehicle type or the operating conditions). These last ones will be further developed later in the document.

1.3 Emission data

The railway emission data consist in two things:

- A database file (Access format)
- A source model "engine" which consists of the laws to obtain the output from the database

The output of the emission data useful as input of the propagation calculation is:

- The sound power level (in third octave bands) of equivalent moving point sources for five possible heights
- The associated directivity

The main objective of WP1.2 was to provide a database structure based on the physical knowledge of the sources, we call this approach "partial sources" in this document.
An escape is proposed to the user who has not sufficient information to use the appropriate emission data for the partial sources and who can only get data provided by pass-by measurements for a whole vehicle or a train. We call this approach "whole vehicle". A proposal has been done in the project to use such data [1]. In that case, the values of the sound power levels are directly implemented in the engineering model.

The purpose of this document is to explain the use of the railway source model database for the partial sources, which is the main purpose of HARMONOISE.

2. Summary of the work carried out in WP1.2 of HARMONOISE to obtain source models.

The sources which can be considered to be representative of railway emission are the rolling noise, the traction noise and the aerodynamic noise. A state of the art report has been delivered at the beginning of the project [2]. This document gives an overview of the knowledge on railway sources. The parameters that should be controlled to define a railway source are in particular given in this document and have been further investigated in the WP1.2. The models proposed in the database are presented in the following paragraphs.

2.1 Source models : physical parameters to obtain sound power levels

The objective of the task on source knowledge of WP1.2 was to determine the relevant physical parameters to obtain the sound power level $L_{w,i}$ (in third octave bands) of equivalent moving point sources. These parameters should be as accurate as possible but in the same time as practical as possible, in particular to allow the future users to fill in the database. Measurement guidelines to obtain the source models and their parameters have been also proposed in the project [3].

2.1.1 Rolling noise

Influences of rail roughness and track composition on rolling noise have been investigated [4], [5]. The rolling noise model is illustrated in Figure 2 and is based on the following parameters:

- The wheel roughness, the rail roughness and the contact filter, the three being defined in a wavelength domain. They should be combined and transformed in the frequency domain through the train speed,
- The vehicle and track transfer function between roughness and sound power.

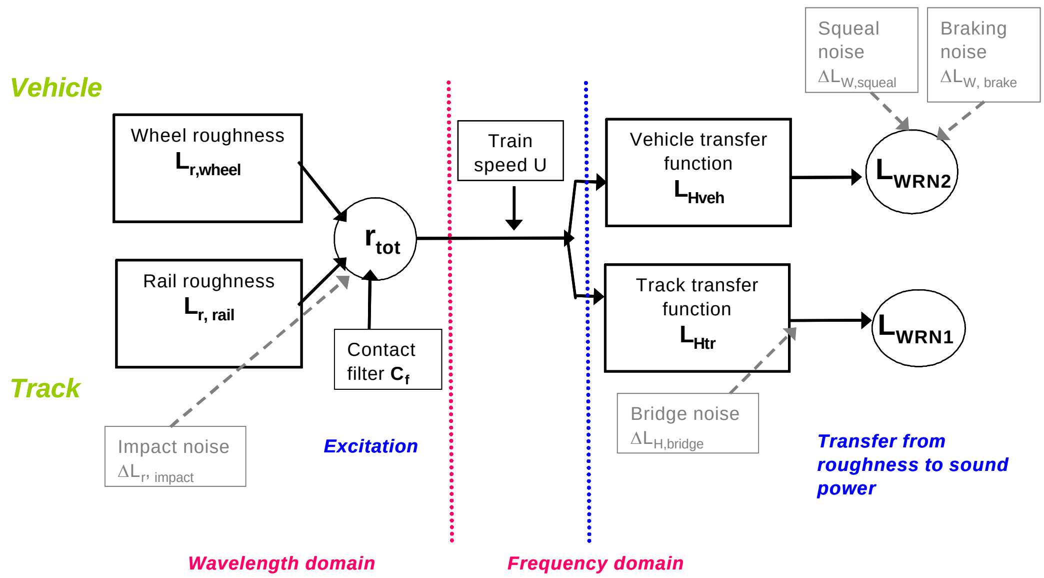

Figure 2: Principle of rolling noise model

The source positions for rolling noise have been discussed [6]. Two different options can indeed be taken: either all the contributions (wheel+track) are put at the contact position, or the contributions are separated, the vehicle contribution being at the wheel height and the track at the contact position. This last option has be chosen (separate the two contributions, see 2.2) because the details of the source heights can be important to modelled some cases like low barriers.

The model of rolling noise proposed here in HARMONOISE can be considered as validated because it is relatively closed to the principle of railway noise modelling tools like TWINS, which is accepted by the rolling noise "community".

Additional sources can be considered to describe specific situations like: train passing bridges, curve squeal, braking or impact noise (flat wheels or rail joints). These "other" sources have been reviewed and are proposed to be considered as correction terms of the rolling noise model [7]. These correction terms can be considered at different stages of the model:

- Roughness for the impact noise at the track position,
- Track transfer function for bridges, at the track position,
- Sound power for curve squeal at the wheel position,
- Sound power for braking noise at the wheel position.

2.1.2 Traction noise

In existing national railway noise prediction schemes, traction noise is covered only rather generally. A description of traction noise sources and parameters has been done in WP1.2 [8]. An overview of available measurement data has been done and a model has been proposed. The wide variety of noise sources associated with traction noise and their duty cycles can make the assessment of traction noise difficult to generalise. An approach is chosen whereby the most important influence parameters of main sources are identified:

- For constant speed and acceleration, the powertrain and cooling fan noise can be given as a function of rpm. Some recommendations have been given in the report for these parameters in average conditions of constant speed, acceleration, standstill/idling and deceleration and are reminded hereafter in Figure 3. A percentage rpm means percentage of the rpm speed range, i.e, rpm=rpmmin+%(rpmmax-rpmmin).

	Engine rpm for diesel powered vehicle	**Drive rpm for electrically powered vehicles**	**Fan rpm for all traction vehicles**
Constant speed	50% or nominal rpm for average train	Actual drive rpm with load correction if necessary	25% or nominal rpm
Acceleration	75%	Actual drive rpm with load correction if necessary	75%
Standstill/idling	Idling rpm	0	50%
Deceleration	Idling rpm	Actual drive rpm	50%

Figure 3: Recommended parameters for traction noise (drive and fan)

In the models for drive (including engine for diesel) and fans, two main effects are included: the level increase and the frequency shift of the spectrum with increasing rpm. The constants C_{drive} and C_{fan} can be obtained through measurements.
The fan noise will also require a duty cycle in some cases.

- Other traction noise sources like compressor or blowoff valves or exhaust must be characterised by a constant power spectrum for a given condition, which is allocated a certain duration,

Source heights will have to be chosen based on the known positions of various sources and frequency content at different positions. Source heights may vary considerably for different vehicle types and traction noise needs to be spread over the whole height of the train in the model. Four of the five positions could be used to put a traction noise source (see §2.2). The position at 0.5m can be used for drive source, position at 2m and 3m for drive, compressor or fan, the position at 4m for fan and exhaust.
The model of traction noise proposed here in HARMONOISE certainly needs more investigations to be completely validated.

2.1.3 Aerodynamic noise

Aerodynamic noise can only be described with very basic parameters. No detailed studies have been carried out for this source. The modelling will stay very basic compared to the rolling noise model. An equivalent source that could describe the main aerodynamic physical sources of a TGV (bogie area, pantograph, cavity of the pantograph) has been built using background data from SNCF. MAT2S software has been used to test the accuracy of this model and define the best position of the aerodynamic sources and a report has been provided [9]. A summary of these results as well as complementary elements for ICE have been given in [10].
Two possible sources could be considered: one for the bogie area and one for the roof and pantograph. For both these sources, the model consists in:

- reference values of $L_{w,i}$ for a reference speed,
- law of evolution with speed (speed exponent).

The model of aerodynamic noise proposed here in HARMONOISE is very simple because it is intrinsically impossible to describe the complex physical phenomena like turbulence induced acoustics with simple parameters.

2.2 Source heights

The Figure 4 describes the final source positions which can be chosen for a good description of railway vehicles.

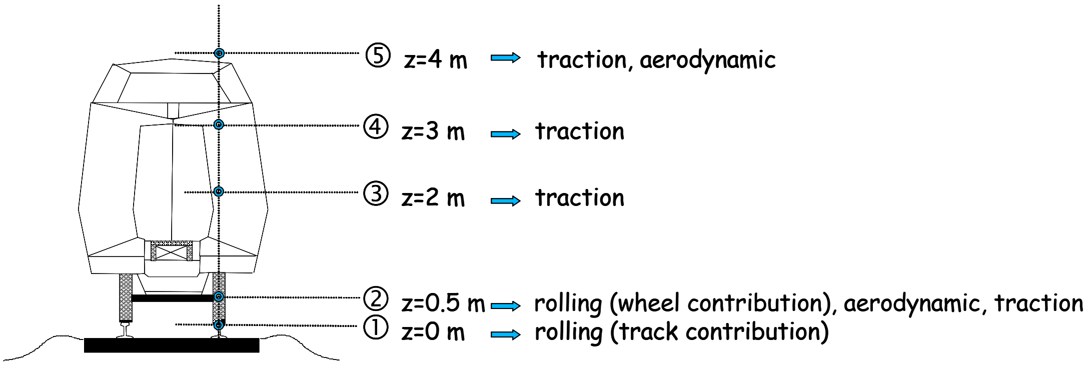

Figure 4: Sources positions for railway

The main criteria which have lead to the choice for the source position are the following:

- The rolling noise source is split into track (at z=0) and wheel (at z=0.5m) contributions. It seems that it is more accurate for treating for example the case of low barriers.
- The traction noise which includes several physical types of sources (traction motors, auxiliary systems, exhausts…) should be spread over the whole height of the train. Four of the five positions could be used to put a traction noise source, at 0.5m, 2m, 3m or 4 m.
- The aerodynamic noise is split into two contributions, one contribution for the bogie aerodynamic source which can be put at z=0.5m, one contribution at 4m for the equivalent source of the pantograph and if any the recess of the pantograph. It has been verified [11] that the aerodynamic source of the bogie area, which is physically closer to 0.8m can be put at 0.5m without increasing the uncertainty. It has been verified as well that the pantograph noise which is physically closer to 5m can be put at 4m without increasing the uncertainty, even with high noise barriers. Some NORD2000 calculations have confirmed this result [12].

2.3 Directivity

The horizontal and vertical directivity of a noise source are defined respectively as the horizontal and vertical angle distribution of the sound power.
Directivity of railway noise sources can not be assessed easily by measurements and its relevance to increase the accuracy of the model can not be simply evaluated. Some suggestions have been made [13], [14], [15] but are not sufficiently validated to be proposed in the final model of HARMONOISE.
For calculation of traffic noise levels, it has been proposed to consider only the horizontal directivity [16] as described in the following.

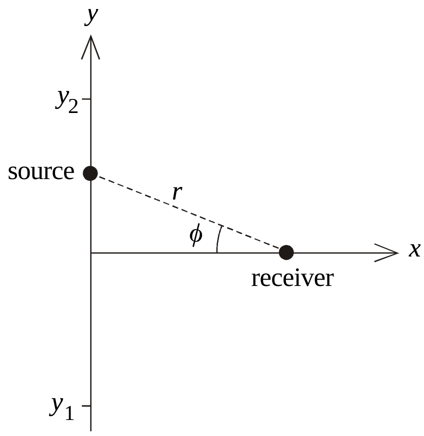

Figure 5: Geometry with a point source at position (0,y) on the y axis and a receiver at position (x,0) on the x axis

The directivity of the point sources can be expressed explicitly by writing: $L_{W,i,\phi} = L_{W,i} + \Delta L_{W,\phi}$

- where $L_{W,i}$ is the constant (in angle) sound power level spectra of the point source,
- $\Delta L_{W,\phi}$ is a function of the angle ϕ. Theoretically, this directivity function is frequency dependent but for practical reason, it is proposed here to consider only a global directivity.

The vertical directivity is ignored.

The directivity function $\Delta L_{W,\phi}$ is chosen such that we have: $\frac{1}{\pi}\int_{-\pi/2}^{\pi/2} 10^{\Delta L_{W,\phi}/10} d\phi = 1$ and $10^{L_{W,i}/10}$ is equal to the total normalized power of the source.

- For monopole sources we have $\Delta L_{W,\phi} \equiv 0$.
- For dipole sources oriented perpendicularly to the *y* axis we have $\Delta L_W, \phi = 10\lg(2\cos^2\phi)$.

The final suggestion consists of using a frequency averaged directivity function in horizontal direction for each source height. That means that it is a global coefficient for all the source types at a defined position:

$$L_{W\#,i,\phi} = L_{W\#,i} + \Delta L_{W\#,\phi} \qquad (1)$$

with # the position of the source, #=1,5.

In the engineering model, it will be proposed to choose:
- A monopole directivity
- A dipole directivity
- A user-defined directivity, defined each 10°

The tables for the five source heights is specified in the source database.

3.Source model engine

3.1 Notations

3.1.1 General

RN: railway noise index (rolling noise + squeal noise + impact noise + braking noise)
AN: aerodynamic noise index
TN: traction noise index
i: index of the frequency, i = ⅓-octaveband i in Hz
f_i: third octave centre frequency
j: wavelength index, j = ⅓-octaveband j in mm
m: vehicle index
n: track index
U: speed (minimum of vehicle speed and track segment speed)
1,…, 5 index for the source height
$L_{W1,m,n,i}$ = total sound power at source height #1 for vehicle m and track n, at ⅓-octave band i (in dB)
$\oplus$ = operator symbol for energy summation

3.1.2 Rolling noise

N_m = number of axles for vehicle m
$L_{RN1,m,n,i}$ = rolling noise sound power at source height #1 for vehicle m and track n, at ⅓-octave band i (in dB)
$L_{r,total,m,n,i}$ = total roughness (wheel+rail+contact filter), for vehicle m and track n, at given speed U, in frequency domain, at ⅓-octave band i (in dB)
$L_{r,total,m,n,j}$ = total roughness (wheel+rail+contact filter), for vehicle m and track n, in wavelength domain, at ⅓-octave band j (in dB)
$L_{r,track,n,j}$ = rail roughness, for track n, in wavelength domain, at ⅓-octave band j (in dB)
$L_{r,wheel,m,j}$ = wheel roughness, for vehicle m, in wavelength domain, at ⅓-octave band j (in dB)
$CF_{m,n,j}$ = contact filter, for vehicle m and track n, in wavelength domain, at ⅓-octave band j (in dB)
$L_{r,eff,impact,n,j}$ = effective equivalent roughness due to impact for track n, in wavelength domain, at ⅓-octave band j (in dB)
$L_{r,total,m,n,i}$ = total roughness (wheel+rail+contact filter), for vehicle m and track n, at given speed U, in frequency domain, at ⅓-octave band i (in dB)
$L_{Htr,n,i}$ = transfer function from effective roughness to sound power, for the track n, at ⅓-octave band i (in dB)
$\Delta L_{Htr,n,i}$ = transfer function correction term for bridges, for the track n, at ⅓-octave band i (in dB)
$L_{Hveh,m,i}$ = transfer function from effective roughness to sound power, per axle, for the vehicle m, at ⅓-octave band i (in dB)
$\Delta L_{W,squeal,n,i}$ = correction spectrum for squeal noise, for vehicle m, at ⅓-octave band i (in dB)
$\Delta L_{W,brake,m,i}$ = correction spectrum for braking noise, for vehicle m, at ⅓-octave band i (in dB)

3.1.3 Traction noise

$L_{WTN2,m,i}$: traction noise sound power at source height #2 for vehicle m, at ⅓-octave band i (in dB)

$L_{Wdrive2,m,ndrive,i}$=drive system sound power at source height #2, for vehicle m, drive rpm n_{drive}, at ⅓-octave band i (in dB)
n_{drive}, $n_{drivemax}$: drive and maximum drive rpm, which are the diesel motor shaft or gearbox input shaft rpm and rpmmax
C_{drive} : constant for rpm dependency of drive sound power (can be around 30 for gear noise and for diesel engine noise)

$L_{Wfan3,m,nfan,i}$ = fan noise sound power at source height #3 for vehicle m, fan rpm n_{fan}, at ⅓-octave band i (in dB)
n_{fan}, n_{fanmax}: fan and maximum fan rpm
C_{fan} : constant for rpm dependency of fan sound power
$dc_{fan:}$ duty cycle for fans

$L_{Wcomp3,m,comp,i}$: compressor sound power level at source height #3 for vehicle m, at ⅓-octave band i (in dB). This source can be characterized for blow-off valves as well.
$dc_{comp:}$ duty cycle for compressors

$L_{Wexhaust5,m,exhaust,i}$: exhaust sound power level, at source height #5, for vehicle m, at ⅓-octave band i (in dB)
$dc_{exhaust:}$ duty cycle for exhaust noise

3.1.4 Aerodynamic noise

$L_{AN2,m,i}$ = aerodynamic noise sound power at source height #2 for vehicle m at ⅓-octave band i (in dB)
U_{ref2}: reference speed for which L_{ANref2} is given at height #2 (bogie area)
$\alpha 2$: speed coefficient for aerodynamic noise at height #2 (bogie area)

3.2 Formulae for each source height

The formulae to obtain the sound power level at each source height are detailed here. More explanations can be obtained further in the user manual. The data given in the database sheets are given in bold.

Source height #1, at z=0m from the rail head: rolling noise (track contribution)

$$L_{W1,m,n,i} = L_{WRN1,m,n,i} + 10\log \mathbf{N_m} \quad (2)$$

$$L_{WRN1,m,n,i} = L_{r,total,m,n,i} + \mathbf{L_{Htr,n,i}} + \mathbf{\Delta L_{Hbridge,n,i}} \quad (3)$$

$L_{r,total,m,n,i}$ is obtained from $L_{r,total,m,n,j}$ following these steps:

- The combined roughness is firstly calculated in the wavelength domain:

$$L_{r,total,m,n,j} = \mathbf{L_{r,rail,n,j}} \oplus \mathbf{L_{r,wheel,m,j}} \oplus \mathbf{L_{r,impact,n,j}} + \mathbf{C_{f,m,n,j}} \quad (4)$$

The formulae to obtain the contact filter are specified in annexe 1.

- From the speed of the vehicle U, the 1/3 octave bands frequencies and the relation $\lambda = \frac{U}{f}$, the corresponding values of λ are calculated. The values of $L_{r,total,m,i}$ are then obtained through an interpolation between values of the two surrounded wavelength 1/3 bands.

Source height #2, at z=0,5m: rolling noise (wheel contribution) + traction noise (drive) + aerodynamic noise of the bogie area

$$L_{W2,m,n,i} = L_{WRN2,m,n,i} + 10\log \mathbf{N_m} \oplus L_{WTN2,m,i} \oplus \mathbf{L_{WAN2,m,i}} \quad (5)$$

$$L_{WRN2,m,n,i} = \mathbf{L_{r,total,m,n,i}} + \mathbf{L_{Hveh,m,i}} + \mathbf{\Delta L_{W,squeal,m,i}} + \mathbf{\Delta L_{W,brake,m,i}} \quad (6)$$

Where $L_{r,total,m,n,i}$ is obtained as explained for the rolling noise source at position #1 and via equation (3)

$$L_{WTN2,m,i} = L_{Wdrive2,m,ndrive,i}$$

$$L_{Wdrive2,m,ndrive,i} = \mathbf{L_{wdrive2,m,ndrivemax,i}}(\mathbf{f_i}.(\mathbf{n_{drive}}/\mathbf{n_{drivemax}})) + \mathbf{C_{drive}}\log(\mathbf{n_{drive}}/\mathbf{n_{drivemax}}) \quad (7)$$

$$\mathbf{L_{WAN2,m,i}} = L_{WANREF2,m,i} + \alpha_2 \mathbf{log U}/U_{ref2} \quad (8)$$

Source height #3, at z=2 m: traction noise (drive+fan+compressor)

$$L_{W3,m,i} = L_{WTN3,m,i}$$

$$L_{WTN3,m,i} = L_{Wdrive3,m,ndrive,i} \oplus L_{Wfan3,m,nfan,i} \oplus L_{Wcomp3,m,comp,i}$$

$$L_{Wdrive3,m,ndrive,i} = \mathbf{L_{wdrive3,m,ndrivemax,i}}(f_i.(\mathbf{n_{drive}}/\mathbf{n_{drivemax}})) + \mathbf{C_{drive}}\log(\mathbf{n_{drive}}/\mathbf{n_{drivemax}})$$

$$L_{Wfan3,m,nfan,i} = \mathbf{L_{wfan3,m,nmax,i}}(f.(\mathbf{n_{fanmax}}/\mathbf{n_{fan}})) + \mathbf{C_{fan}}\log(\mathbf{n_{fan}}/\mathbf{n_{fanmax}}) + 10\log(\mathbf{dc_{fan}}) \quad (9)$$

$$L_{Wcomp3,m,comp,i} = \mathbf{L_{wcomp3,m,i}} + 10\log(\mathbf{dcc_{omp}}) \quad (10)$$

Source height #4, at z=3 m: traction noise (drive+fan+compressor)

$L_{W4,m,i} = L_{WTN4,m,i}$

$L_{WTN4,m,i} = L_{Wdrive4,m,ndrive,i} \oplus L_{Wfan4,m,nfan,i} \oplus L_{Wcomp4,m,comp,i}$

$L_{Wdrive4,m,ndrive,i} = \mathbf{L_{wdrive4,m,ndrivemax,i}}(f_i.(\mathbf{n_{drive}}/\mathbf{n_{drivemax}}) + \mathbf{C_{drive}}\log(\mathbf{n_{drive}}/\mathbf{n_{drivemax}})$

$L_{Wfan4,m,nfan,i} = \mathbf{L_{wfan4,m,nmax,i}}(f.(\mathbf{n_{fanmax}}/\mathbf{n_{fan}})) + \mathbf{C_{fan}}\log(\mathbf{n_{fan}}/\mathbf{n_{fanmax}}) + 10\log(\mathbf{dc_{fan}})$

$L_{Wcomp4,m,comp,i} = \mathbf{L_{wcomp4,m,i}} + 10\log(\mathbf{dcc_{omp}})$

Source height #5, at z=4 m: aerodynamic noise of the pantograph area + traction noise (fan+exhaust)

$L_{W5,m,i} = L_{WTN5,m,i} \oplus L_{WAN5,m,i}$

$L_{WTN5,m,i} = L_{Wfan5,m,i} \oplus L_{Wexhaust5,m,i}$

$L_{Wfan5,m,nfan,i} = \mathbf{L_{wfan5,m,nmax,i}}(f.(\mathbf{n_{fanmax}}/\mathbf{n_{fan}})) + \mathbf{C_{fan}}\log(\mathbf{n_{fan}}/\mathbf{n_{fanmax}}) + 10\log(\mathbf{dc_{fan}})$

$$L_{Wexhaust4,m,comp,i} = \mathbf{L_{wexhaust4,m,i}} + 10\log(\mathbf{dc_{exhaust}}) \qquad (11)$$

$L_{WAN5,m,i} = \mathbf{L_{WANREF5,m,i}} + \alpha_5 \log U/\mathbf{U_{ref5}}$

4. Database structure and "user manual"

4.1 Global structure of the database

The content of the database is illustrated in Figure 6.

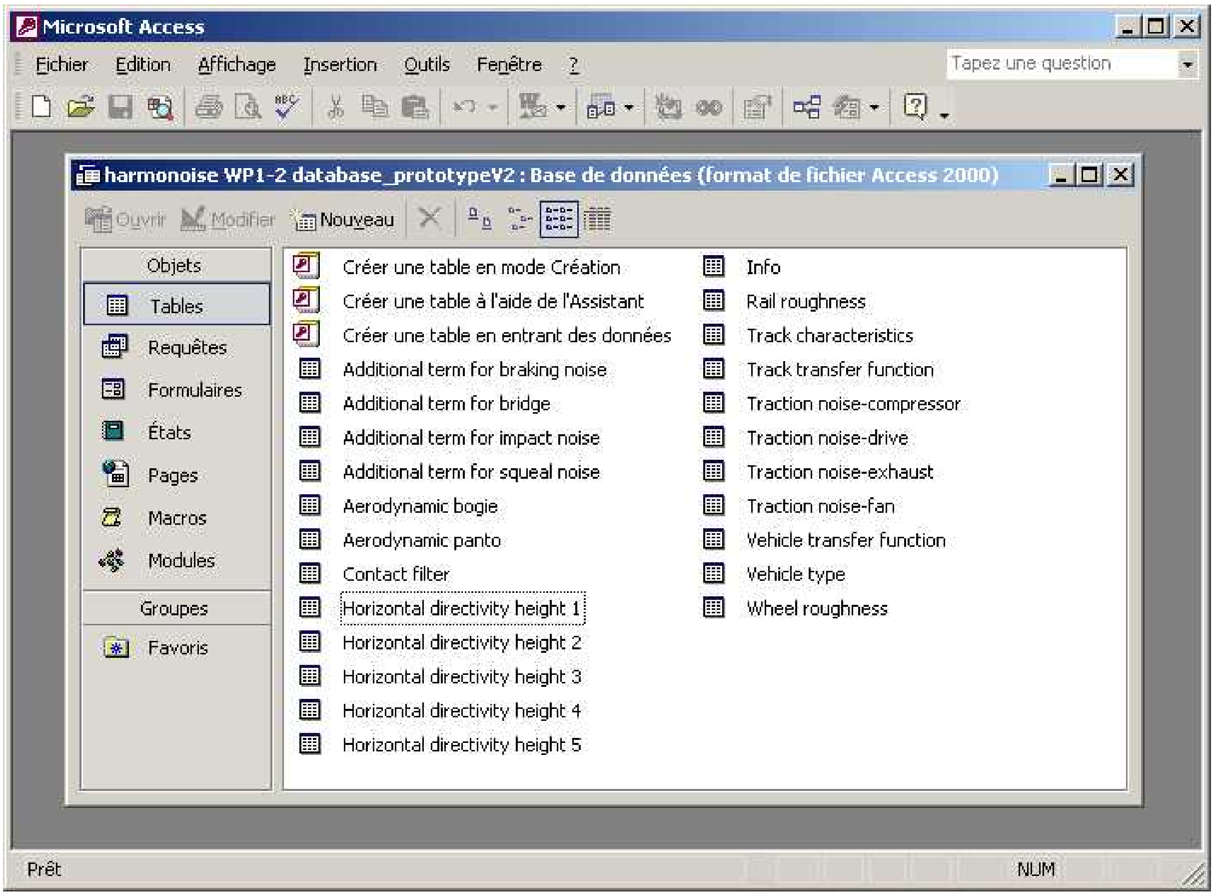

Figure 6: Database content

The database is organised around two main tables which defined the use of the other tables.

- One table that specifies the track characteristics,
- One table which specifies the vehicle characteristics.

The other tables contain the data and the parameters useful to calculate the sound power according to the formulae and the parameters described previously:

- Four tables allow to calculate the rolling noise: rail roughness, track transfer function, wheel roughness, vehicle transfer function, contact filter,
- Four tables allow to calculate the other sources : "additional term for impact noise", "additional term for bridge", "additional term for squeal noise", "additional term for braking noise",
- Four tables allow to calculate the traction noise: "traction noise-drive", "traction noise-fan", "traction noise-compressor", "traction noise-exhaust",
- Two tables allow to calculate the aerodynamic noise: "aerodynamic bogie" and "aerodynamic panto",
- Five tables for respectively the five source heights specify the horizontal directivity.

The relations between the tables are given in Figure 7 and the details of the tables are explained in the following paragraphs.

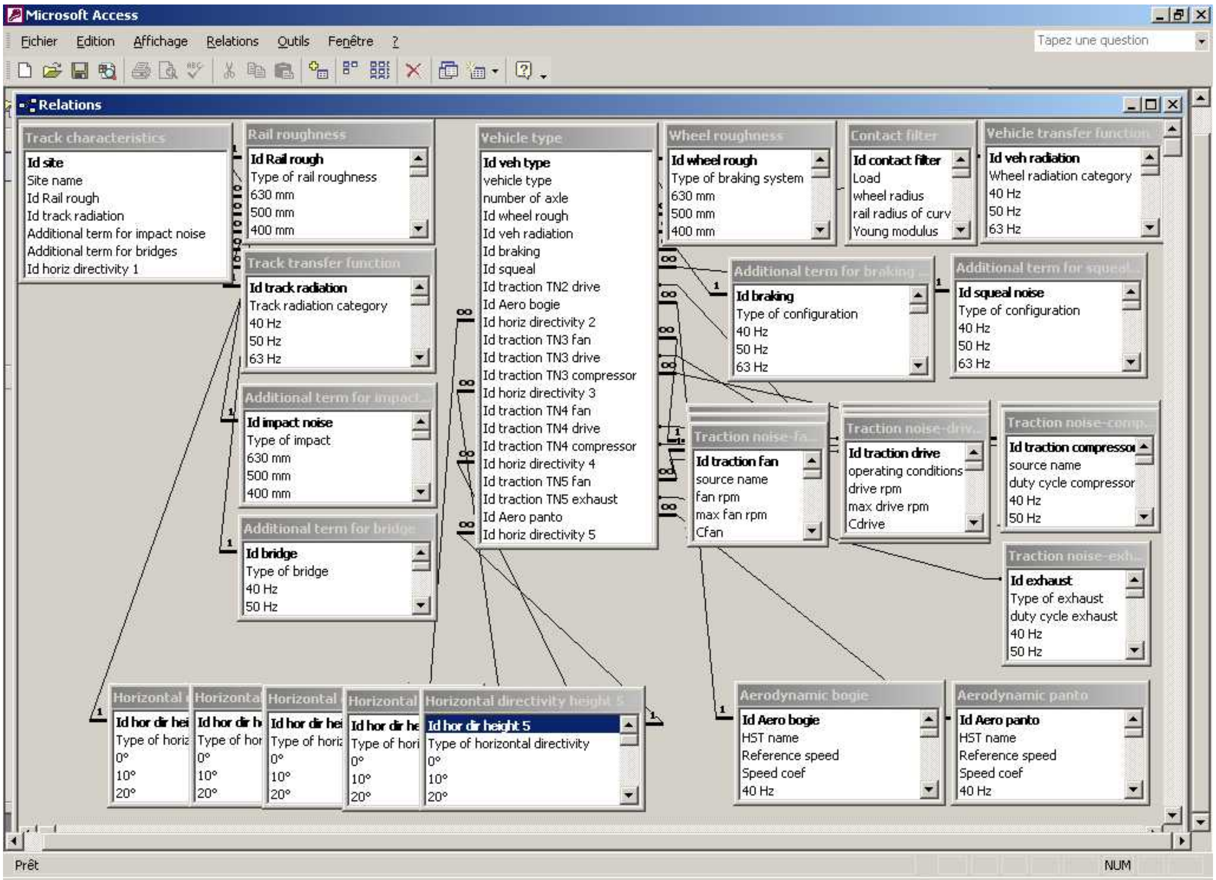

Figure 7: relations between database tables

4.2 Track characteristics

The database contents a table relative to the track characteristics which are useful for the calculation of the rolling noise and the possible additional sources due to impact noise or bridge noise (see 3.2).
This table contents the following columns:

- the site name (specified by the user)
- the rail roughness characteristics (which is linked to the table "Rail roughness")
- the track radiation characteristics (which is linked to the table "Track transfer function")
- The additional term for impact noise (which is linked to the table "Additional term for Impact noise") to specify if there is an additional source of impact noise
- The additional term for bridges (which is linked to the table "Additional term for bridges") to specify if there is an additional source of bridge
- The horizontal directivity for the source height #1, which is linked to the table "horizontal directivity height 1")

As illustrated in Figure 8 for rail roughness, the user can choose in this table the appropriate characteristics for each of the column.

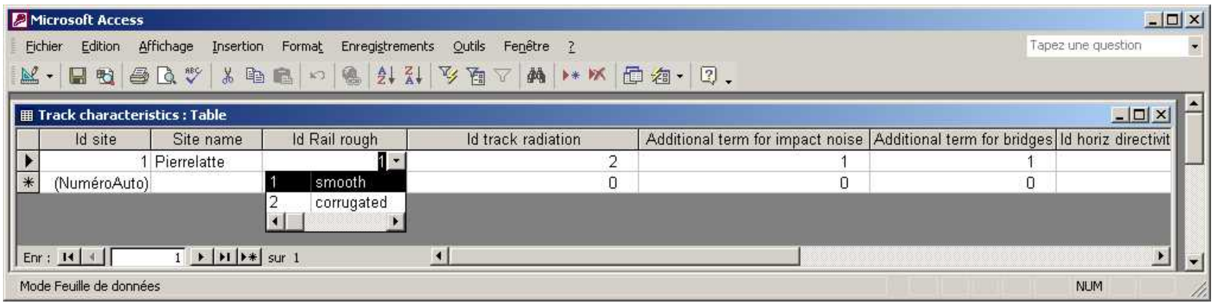

Figure 8: Track characteristics table

4.3 Default Vehicle type

4.3.1 Vehicle categories

The database contents a table "Vehicle type", illustrated in Figure 10 and Figure 11, which allow specifying different vehicle types according to the different partial sources that can describe it.
We remind here that the database contents only examples for helping the understanding of the structure. The different countries are responsible of filling in the database following the practical methods proposed in HARMONOISE.
We consider here vehicles concept which can be in practice vehicles or for some cases trains (like for EMUs, DMUs or High Speed Trains).
An illustration of the vehicle categorization principle is given in Figure 9.

Vehicle type	**Source type at z=0 m**	**Source type at z=0.5 m**	**Source type at z=2 m**	**Source type at z=3 m**	**Source type at z=4 m**
Freight wagon	Rolling (track part)	Rolling (wheel part)	----	----	----
Passenger coach	Rolling (track part)	Rolling (wheel part) + Traction (drive)	----	----	----
Diesel locomotive	Rolling (track part)	Rolling (wheel part)	Traction (drive+fan+compressor)	----	Traction (exhaust)
Electric locomotive	Rolling (track part)	Rolling (wheel part)	Traction (drive+fan)	Traction (compressor)	----
DMU	Rolling (track part)	Rolling (wheel part)	Traction (drive+fan+compressor)	----	Traction (exhaust)
EMU	Rolling (track part)	Rolling (wheel part)	Traction (drive+fan)	Traction (compressor)	----
High speed train	Rolling (track part)	Rolling (wheel part) + aero bogie	----	----	Aero panto + traction (fan)

Figure 9: Illustration of vehicle categorization principle

4.3.2 Content of the sheet

This table contents the following columns:

- The name of the vehicle type (specified by the user). The different examples of categories are thus for which the types of sources are different (see Figure 9).
- The number of axle (specified by the user), will be use to calculate the total rolling noise. It specifies the number of rolling noise partial sources.
- The wheel roughness, which is linked to the table "wheel roughness", as illustrated in Figure 10.
- The vehicle radiation characteristics, (which is linked to the table "vehicle transfer function")
- The braking noise, which is linked to the table "Additional term for braking" to specify if there is an additional source of braking
- The squeal noise, which is linked to the table "Additional term for squeal noise") to specify if there is an additional source of squeal noise
- Id traction TN2-drive, (which is linked to the table "Traction noise-drive") to specify if there is a traction noise drive source at the height #2
- The aerodynamic source of the bogie area, (which is linked to the table "Aero bogie") to specify if there is a aerodynamic source of the bogie area at the height #2
- The horizontal directivity for the source height #2, which is linked to the table "horizontal directivity height 2")
- The traction TN3-fan, (which is linked to the table "Traction noise-fan") to specify if there is a traction noise fan source at the height #3
- The traction TN3-drive, (which is linked to the table "Traction noise-drive") to specify if there is a traction noise drive source at the height #3
- The traction TN3-compressor, (which is linked to the table "Traction noise-comp") to specify if there is a traction noise compressor source at the height #3
- The horizontal directivity for the source height #3, which is linked to the table "horizontal directivity height 3")
- The traction TN4-fan, (which is linked to the table "Traction noise-fan") to specify if there is a traction noise fan source at the height #4
- The traction TN4-drive, (which is linked to the table "Traction noise-drive") to specify if there is a traction noise drive source at the height #4
- The traction TN4-compressor, (which is linked to the table "Traction noise-comp") to specify if there is a traction noise compressor source at the height #4
- The horizontal directivity for the source height #4, which is linked to the table "horizontal directivity height 4")
- The traction TN5-fan, (which is linked to the table "Traction noise-fan") to specify if there is a traction noise fan source at the height #5
- The traction TN5-exhaust, (which is linked to the table "Traction noise-exhaust") to specify if there is a traction noise exhaust source at the height #5
- The aerodynamic pantograph source, (which is linked to the table "Aerodynamic panto") to specify if there is an aerodynamic source for the pantograph area at the height #5
- The horizontal directivity for the source height #5, which is linked to the table "horizontal directivity height 5")

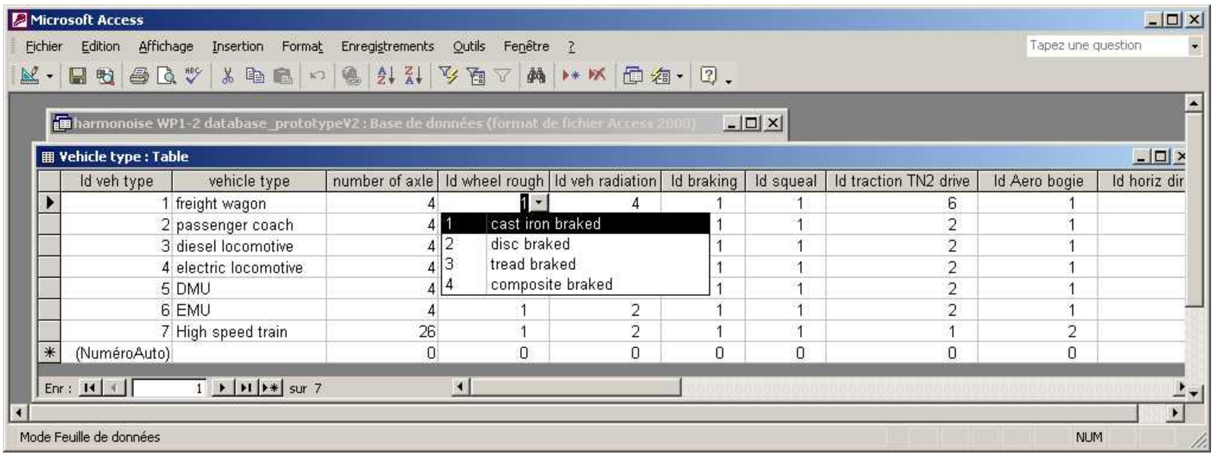

Figure 10: "Vehicle type" table, part 1

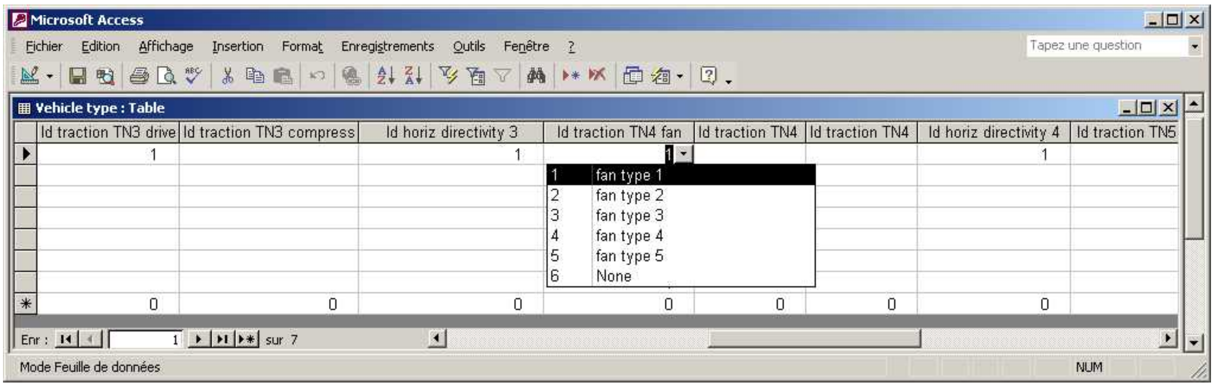

Figure 11: "Vehicle type" table, part 2

5. Conclusion

This document summarises the work carried out by the work-package WP1.2 of HARMONOISE project and the results which have lead to propose a database for the railway source models.

- The rolling noise model could be considered as relatively validated because it is close to the modelling principle of rolling noise well known and validated like TWINS.
- The traction noise model is a first proposal that needs to be further investigated and validated.
- The model of aerodynamic noise proposed is very simple because it is intrinsically impossible to describe the complex physical phenomena like turbulence induced acoustics with simple parameters.

The interface between the railway source data and the engineering model for propagation calculation should be done in the future to help the end-users.

6. Annexes

6.1 Annexe 1: Formulae to obtain the contact filter [17].

The contact filter formulae proposed by Remington in the wavelength domain λ is developed:

$$C_f(\lambda) = \left[1 + \frac{\pi}{4}.\frac{(2\pi b)^3}{\lambda^3}\right]$$ with:

b, the semi axe of the elliptical contact filter in the transverse direction defined as follows:

$$b = \sigma\left(\frac{3F_0 r_e}{2E^*}\right)^{\frac{1}{3}}$$ where:

- E^* is the plain strain elastic modulus $E^* = \frac{E}{1-\upsilon^2}$, E being the Young modulus and ν the Poisson coefficient.
- r_e is an effective radius of curvature of the surfaces in contact given by: $\frac{1}{r_e} = \frac{1}{2}\left(\frac{1}{r_1^w} + \frac{1}{r_2^w} + \frac{1}{r_1^r} + \frac{1}{r_2^r}\right)$, where r_1 is the respective radius of curvature of wheel and rail in the rolling direction and r_2 is the respective radius of curvature of the transverse profile. Generally r_2^w and r_1^r are ∞.
- σ is dimensionless quantity dependent on the radii of curvature of the two surfaces. Values of σ are given in the following table versus the parameter θ which is defined as: $\cos\theta = \frac{r_e}{2}\left(-\frac{1}{r_1^w} + \frac{1}{r_2^w} - \frac{1}{r_1^r} + \frac{1}{r_2^r}\right)$

θ (degrees)	σ
30	0.493
35	0.530
40	0.567
45	0.604
50	0.641
55	0.678
60	0.717
65	0.759
70	0.802
75	0.846
80	0.893
85	0.944
90	1

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