Adaptation and revision of the interim noise computation methods for the purpose of strategic noise mapping

Final Report
Part A

Reference:	B4-3040/2001/329750/MAR/C1
Commissioned by:	EUROPEAN COMMISSION DG Environment
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Wölfel project:	Z070/01
Date:	25 March 2003

This report encompasses 144 pages.

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1. General Considerations

1.1. Introduction

In 1996, EC DG XI (now EC DG Environment) published the Green Paper on the future noise policy. During a public consultation campaign several hundred remarks were collected. Both the Green Paper and these remarks formed the basis of the official EC communications during the 1998 invitational Copenhagen Conference where the work of preparing the END was started.

This conference was also the starting point for the work of up to ten different Working Groups headed by a Steering Group. The result of four years of concentrated work of invited international experts and subsequent debates in the Council and the Parliament has been published on 18 July 2002 as DIRECTIVE 2002/49/EC.

At the end of 2001 the existing groups working on the perception of noise were dissolved and a new structure was created to accompany the next phase of the implementation of the END.

Figure 1 - The EU Noise Expert Network

Strategic noise mapping and interim computation methods are central to the END. The following Articles and Annexes are of crucial importance to the practical implementation of the END:

- Article 7 and Annex IV are directly concerned with strategic noise mapping.
- Articles 6 and 5 and Annexes I and II define other technical aspects including the noise indicators to be used for strategic noise mapping.

Further articles and annexes are of primary importance for the transposition into national legislation, organisational aspects and communication with the European Commission. These articles and annexes are beyond the scope of this study which is only concerned with the Adaptation and Revision of Interim Computation Methods for Strategic Noise Mapping.

It is important to note that the END has a well-defined scope and pursues well-defined aims:

- In terms of noise mapping, END deals with strategic noise maps only! The latter are large scale displays of the noise pollution in a Member State expressed in terms of the noise indicators L_{den} and L_{night}. Their primary use is to inform the public and to report to the EC.
- The END provides common basic definitions and imposes the use of common indicators and equivalent computation methods to ensure for the first time comparability of noise pollution statistics across the entire European Union. Furthermore, the END requires action planning on the basis of strategic noise maps to manage and where necessary actively reduce levels of environmental noise.

- The END neither interferes nor competes with existing national noise abatement strategies or programmes or EIA, IPPC and similar permitting regulations. However, the END does provide the first harmonised legal Europe-wide legislation to complement existing national legislation and ensures that those Member States who do not yet have their own national regulations start finally to address the problem of environmental noise.

Annex 4 of the END identifies the recommended interim computation methods for strategic noise mapping. These methods are listed below:

For INDUSTRIAL NOISE: ISO 9613-2: 'Acoustics — Abatement of sound propagation outdoors, Part 2: General method of calculation'.

Suitable noise-emission data (input data) for this method can be obtained from measurements carried out in accordance with one of the following methods:

— ISO 8297: 1994 'Acoustics — Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment — Engineering method',

— EN ISO 3744: 1995 'Acoustics — Determination of sound power levels of noise using sound pressure — Engineering method in an essentially free field over a reflecting plane',

— EN ISO 3746: 1995 'Acoustics — Determination of sound power levels of noise sources using an enveloping measurement surface over a reflecting plane'.

For AIRCRAFT NOISE: ECAC.CEAC Doc. 29 'Report on Standard Method of Computing Noise Contours around Civil Airports', 1997. Of the different approaches to the modelling of flight paths, the segmentation technique referred to in section 7.5 of ECAC.CEAC Doc. 29 will be used.

For ROAD TRAFFIC NOISE: The French national computation method 'NMPB-Routes-96 (SETRA-CERTU-LCPC-CSTB)', referred to in 'Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10 mai 1995, Article 6' and in the French standard 'XPS 31-133'. For input data concerning emission, these documents refer to the 'Guide du bruit des transports terrestres, fascicule prévision des niveaux sonores, CETUR 1980'.

For RAILWAY NOISE: The Netherlands national computation method published in 'Reken- en Meetvoorschrift Railverkeerslawaai '96, Ministerie Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 20 November 1996'. [1]

These methods may be used, once adapted and revised, for strategic noise mapping as required by the END. Alternatively, END allows the use of national methods provided EU M.S. demonstrate that the results produced using such methods are equivalent with the results produced using the interim methods. This is meant to ensure comparability of results across EU Member States which is one of the ultimate goals of the END. Interim methods and national methods will be superseded by the planned harmonised calculation method. Until then, interim and national methods will co-exist for strategic noise mapping. On the one hand, a Member State that does not have any national methods of its own is required to use the interim methods. On the other hand, Member States which do have their own national methods may adopt the interim methods for strategic noise mapping whilst continuing to use their own national methods for other applications.

The three methods that deal with the surface noise sources of road traffic, railway traffic and industry have one common denominator in that they are either based on ISO 9613-2 or employ equations derived from ISO 9613-2. The method to calculate noise contours around airports is different.

It should be noted that, with the exception of industrial noise, the release date of the methods is specified in the END. This implies a legal obligation to use a particular edition of the methods or an adapted version of them provided by the EC and announced in END:

Those methods must be adapted to the definitions of L_{den} and L_{night}. No later than 1 July 2003 the Commission will publish guidelines in accordance with Article 13(2) on the revised methods and provide emission data for aircraft noise, road traffic noise and railway noise on the basis of existing data. [2]

The above clause splits into two parts: The first sentence on adaptation to noise indicators L_{den} and L_{night} is applicable to both the interim methods and the national methods that a Member State may

[1] quote from Directive 2002/49/EC, Annex IV

[2] quote from Directive 2002/49/EC, Annex IV

choose to use. This adaptation is an element of primary importance in the search for comparability of noise maps. The designated competent authority of a Member State which decides to use its own national method is responsible for producing both the adaptation and for demonstrating the equivalence of the results.

In the second sentence, the EC sets itself a time limit to produce guidelines on the revised interim methods.

1.2. Definitions

In both, Part A (this text) and Part B (the collection of individual reports by team members), the following acronyms are used:

- Contract means EC Contract B4-3040/2001/329750/MAR/C1 “Adaptation and revision of the interim noise computation methods for the purpose of strategic noise mapping”.
- Technical Annex means the technical annex to the Contract.
- AR-INTERIM-CM means the project “Adaptation and revision of the interim noise computation methods for the purpose of strategic noise mapping”.
- END means DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND THE COUNCIL of 25 June 2002 relating to the assessment and management of environmental noise.
- EU M.S. means either EU Member State or EU Member States.
- MTR means Mid-Term Report.
- FDR means Final Draft Report.
- NMPB or XP S 31-133 or NMPB/XP S 31-133 means The French national computation method ‘NMPB-Routes-96 (SETRA-CERTU-LCPCCSTB)’, referred to in ‘Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10 mai 1995, Article 6’ and in the French standard ‘XPS 31-133’.
- ISO 9613 or ISO 9613-2 means ISO 9613-2: ‘Acoustics — Abatement of sound propagation outdoors, Part 2: General method of calculation’.
- SRM II means The Netherlands national computation method published in ‘Reken- en Meetvoorschrift Railverkeerslawaai ’96, Ministerie Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 20 November 1996’.
- ECAC or ECAC.CEAC Doc.29 or Doc. 29 means ECAC.CEAC Doc. 29 ‘Report on Standard Method of Computing Noise Contours around Civil Airports’, 1997.

1.3. Scope

Early in 2002, EC DG Environment awarded a contract concerning the adaptation and revision of the interim computation methods for strategic noise mapping to Wölfel. The aim of the study is to propose adaptations and revisions of the interim methods to make them suitable for strategic noise mapping in all EU Member States.

The need for the project results from the time limit (1 July 2003) the EC set itself with the clause of Annex II on the publications of guidelines on adapted interim methods.

The terms of reference define the project as a desk study. As a consequence this project qualifies as an application project. The aim is strictly limited to studying existing data, reports, methods and information. It is of utmost importance to note that the project AR-INTERIM-CM by definition is not meant to produce new computation methods. This is the goal of a project called HARMONOISE.

HARMONOISE is a research project aimed at finding new harmonised methods for road traffic and railway noise. There is no competition between the projects: their aims are neither similar nor congruent. AR-INTERIM-CM has to keep as close as possible to the original text of the editions of the calculation methods referred to in the END and will not develop new calculation methods.

1.4. The project team

The project team contracted by EC DG Environment in early 2002 consist of experts from five EU Member States (listed in alphabetic order):

- AIB-Vinçotte EcoSafer (B),
- AKRON n.v.-s.a. (B),
- LABEIN Technological Centre S.L. (E),
- Honorar-Professor Dipl.-Ing.Dr.techn. Judith LANG (A),
- LÄRMKONTOR GmbH (D),
- Proscon Environmental Ltd. (UK), and
- Wölfel Meßsysteme · Software GmbH & Co (D)+(B) as main contractor.

1.5. Work Packages & Tasks

Table 1 - Work Packages and Tasks

Work package	Task	Name
1		**Road Traffic Noise (NMPB/XP S 31-133)**
	1.1	Description of the calculation method
	1.2	Noise emission: databases
	1.3	Guidance on the application
	1.4	Guidelines on a basic software package
2		**Railway Noise (Dutch Railway Method)**
	2.1	Description of the calculation method
	2.2	Noise emission: databases
	2.3	Guidance on the application
	2.4	Guidelines on a basic software package
3		**Aircraft noise around airports (ECAC.CEAC Doc. 29)**
	3.1	Description of the calculation method
	3.2	Adaptation of the transmission model
	3.3	Noise emission: databases
	3.4	Guidance on the Application
	3.5	Guidelines on a basic software package
4		**Industrial Noise (ISO 9613-2)**
	4.1	Description of the calculation method
	4.2	Noise emission: measurement methods
	4.3	Guidance on the application
	4.4	Guidelines on a basic software package

The following gives a short explanation of the different tasks of AR-INTERIM-CM :

- Description of the calculation method:
  - for the French NMPB/XP S 31-133 and the Dutch SRM II methods, this task subdivides into two parts: first the translation into 'non-contextual' English. This means that a neutral English text has to be produced that is free from any national or country-specific text. Second, the language has to be adapted to the terminology of END. Furthermore, separate documents have to be produced in which the similarities and differences with the END have to be explained[3].
  - in the case of ISO 9613-2 and ECAC.CEAC Doc. 29 no translation is needed as both these texts are available in English. ISO 9613-2 is a recognised international standard and as such any modification is precluded. ECAC.CEAC Doc. 29 has to be adapted as the END requires the use of 'segmentation' instead of the 'point of closest approach' method described in this document. Even though the 1997 edition allows the use of a segmentation method, it does not describe how this could work in the frame of the existing set of equations and constraints.
- Guidance on the application:
  - in these documents practical hints on the use of the different methods will be provided.
- Guidelines on a basic software package:
  - for all calculation methods, the basic requirements for a suitable software package for all interim calculation methods will be described.

Finally there is the requirement to produce suitable emission data for the different recommended interim methods. In the case of ISO 9613-2, the emission measurement methods listed in the END are described. In the case of NMPB/XP S 31-131 the existing French method "Guide du Bruit" is revised. For SRM II, the existing railway emissions method is used and the measurement method is revised. Finally, ECAC.CEAC Doc.29 does not provide any emission data at all. Here a suitable set of emission groups is selected from existing data already in use in one or more EU Member States.

1.6. Products and Deliverables

1.6.1. Guide to Part A of this report

The final report is organised in two parts:

- Part A presents the results in a condensed form. All important results and recommendations can be found in this part of the final report.
- Part B is a comprehensive collection of all documents produced during the term of the project. The reader is encouraged to revert to Part B for detailed information, technical background, validation and justifications.

Part B is organised following the structure of the project in Work Packages and Tasks. For enhanced legibility, a different structure is used in Part A: here information is organised by topics. Each topic has a dedicated section for each of the four interim computation methods.

[3] both 'non-contextual' English and 'similarities and differences' with END are expressions used by the Terms of Reference of the contract.

1.6.2. Guide to Part B of this report

1.6.2.1. General considerations

Part B is the collection of all contributions in written form produced by the team and individual team members during the study. The documents in Part B provide background information for the condensed information given in Part A. Part B of the report is available in both print and digital files. A CD-ROM is inserted in the binder with the printouts and contains all files in several file formats (see below).

Part B contains numerous printed documents, at least one for each of the tasks identified in 1.5. Some of the documents are compounds of documents produced by different partners. Finally there is a miscellaneous section where additional documents are gathered that contain side-information either from external sources or team reports that go do not fit the task structure, e.g. the full text on the precautionary principle, the different documents received from ISO regarding copyrights, the original French progress report on the new emission data.

Basically printed documents and files on CD-ROM are organised according to the following structure:

- **3.1. Road traffic noise**
- 3.1.1. Description of the calculation method
- 3.1.2. Noise emission: databases
- 3.1.3. Guidance on the application
- 3.1.4. Guidelines on a basic software package
- **3.2. Railway Noise**
- 3.2.1. Description of the calculation method
- 3.2.2. Noise emission: databases
- 3.2.3. Guidance on the application
- 3.2.4. Guidelines on a basic software package
- **3.3. Aircraft noise around airports**
- 3.3.1. Description of the calculation method
- 3.3.2. Adaptations of the transmission model
- 3.3.3. Noise emission: databases
- 3.3.4. Guidance on the application
- 3.3.5. Guidelines on a basic software package
- **3.4. Industrial noise**
- 3.4.1. Description of the calculation method
- 3.4.2. Guidance on Noise Emission Measurement Methods
- 3.4.3. Guidance on the application
- 3.4.4. Guidelines on a basic software package
- Some files cannot be directly assigned a task. These files are marked as "*Miscellaneous*".

Each of these files is presented on the CD in the following formats:

Table 2 – Final Draft Report Part B: File Formats

DOC	**Microsoft Word Document**
RTF	**Rich Text Format**
TXT	**ASCII-Text**
PDF	**Adobe Acrobat**

1.6.2.2. Guide to Digital Files

The basic structure of the work packages and tasks forms the naming convention for the files accompanying this written report. All text elements of the report are made available in digital form. The naming convention for the files is:

`AR-INTERIM-CM MTR WPx Ty-z [string].ext`

where:

Table 3 - File naming conventions

`AR-INTERIM-CM`	is the project acronym as defined above
`FDR`	is the acronym for Final Draft Report.
`WPx`	is the identifier of the work package, with WP being a fixed text and x is the number of the work package
`Ty-z`	is the identifier of the task of the aforementioned work package, with T being a fixed text and y-z is the number of the task
`[string]`	is an optional string of characters used to differentiate multiple documents belonging to the same task
`.ext`	is the filename extension

Thus

`AR-INTERIM-CM FDR WP2 T2-1 P1.doc`

is a Microsoft Word document containing the Final DRAFT Report of Task 2-1 of Work Package 2. P1 signifies that this is the first of several parts, some of which might not be available yet.

`AR-INTERIM-CM FDR WP4 T4-1 ISO 3744.doc`

is a Microsoft Word document containing the text version of ISO 3744 for the Final DRAFT Report of Task 4-1 of Work Package 4.

1.7. Validation of proposed adaptations and revisions

Significant efforts were conducted to validate the proposed adaptations and revisions where necessary. No experimental validation has been conducted as this was not allowed for in the scope and budget of the project. Nevertheless, comparison with existing data and use of existing comparisons where available were used to verify the quality and feasibility of the proposed adaptations and revisions.

This validation testifies to the overall quality of the proposed adaptation or revision for strategic noise mapping. Limitations of the proposed adaptations and revisions cannot be excluded. However, the influence on the overall quality of the strategic noise maps is expected to be rather small.

Most validations are presented in figures included in the relevant background papers in Part B of this report. Some individual documents included in Part B are validation efforts in their own right, i.e. the documents comparing interim methods with national methods from EU M.S.

Validations were produced and are documented for the following adaptations and revisions:

- revision of Guide du Bruit 1980 (both default and alternate proposal).
- noise emission data for ECAC.CEAC Doc. 29.
- influence of overall estimates on calculated noise levels (French case study on XP S 31-133).

1.8. Copyright of ISO standards

The project team obtained the written authorisation to provide one copy of the ISO standards listed in the END to EC DG Environment as part of this report.

For further publication and dissemination of ISO standards as part of the guidelines announced in the END, EC DG Environment, as the responsible editor, must enter into negotiations with ISO in Geneva (CH) on their own. This information was obtained by email from copyright officers at the ISO headquarters and further confirmed by the German DIN institute.

2. Adaptations of interim computation methods

2.1. Common adaptations

2.1.1. Receiver height

The END uses the term “assessment point” to define the reception point. To remain consistent with existing text and naming conventions, and in order to avoid translation difficulties, it is recommended to use “reception point” or “receiver” in all computations method texts.

For the purpose of strategic noise mapping, and here in particular for the computation of L_{den} and L_{night}, the **END** imposes the reception point height at 4 ± 0,2 m above the ground[4].

Considering that L_{den} is a compound indicator calculated from L_{day}, $L_{evening}$, L_{night}, this height is mandatory for all END indicators.

2.1.2. LDEN & LNIGHT

2.1.2.1. General considerations

Article 5 and Annex III of the END define the noise indicators L_{day}, $L_{evening}$, L_{night} and the compound indicator L_{den}. This definition identifies the duration of the individual assessment periods and provides an equation to calculate L_{den}.

According to Article 5 of END, the noise indicators defined in both Article 3 and in Annex I must be used for strategic noise mapping. These indicators are: L_{den} (day-evening-night noise indicator), L_{day} (daytime noise indicator), $L_{evening}$ (evening noise indicator), and L_{night} (night-time noise indicator).

L_{den} is derived from L_{day}, $L_{evening}$ and L_{night} using

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

The END requires L_{day}, $L_{evening}$ and L_{night} to be long-term noise levels according to ISO 1996-2:1987. They are determined over ***all*** day, evening and night periods of a year. Furthermore, the END contains a clause on including variations in emissions and propagation conditions.

ISO 1996-2:1987 defines the average long-term level as an equivalent A-weighted continuous sound pressure level[5]. The standard allows this level to be determined by calculation[6]. Measurement or prediction must account for variations in both source activity and meteorological conditions influencing

[4] END, ANNEX I, 1. Definition of the Day-evening-night level L_{den} and 2. Definition of the night-time noise indicator

[5] ISO 1996-2:1987, 4.3 Long-term average sound level: $L_{Aeq,LT} = 10\lg\left[\frac{1}{N}\sum_{i=1}^{N} 10^{0,1(L_{Aeq,T})_i}\right]$

[6] ISO 1996-2:1987, 5.1 General: In general, these quantities are determined from measurements and/or calculations.

the propagation conditions[7]. The use of meteorological correction terms is allowed[8] and references is made to the meteorological corrections in ISO 1996-1. However, this standard fails to provide a method to determine and apply meteorological correction. It should be noted here, that both these standards are more than 10 years old and concentrate on measurement rather than computation of environmental noise. Nevertheless, the use of prediction methods to determine long-term noise levels by calculation is allowed[9].

ANNEX I of the END permits EU Member States to shorten the evening period by 1 or 2 hours. Daytime and/or night-time periods must be lengthened accordingly[10]. The basic equation to calculate L_{den} has to be adapted to reflect these changes in one or more of the rating periods. This leads to a more general form of the equation:

$$L_{den} = 10 \cdot \lg \frac{1}{24}\left(t_d \cdot 10^{L_{day}/10} + t_e \cdot 10^{(L_{evening}+5)/10} + t_n \cdot 10^{(L_{night}+10)/10}\right)$$

where:

t_e is the length of the shorter evening period and $2 \le t_e \le 4$,

t_d is the resulting length of the daytime period,
t_n is the resulting length of the night-time period,

and

$$t_d + t_e + t_n = 24 \text{ hours.}$$

2.1.2.2. Meteorological correction

The need for a meteorological correction has been shown in the above (General considerations). The interim computation methods NMPB/ XP S 31-133 [5] and ISO 9613-2 [4], use meteorological correction terms of various complexity to permit the determination of long-term equivalent levels.

The following clause from Annex II of the END defines characteristics of the time period "year" with respect to sound emission and meteorological conditions:

— a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances; [11]

Unfortunately, the END does not provide a definition of the "average year as regards the meteorological circumstances". In the meteorological community, it is common practice to derive the

7 ISO 1996-2:1987, 5.4.2 Long-term time interval: The choice of the long-term time interval is related to the noise control objective, the nature and activity of the receiver, the operation of the sources and variations in propagation conditions. NOTE – The long-term time interval should be chosen so that long-term variations in noise emission are covered.

8 ISO 1996-2:1987, 4.2 Meteorological adjustment

9 ISO 1996-2:1987, 6 Prediction of noise levels

10 END, ANNEX I, 1. Definition of the Day-evening-night level L_{den} [...] The Member States may shorten the evening period by 1 or 2 hours and lengthen the day and/or night period accordingly, provided that this choice is the same for all the sources [...]

11 END, ANNEX I, 1. Definition of the day-evening-night level L_{den}

meteorological characteristics typical for a site from a statistical analysis of 10 years of meteorological data measured on the site. Shortening the total time of observation reduces the longevity of the typical statistical meteorological data file and makes the data less representative for the site. This requirement for long-term measurements and other difficulties linked to spatial location of specific sites (i.e. in mountainous regions) reduce the probability of finding suitable data for all sites that have to be noise mapped. Thus the idea of using a simplified form of meteorological correction proportional to the occurrence of variations in propagation conditions is conceived. Following the example of the simplified assumptions of XP S 31-133, they will be chosen in accordance with both the precautionary principle and the prevention principle of EU environmental legislation, which provides for protection of the citizen from potentially dangerous and/or harmful effects. For a detailed discussion see ANNEX I.

With regard to meteorological correction for calculating EU noise indicators, the following two-tier approach is recommended:

Table 4 - Meteorological correction decision grid

Condition	Action
meteorological data measured on the site or derived from a sufficiently large number of nearby sites by meteorological methods that ensure that the resulting data is representative for the site of interest o sufficiently long measurement time to allow for a statistical analysis that describes the average year with sufficient accuracy, o continuity to assure that the data sampled is representative of all daytime, evening and night-time periods of the year, o the data must be representative for the site of interest.	**derive meteorological corrections from an analysis of detailed meteorological data (see Annexes of NMPB/XP S 31-133[12] and 2.4.2)**
no meteorological data available for the site of interest or the available meteorological data does not comply with the above requirements	**use overall meteorological corrections**

The simplified approach starts from a suggestion found in the interim computation method NMPB/XP S 31-133. It is considered that amongst the 4 interim methods, this method provides the most advanced scheme for meteorological correction. NMPB/XP S 31-133 explicitly allows the use of the overall estimates on all sites for which no detailed data can be provided[13]. Overall estimates adapted to the requirements of the END and suitable to calculate L_{den} are:

- 100 % of favourable occurrence for the night period,
- 50 % of favourable occurrence for the daytime period, and
- 75 % of favourable occurrence for the evening period.

If an EU M.S. defines an evening period shorter than the default 4 hours, the above overall estimates have to be adapted accordingly. The occurrence for favourable conditions is kept constant at 75% for the evening period regardless of any changes in its length.

The following figure illustrates the influence of using overall estimates for p in XP S 31-133: The differences between 40% favourable and 100% favourable are approximately 2 dB at a distance of 400m from a road and are very small in the proximity of the road. The deviation are slightly larger in the presence of obstacles (not shown here; see Part B of the report). Here again it shows why the

[12] The method described in these annexes is considered insufficient on its own to determine occurrences without ambiguity. More information on the method should be requested from the French authorities. One possible source for additional information is [19]

[13] [5], 4.3. Détermination des occurrences de long terme des conditions favorables à la propagation du son, p.11

meteorological correction is not to be applied in heavily obstructed environments like agglomerations. In all cases the error introduced by meteorological correction seems significantly smaller than errors produced by wrong building or obstacles heights or other inaccuracies in input data.

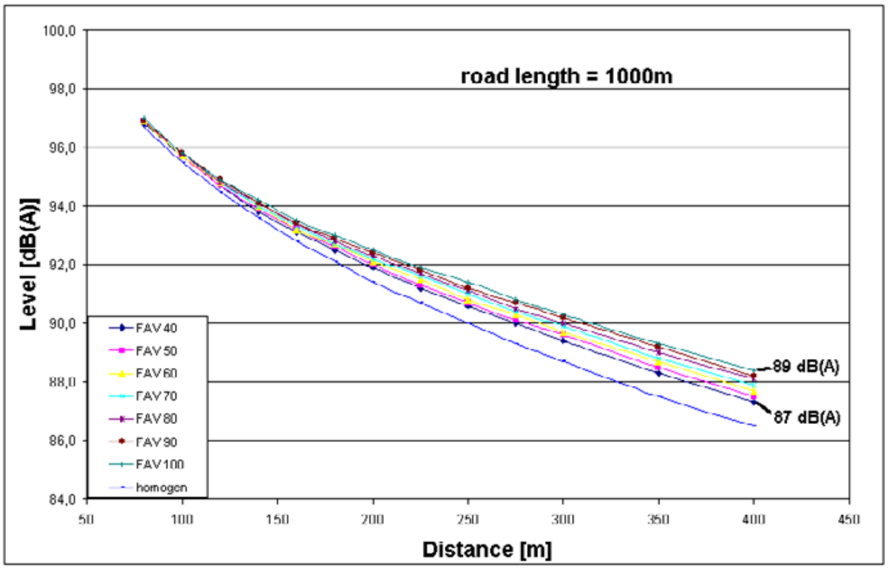

Figure 2 – Changes of sound level over distance for different values of p

2.1.3. Façade reflections

— the incident sound is considered, which means that no account is taken of the sound that is reflected at the façade of the dwelling under consideration (as a general rule, this implies a 3 dB correction in case of measurement). [14]

For the purpose of strategic noise mapping with interim or national computation methods, the above clause of the END should be read as *“omitting the last reflection from the nearest façade. Reflections from other façades are to be taken into account.“[15]*.

The above does not specify a distance criterion which can be seen as a difficulty for noise mapping. No international agreed distance for measurements in front of the open window could be found. Values seem to range from 0 m to 1.5 m. Larger distances are uncommon. Nevertheless, no single commonly agreed value could be identified[16].

2.1.4. Other reflections

For reception points that do not fall under 2.1.3, reflections must be calculated. The study revealed that none of the interim computation methods provides a satisfactory description of the absorbing nature of walls or buildings. The use of one single set of absorbing coefficients **α** for all interim computation methods is recommended.

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[14] END, ANNEX I, 1. Definition of the day-evening-night level L_{den}

[15] [15], Discussion on the NMPB method (road traffic noise), answer to comment 1

[16] the investigation for an international definition of the “open window” was conducted following a request of WG AEN; see [15].

2.2. Adaptations of NMPB/XP S 31-133

2.2.1. Introduction

XP S 31-133 is a reviewed and corrected release of NMPB-Routes-96. XP S 31-133 has the status of a draft standard. All translation efforts and similarities/differences studies were based on the text of XP S 31-133. There is one exception: The equations correlating the emissions of Guide du bruit 1980 with XP S 31-133 are taken from NMPB-Routes-96.

Both the context-free English translation of XP S 31-133 and the similarities and differences background report can be found in Part B of this report.

2.2.2. Meteorological correction and calculation of long-term levels

The long term-level $L_{longterm}$ is calculated by the following formula:

$$L_{longterm} = 10\,.\lg\left[p.10^{L_F/10} + (1-p).10^{L_H/10}\right]$$

where:

- L_F is the sound level calculated in favourable sound propagation conditions,
- L_H is the sound level calculated in homogeneous sound propagation conditions, and
- p is the long-term occurrence of meteorological conditions favourable to the propagation of sound.

NMPB/XP S 31-133 can be used either with detailed meteorological data representative for the site of interest or overall estimates according to 2.1.2.2 can be used. In this case, the following applies:

For the default duration of day 12 hours, evening 4 hours and night 8 hours, p has to be set as follows:

- for day p_{day} = 0,5
- for evening $p_{evening}$ = 0.75
- for night p_{night} = 1,0

If 1 or 2 hours of the evening period are added to the day period or to the night period the p-value may be calculated as follows:

$$p_{day} = \frac{12 \cdot 0{,}5 + t_{ev(day)} \cdot 0{,}75}{12 + t_{ev(day)}}$$

$$p_{night} = \frac{8 \cdot 1 + t_{ev(night)} \cdot 0{,}75}{8 + t_{ev(night)}}$$

where:

- $t_{ev(day)}$ is the number of hours taken from the default 4-hour evening period and added to the daytime period
- $t_{ev(night)}$ is the number of hours taken from the default 4-hour evening period and added to the night-time period

2.2.3. Calculating $L_{AW/m}$ from E

The recommended noise emission model Guide du Bruit 1980 defines a noise emission level E. XP S 31-133 requires LAW/m as input level. This section shows how to calculate LAW/m from E. For information on how to determine E refer to section 3.1.

The frequency-dependent basic sound power level L_{Awi}, in dB(A), of a compound point source ***i*** in a given octave band ***j*** is calculated from the individual sound emission levels for light and heavy vehicles obtained from Figure 5 - Nomogram 2 using the following equation:

$$L_{Awi} = L_{Aw/m} + \Psi + 10lg(l_i) + R(j)$$

Equation 1

where:

$L_{Aw/m}$ is the sound power level per meter length along the lane attributed to the specified source line in a given octave band, in dB(A), given by:

$$L_{Aw/m} = [(E_{lv} + 10lg(Q_{lv}) \oplus (E_{hv} + 10lg(Q_{hv})] + 20$$

Equation 2

where:

E_{lv} is the sound emission for light vehicles as defined in Figure 5 - Nomogram 2,

E_{hv} is the sound emission for heavy vehicles as defined in Figure 5 - Nomogram 2,

Q_{lv} is volume of light traffic during the reference interval

Q_{hv} is traffic load in terms of heavy vehicles for the duration of the reference interval

$\oplus$ is the energetic addition: $L_1 \oplus L_2$ = 10*log[10^(L_1/10) + 10^(L_2/10)]

Ψ is the road surface correction defined in the relevant noise emission model

l_i is the length of the section of the source line represented by a component point source ***i***

$R(j)$ is the spectral value, in dB(A), for octave band ***j*** given in Table 5.

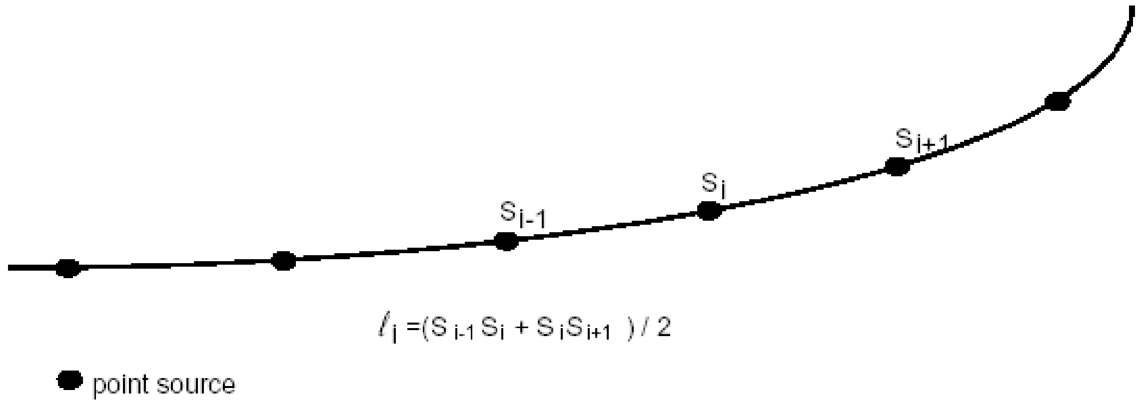

Figure 3 - Calculation of the length of the source represented by a point source i

Table 5 – Normalised A-weighted octave band traffic noise spectrum calculated from third octave spectrum of EN 1793-3

j	octave band in Hz	values of (R(j) in dB(A)
1	125	-14.5
2	250	-10.2
3	500	-7.2
4	1000	-3.9
5	2000	-6.4
6	4000	-11.4

2.2.4. Summary table of adaptations needed

Table 6 – Proposed adaptations of XPS 31-133

Subject	result of comparison / action
Noise indicator	The definition of the base indicators are found to be identical A-weighted long-term average sound level determined over the year taking into account variations in emission and transmission. Assessment periods day, evening, night according to the END have to be introduced
Reception point	No objections to using 4 ± 0,2 m above the ground as required by the END. There is no need to restrict the position of single reception points in front of façades to 2 m in front of that façade.
Source	Source emission data have to be established or alternatively a method to determine them has to be defined (see in this report) Provisions must be made to reflect the variations in vehicle fleet composition across EU M.S.. Segmentation techniques: no objections and no further adaptation needed. Calculation of $L_{Aw/m2}$: a formula must be provided to link the emission E of Guide du Bruit 1980
Propagation ***- influence of meteorological conditions*** ***- geometrical divergence*** ***- atmospheric absorption*** ***- ground effect*** ***- diffraction***	2 types of propagation: homogeneous and favourable. Define percentage of probability of occurrence of favourable conditions; proposed EU overall estimates 50 % for day, 75 % for evening, 100 % for night with the possibility to adopt a shorter evening period if needed. No objections and no further adaptation needed. Table with air attenuation coefficient versus temperature and relative humidity typical for European regions based on ISO 9613-1 has to be inserted and relevant data have to be chosen at a national level. No objections and no further adaptation needed. No objections and no further adaptation needed, retain paragraph on diffraction on vertical edges from XP S 31-133.
Reflection	No objections and no further adaptation needed.

2.3. Adaptations of the Dutch railway noise computation method

2.3.1. Choice of the calculation method

The END does not indicate which of the two calculation methods contained in the Dutch SRM II of 1996 [10] must be used. The three interim methods dealing with surface noise sources road traffic, railway traffic and industry have ISO 9613-2 as their common denominator. SRM II[17] is the only method that stays close enough to ISO 9613-2 to be retained as an interim computation method in its own right. It is therefore recommended to impose the use of SRM II for strategic noise mapping. The use of the preferred Dutch computation method for large-scale strategic noise mapping ARM 1,5 defined in RMR 2002 [16] cannot be recommended if the requirement for harmonisation is to be taken seriously[18]. The use of a substantially simplified method for railway noise is inappropriate if similar methods either for road traffic or for industry are not available.

Since the publication of the END, the Dutch ministry came up with a new release of the Dutch railway computation method. This new release describes three different computation methods, two of which are corrected versions of the 1996 calculation method. The third one is ARM 1,5, a method not suitable for reasons explained in the above. The new release of SRM II called RMR 2002 basically consists of the SRM II method of 1996 with some errors corrected. Together with the adaptations described in the remainder of this section, this text is recommended as the basis for the adapted Dutch railway method 1996. An adapted version of this method translated in to context-free English is provided in Part B of the report. In addition, the context-free English translation of the original SRM II of 1996 is available in Part B.

2.3.2. Meteorological correction and calculation of long-term levels

SRM II defines a meteorological correction term C_M[19]. The equations used to determine C_M are identical to the equations used in ISO 9613-2 to determine C_{met}. However, instead of the variable C_0 an upper limit of 3.5 dB is used. The adaptation needed to calculate long-term levels in accordance with ISO 1996-2:1987, would be to replace 3.5 by C_0 and then to follow the procedure described hereafter for ISO 9613-2 (see 2.4.2).

[17] [10], pages 22 to 38

[18] [15], General discussion on the extent to which the “interim” methods can be “simplified” or “adapted”, answer to comment 1

[19] [10], section 5.5.3.

2.3.3. Summary table of adaptations needed

Table 7 – Proposed adaptations of the Dutch railway noise computation method

subject	result of comparison / action
Noise indicator	SRM II calculates equivalent noise levels but does not calculate long-term equivalent noise levels according to ISO 1996-2:1987. To calculate long-term indicators with SRM II, the following conditions must be met: - average yearly train data have to be provided, and - the meteorological correction term must be adapted. Assessment periods day, evening, night have to be introduced.
Assessment point	No objections to using 4 ± 0,2 m above the ground as required by the END.
Source	No objections to using norms as required by the END to determine sound power levels. No objections to the method described to divide extended sources into component point sources.
Propagation	Caution: long-term average levels are calculated only if meteorological correction factor C_{Mt} is modified as outlined in 2.4.2.
- influence of meteorological conditions	Change equation by replacing the constant upper limit by C_0: use the same approach as for industrial noise. Define percentage of probability of occurrence of favourable conditions; proposed EU overall estimates 50 % for day, 75 % for evening, 100 % for night with the possibility to adopt a shorter evening period if needed.
- geometrical divergence	No objections and no further adaptation needed.
- atmospheric absorption	It is recommended to replace the fixed air absorption coefficients of TABLE 5.1 of SRM II 1996 by suitable coefficients derived from ISO 9613-1 for each M.S.
- ground effect	No objections or amendments.
- diffraction	Caution: the method uses equivalent screens instead of multiple diffraction; this does not conflict with the END but is an approach different to that used in the two other computation methods for surface based sound sources.
Reflection	SRM II makes special provisions for façade reflections; the use of this correction term is prohibited for the purpose of strategic noise mapping.

2.4. Adaptations of ISO 9613-2

2.4.1. Introduction

The text of ISO 9613-2 is included in Part B of this report as a Word document. No changes were made in the text. All proposed adaptations are described in a separate similarities and differences document included in Part B of this report.

2.4.2. Meteorological correction and calculation of long-term levels

From the outset, ISO 9613-2 is designed to account for meteorological correction to calculate long-term noise levels. The meteorological correction term is called C_{met}.

ISO 9613-2 fails to provide a scheme to evaluate local wind statistics to determine the value of C_0, the met-dependent factor in the calculation of C_{met}. The following text presents a simple scheme that can serve as the harmonised method to calculate C_0 from wind statistics. The method was selected for its simplicity and minimal requirements on both the input data and degree the user's special meteorological knowledge. It can be used in all relief types from flat terrain to mountainous regions and it does not rely on any specific national data format.

The calculation of C_0 in decibels must be based on a scheme that respects both NOTE 20 and NOTE 22 of ISO 9613-2. NOTE 20 of ISO 9613-2 states that an average situation with 50% favourable conditions and 50% homogeneous conditions results in C_0 = 3 dB. Taking into account the definition of conditions favourable to sound propagation elsewhere in the standard[20], three wind sectors can be defined[18]:

- downwind and thus favourable conditions: either "wind direction within an angle of ±45° of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver"[21] and calm wind, or, "a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights"[22].
- crosswind and thus less favourable conditions: wind blowing either from a sector between 45° to 135° or from a second sector between 225° to 315° measured from the line connecting the centre of the dominant source with the centre of the specified receiver.
- upwind and thus unfavourable conditions: ±45° of the line connecting the centre of the dominant sound source with the centre of the specified receiver region, with the wind blowing from receiver to source.

The probabilities of occurrences of favourable and homogeneous conditions can then be deduced by statistical analysis of wind data files using the three sectors defined above as a selection criterion.

For the use of overall estimates and in an attempt to harmonise meteorological correction across the INTERIM calculation methods, the example of XPS 31-133 is followed and cross- and upwind are grouped together as "homogeneous" conditions. However, to ensure that NOTE 22 is respected[23] each term is represented separately in the following formula.

---

[20] ISO 9613-2:1996, 5 Meteorological conditions

[21] [4] 5 Meteorological conditions

[22] ditto

[23] [18]: "[...] values of C_0 in practice are limited to the range from zero to approximately +5 dB, and values in excess of 2dB are exceptional"

For both detailed meteorological site data and overall estimates, the following equation is used to calculate C_0:

$$C_0 = -10\lg\left(\frac{p_f}{100}\cdot 10^{-\frac{C_f}{10}} + \frac{p_{hc}}{100}\cdot 10^{-\frac{C_{hc}}{10}} + \frac{p_{hu}}{100}\cdot 10^{-\frac{C_{hu}}{10}}\right)$$

where:

- p_f, and p_{hc} and p_{hu} are the respective probabilities of occurrences of ***f***avourable and ***h***omogeneous meteorological conditions.
  - ***detailed meteorological data:*** Actual numbers resulting from the statistical analysis of the meteorological data for downwind (favourable), ***c***ross- and ***u***pwind conditions are used if detailed meteorological data is available for the site.
  - ***overall estimates:*** The overall estimates (2.1.2.2) define the probability of occurrence of favourable conditions. The probability of occurrence of homogeneous conditions is then100-p_f. In the above equation, (100-p_f) is split 50-50 to determine the probabilities of occurrence of ***c***ross- p_{hc} and ***u***pwind p_{hu} conditions.
- following NOTE 20 of ISO 9613-2, C_f = 0 dB and C_{hu} = 10 dB,
- to ensure that NOTE 22 of ISO 9613-2 is respected, C_{hc} = 1,5 dB.

For the standard length of daytime, evening and night-time defined in END and the overall estimates defined in 2.1.2.2, the respective value of C_0 is given by:

$$C_{0day} = -10\lg\left(\frac{50}{100} + \frac{25}{100}\cdot 10^{-\frac{1,5}{10}} + \frac{25}{1000}\right)dB = 1,54dB$$

$$C_{0evening} = -10\lg\left(\frac{75}{100} + \frac{12,5}{100}\cdot 10^{-\frac{1,5}{10}} + \frac{12,5}{1000}\right)dB = 0,7dB$$

$$C_{0night} = 0dB$$

Note that

- the above is true for the standard length of the three assessment periods. To calculate C_0 for any other length of these assessment periods, p_f, and p_{hc} and p_{hu} must be adapted accordingly. The values of C_f, C_{hu} and C_{hc} remain constant. For more information refer to 2.1.2.2.
- C_0 is only one term of the equation determining C_{met}. Other elements that come into play are source to receiver distance and their respective height above the ground.

2.4.3. Summary table of adaptations needed

Table 8 – Proposed adaptations of ISO 9613-2

subject	result of comparison - action
Noise indicator	The definition of the base indicators are found to be identical. A-weighted long-term average sound level determined over a long period of time of several months or a year taking into account variations in both emission and propagation . Assessment periods day, evening, night have to be introduced.
Assessment point	No objections to using 4 ± 0,2 m above the ground as required by the END.
Source	No objections to using the standards recommended by the END to determine sound power levels. No objections to the method described to divide extended sources into component point sources.
Propagation	Caution: long-term average levels are calculated only if meteorological correction factor C_{met} is applied!
- influence of meteoro-logical conditions	Define percentage of probability of occurrence of favourable conditions; proposed EU overall estimates 50 % for day, 75 % for evening, 100 % for night with the possibility to adopt a shorter evening periods if needed.
- geometrical divergence	No objections and no further adaptation needed.
- atmospheric absorption	Table with air attenuation coefficient versus temperature and relative humidity typical for European regions based on ISO 9613-1 has to be inserted and relevant data have to be chosen at a national level.
- ground effect	Use alternate method 7.3.2, equation (10) for overall A-weighted sound power levels and equations of table 3 for all frequency-dependent calculations. No other objections.
- diffraction	A-weighted: calculate at 500 Hz; frequency-dependent: no objections and no further adaptation needed.
Reflection	No objections and no further adaptation needed.
Additional attenuations	In order to harmonise with other INTERIM calculation methods (especially NMPB/XP S 31-133 based on the same propagation algorithm) it may be necessary to prohibit the use of these attenuations for the purpose of strategic noise mapping.

2.5. Adaptations of ECAC.CEAC Doc.29

2.5.1. Introduction

ECAC.CEAC Doc. 29 [12] is the interim computation method which needed the most significant adaptations. This is due to the request of the END to use segmentation technique rather than the noise-power-distance approach implemented in ECAC.CEAC Doc.29. On the other hand, the method itself is in some respects not sufficiently well developed to be considered *ready for immediate use*.

A full-detail text on the similarities and differences with the END is included in part B of this report. This document contains background information and discussion of decisions. To better illustrate the extent of the changes proposed, a colour coded version showing the merger of the non-contextual English original with the adaptations made by the project group was produced and is included in Part B of this report.

2.5.2. Proposal

The following table contains a discussion of the contents of the document chapter by chapter showing similarities and differences with the END and pointing out which supplements have to be defined to produce a complete viable calculation procedure.

Table 9 – Proposed adaptation of ECAC Doc. 29

section of the original text	required adaptations
1) Introduction	Adapt to segmentation technique as required by Annex II of END and adapt to noise indicators of END.
2) Explanation of terms and symbols	Adapt to the use of noise indicators of END. Noise unit must be A-weighted overall sound level. Noise scale must be A-weighted equivalent sound level. Replace “noise index” by END noise indicators. Notation for sound exposure level should be SEL throughout not L_{AE}. Correct notation of logarithm to base 10 in 2.2.7: lg.
3) calculation of contours	Where appropriate and where the physical quantity is meant rather than a psychological quantity, dealing with subjective response, the term “noise” has to be replaced by “sound”. “Period of some months” has to be changed to “period of a year” to reflect the requirement of the END for the “average year”. Add forms of airport, flight path and aircraft input data. $SEL(x,y) = L_{A,max}(\xi,d) - \Lambda(\beta,\ell) + \Delta_L + \Delta_A + \Delta_F \quad (1)$[24] (for details see edited text of ECAC.CEAC Doc.29 in Part B)
4) Format of aircraft noise and performance information to be used	“noise-power-distance data” (NPD-data): data should be supplied as both maximum A-weighted sound pressure level <u>and</u> sound exposure level. Adapt cut-off levels to the lowest contour levels to be calculated according to END: minimum L_{night} contour at 50 (45) dB -> the cut-off levels are L_{max} = 40 dB or SEL = 55 dB. Noise emission data with complete information on flight profiles, engine thrust and flight speeds for the purpose of strategic noise mapping: see 3.4.

[24]) There is a printing error in formula (1)in doc. 29: $\Lambda(\beta,\ell)$ has to be subtracted and not added.

5) Grouping of aircraft types	Proposed noise emission data is – as far as possible - compatible with grouping requirements of ECAC.CEAC Doc.29: some extension required to accommodate all aircraft types frequently operated on airports in EU M.S. Keep section 5.4 to allow for completion of emission data where necessary.
6) calculation grid	Grid spacing is not within the scope of this study[25].
7) Basic calculation of the noise from individual aircraft movements	Leave 7.1 unedited: relationship between slant distance and NPD-data. Leave 7.2 unedited. Edit 7.3: explain the need for using duration correction with SEL vs. distance data due to the simplified assumption of defined speed (160 knots) and the use of actual speed with $L_{A,max}$ –vs. distance values without further correction. Edit 7.4: lateral attenuation is considered by all experts as too conservative; new schemes are under development; in the meantime the alternate equation of Appendix E should be used. Edit 7.5: add technical description of segmentation technique; proposed techniques relies on the one described INM 6.0 Technical Manual [11] and uses a fourth-power 90-degree dipole time history with symmetric dispersion; slight adaptation needed to make it comply with proposed emission data. Delete 7.6: useless with segmentation technique.
8) noise during take-off and landing ground roll	Edit 8.2: general scheme of directivity behind the start-of-roll point is OK but equations (16) and (17) must be corrected to avoid discontinuity at 148,4° and the case $\Phi \leq 90°$ should be included for enhanced clarity. Former equation (18) then becomes (19) and is written: $SEL_K = L_{A,max,TO} + \Delta_v - G(r) + \Delta_L$. Edit 8.3: delete mention of $L_{A,max}$.
9) summation of sound levels	Significant changes required to adapt to END requirements. Equations L_{den} (includes penalties for evening and night) and L_{night} added and text completely revised. $$L_{den} = 10 \cdot \lg\left(\frac{1}{86400}\sum_{i,j}(N_{d,i,j} + 3{,}16 \cdot N_{e,i,j} + 10 \cdot N_{n,i,j}) \cdot 10^{SEL_{i,j}/10}\right)$$ and $$L_{night} = 10 \cdot \lg\left(\frac{T_0}{T_n}\sum_{i,j} N_{n,i,j} \cdot 10^{SEL_{i,j}/10}\right)$$
10) modelling of lateral and vertical dispersion of flight paths	Section 10.1: no modifications required. Edit 10.2: additional information on default profiles are given in the proposed emission data for individual aircraft groups and take-off weight.
11) computation of sound exposure level with correction for track geometry	Delete whole chapter: redundant when segmentation is used.
12) overall guidance on the computation of the noise contours	Edit: for strategic noise mapping only the END noise indicators may be used & impose use of one unified emission data set.
13) Appendix A	To be replaced by updated example.
14) Appendix B	The END is concerned with fixed-wing aircraft only: delete appendix.
15) Appendix C	Delete together with section 4.2.
16) Appendix D	Delete since this deals with general aviation aircraft; not the main topic of the END; the proposed emission groups contain some approximate data for general aviation aircraft that should be sufficient for the purpose of strategic noise mapping.
17) Appendix E	Move scheme for lateral attenuation to chapter 7.

[25] [15], Discussion on the NMPB method (road traffic noise), answer to comment 1

2.5.3. Alternate proposal

ECAC has a Working Group called AIRMOD developing a new release of the ECAC.CEAC Doc.29. As work is still progressing, it cannot be said at the time of writing of this report to what extent the new ECAC.CEAC Doc.29 can be considered an adaptation of the 1997 release in the sense of the END, or whether it must be considered a new release. No information is available on when the new release of ECAC.CEAC Doc.29 will be available. While compiling the guidelines announced in the Directive 2002/49/EC it may make sense to liaise with ECAC to check whether their results constitute an alternative to the above proposal.

3. Noise Emission Data

In this section, suitable noise emission data for the different interim noise computation methods are provided on the basis of existing data. In addition, measurement methods are provided to complete or replace existing or proposed data if needed.

The default recommendation does not preclude the use of other suitable databases if available.

3.1. Revision of “Guide du Bruit” of 1980

The following tasks have been carried out:

- Comparison of noise emission methods from different EU Member States
- Liaison with French authorities to obtain information on the state of progress of the ongoing project on the production of an updated noise emission database.
- Study an description of the noise emission model Guide du Bruit 1980.
- Translation of Guide du Bruit 1980 into non-contextual English.
- Comparison of noise emission data from several European noise emission models to validate the noise emission data from Guide du Bruit 1980.

3.1.1. Introduction

XP S 31-133 is a reviewed and corrected release of NMPB-Routes-96. The emission model recommended by the END is Guide du bruit 1980. The context-free English translation of this document is printed below. A series of comparisons with other European emission models were made and are documented in Part B of this report. A validation documents is available in Part B of this report comparing the emissions of Guide du Bruit 1980 with those of two other emission models used in Europe. The original French progression report on the project of updating the emission data is contained in Part B of this report.

3.1.2. Measurement procedure

Directive 22002/49/EC refers to the “Guide du Bruit 1980” [20] as the emission method of choice for the interim computation method for road traffic noise NMPB/XP S 31-133. If a M.S. who adopts this interim computation method wishes to update the emission factors, the following measurement procedure is recommended.

The noise emission level of a vehicle is characterized by the maximum pass-by sound level in dB(A) L_{Amax} measured at 7.5m from the centreline of the trajectory of the vehicle. This sound level is determined separately for different vehicle types, speeds and traffic flows. The slope of the road is identified. The road surface is not explicitly taken into account. To remain compatible with the original measurement conditions, measurements should be made for vehicles driving on either of the following road surface types: cement concrete, very slim bituminous concrete 0/14, half-granulated bituminous concrete 0/14, superficial seal 6/10, superficial seal 10/14. A surface correction is then added according to the scheme presented elsewhere in this text. It should be noted that the proposed road surface correction is not tied to and were determined in complete independence of any specific French road surface data. The aforementioned road surface types were used in France in the 1970s when the noise emission measurements for the Guide du Bruit were conducted. It is most likely that noise emission were measured on a variety of these surfaces. The results were then collated and the final emission level is representative for an average road surface.[26]

Measurements can be made either on single isolated vehicles of the traffic or on specific circuits under controlled conditions.

The vehicle speed should be measured with a Doppler radar (accuracy of approximately 5% at slow speeds). The traffic flow is determined either by measurement or by subjective observation (accelerated, decelerated or fluid).

The microphone is positioned 1.2m above ground and 7.5m horizontally from the centreline of the vehicle trajectory.

For use with XP S 31-133 and in accordance with the specifications of Guide du Bruit 1980, the emission E and the sound power level L_w are calculated from the measured sound pressure levels by:

$$\mathbf{L_W = L_p + 25{,}5} \qquad\qquad \mathbf{E = L_W - 10\ lg(V) - 50}$$

[26] Personal communication F. Besnard (SETRA)

3.1.3. Non-contextual English translation of Guide du Bruit 1980

3.1.3.1. General considerations

The noise emission model is described on pages 90 to 103 of Guide du Bruit 1980. The non-contextual English translation concentrates on those parts that are of use and interest today to compute noise emission data for road traffic schemes. Individual obsolete chapters and sentences are deleted from the translation following a request by WG AEN (in the following text elements that should be removed from the translation are written in brackets and formatted in the following style: ***leave out***). The following chapters are deleted from the translated text (the numbering complies with the original numbering in the French text of Guide du Bruit 1980):

- 2.1 Rappels théoriques: all sub-chapters from 2.1.1 up to 2.1.5 included.

3.1.3.2. Noise Emission

The term noise emission is defined as follows:

$$E = (L_w - 10 \log V - 50)$$

Equation 3

The emission ***E*** is therefore a sound level which can be described in terms of dB(A). (***It is the sound level L_{eq} on the reference isophone due to a single vehicle per hour in traffic conditions specified below).***

3.1.3.3. Traffic Characteristics

Following extensive research, the major parameters influencing the sound emission from a single vehicle have been identified. From these parameters, the following are used for predicting noise:

- vehicle type
- speed (or velocity)
- traffic flow
- longitudinal profile

3.1.3.4. Two Vehicle Types

(the introductory text explaining the situation in 1980 is left out)

In the rest of the text, two vehicle categories for noise prediction are used:

- light vehicles (vehicles less than 3,5 tonne net load),
- heavy vehicles (vehicles greater than 3,5 tonne net load).

3.1.3.5. Speed

It is recommended to omit the following translation of the original text in favour of a more practicable and modern approach that was decided upon at the meeting with subgroup AEN on 14 October 2002.

(Today, it seems that specialists agree that the emitted sound power of a vehicle driving at slow speed primarily depends on the load of the engine rather than on the velocity.

On the other hand, if a vehicle rides in a high gear, average emitted sound power can be modelled by a simple equation as a function of speed.

For reasons of simplicity, the parameter vehicle speed is used in this method for the whole average speed range (from 20 to 120 km/h).

In the case of lower speeds (lower than 60 or 70 km/h) however, the method is completed by means of the subsequently described traffic flow.

To determine a long-term sound level in L_{eq} it is sufficient to dispose of the average speed of a fleet of vehicles. This average speed of a fleet of vehicles can be defined as follows:

the median speed V50, or the speed that is reached or exceeded by 50% of all vehicles; or

the median speed V50 plus halve the standard deviation of speeds.

All average speeds determined with either of these methods that turn out to be below 20 km/h are set to 20 km/h.)

The maximum allowed speed should be used for each road segment. A new road segment must be defined whenever the allowed maximum speed changes.

The method relies on an additional correction for the lower speed range (lower than 60 to 70 km/h)[27]. In these slow speed conditions, one of the four flow types is used to apply an additional correction[28].

All speeds below 20 km/h are set to 20 km/h.

3.1.3.6. Four Types of Traffic Flow

3.1.3.6.1. General considerations

Flow type is a complementary parameter to speed which accommodates acceleration, deceleration, engine load, and pulsated or continuous traffic motion. This is achieved by means of categories that are still approximate, but probably sufficient to predict noise levels.

3.1.3.6.2. Fluid continuous flow

This is a flow where vehicles move with a nearly constant velocity on the road section of interest. It is “fluid” in that the flow is stable in both space and time for periods of at least ten minutes. Variations during the course of a day may be observed but without abrupt or rhythmic variations. Furthermore, it is neither accelerated nor decelerated but of steady velocity.

This flow type corresponds to the traffic on a motorway/autobahn link or an interurban road, on an urban expressway (outside rush hours), and on major roads in an urban environment.

3.1.3.6.3. Pulsed continuous flow

A pulsed flow is characterised by a certain amount of turbulence, which in the present context, is a term comparable to the one used in fluid dynamics. A turbulent flow has a significant proportion of vehicles in a transitory state (i.e. either accelerating or decelerating). It is the opposite of a laminar flow. It is stable neither in time (i.e. there exist abrupt variations of flow during small time periods) nor in space (i.e. at any given moment in time irregular concentrations of vehicles exist on the road section of interest).

However, it is possible to define an average overall velocity for a pulsed continuous flow of vehicles which is stable and repetitive for a sufficiently long period of time.

This flow type corresponds to that found on city-centre roads, on major roads close to saturation, on dispatching or connecting roads with numerous crossings, in car parks, at pedestrian crossings and at junctions to housings.

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[27] the correction is applied only in the specified low speed range. Figure 5 - Nomogram 2 shows thus some situations where the upper speed limit is within the range of 60-70 km/h

[28] for practical purposes see [15]: “For strategic noise mapping, the use of “continuous flow” for all roads except road junctions with traffic lights where the simple method outlined in “Guidance on the application” should be used to determine “pulsed accelerated” and “pulsed decelerated” flows was considered accurate enough.”

3.1.3.6.4. Pulsed accelerated flow

This is a pulsed flow and thus turbulent. However, a significant proportion of all vehicles is accelerating, which in turn means that the notion of speed has a meaning only in discrete points as it is not stable during displacement. This is typically the case for traffic either on an expressways after a crossing, or at a motorway slip road, at a tollbooth, etc.

3.1.3.6.5. Pulsed decelerated flow

This is the opposite of the previous one, in which a significant proportion of vehicles is decelerating.

It is generally found on the approach of major urban crossings, on motorway or expressway exits or on the approach to a tollbooth, etc.

3.1.3.7. Three Longitudinal Profiles

Car drivers and pedestrians both know by experience that the sound power emitted by vehicle travelling along a flat horizontal surface is significantly different to that emitted on a road having a gradient. This concept is described here. Therefore three longitudinal profiles are defined:

- A horizontal carriageway or a horizontal carriageway section whose gradient in direction of traffic flow is less than 2%;
- An ascending carriageway is one where upward gradient in the direction of traffic flow is greater than 2%;
- A descending carriageway is one where the downward gradient in the direction of traffic flow is more than 2%.

In the case of a one-way road this definition is directly applicable. In the case of two-way traffic a separate calculation for each driving direction and subsequent accumulation of results is required to obtain a precise estimate.

3.1.4. Quantified Noise Emission Values for Various Road Traffic Types

3.1.4.1. Schematic Representation

Figure 4 and Figure 5 show nomograms which provide the value of the sound level ***Leq (1 hour)***, in dB(A), [also known as noise emission ***E***, described in 3.1.3.2]. The sound level is given separately for a single light vehicle and a single heavy vehicle per hour. For these separate vehicle types, it is a function of traffic flow (see 3.1.3.6), longitudinal profile (see 3.1.3.7) and speed***. The sound level shown in these figures does not, however, include any corrections for road surface.***

Figure 5 modifies Figure 4 by removing any non-linearity which might hinder implementation in computer software.

The sound emission levels read from nomogram 1 or 2 are called:

- E_{lv} for the sound emission of a light vehicle, and
- E_{hv} for the sound emission of a heavy vehicle.

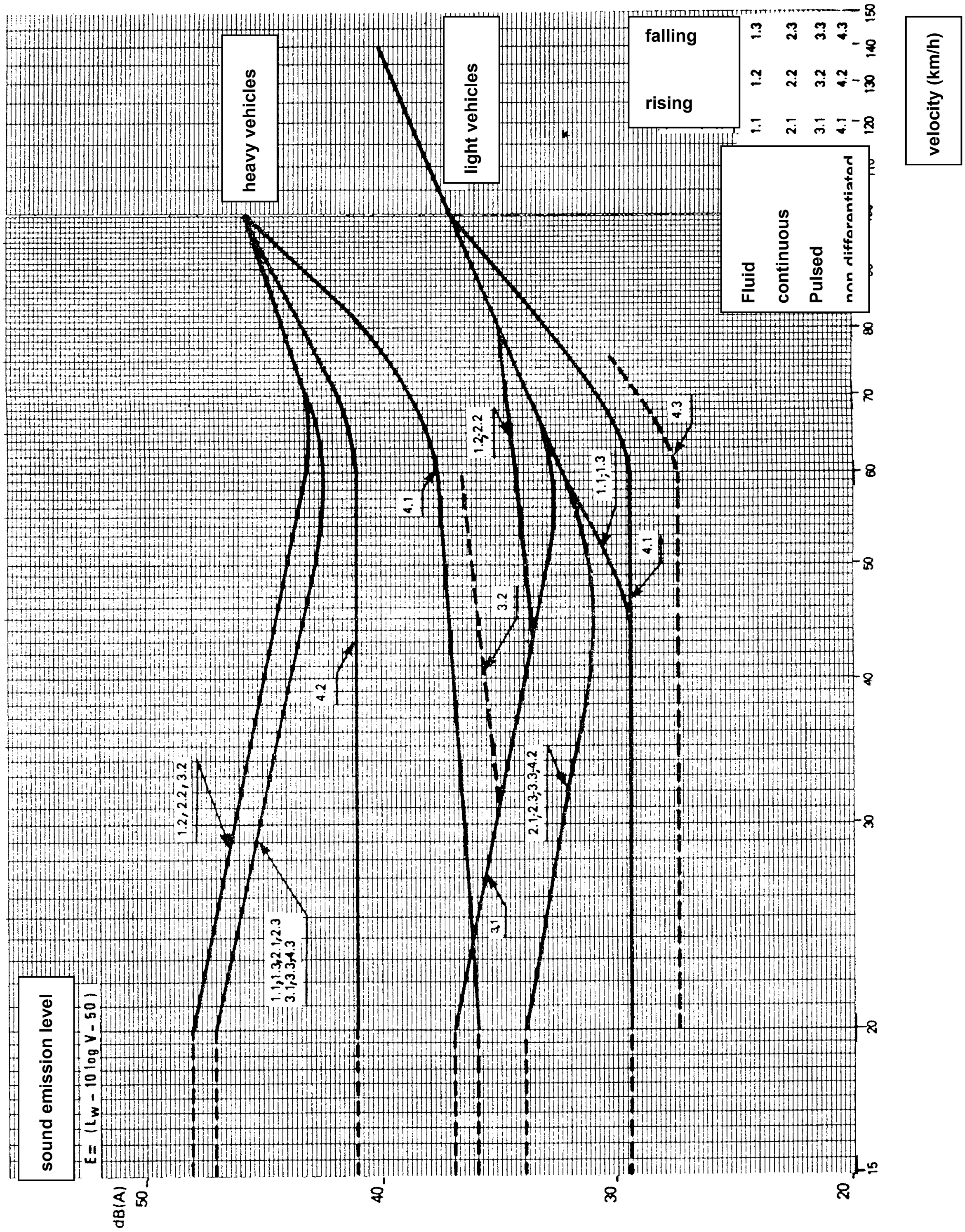

Figure 4 - Nomogram 1

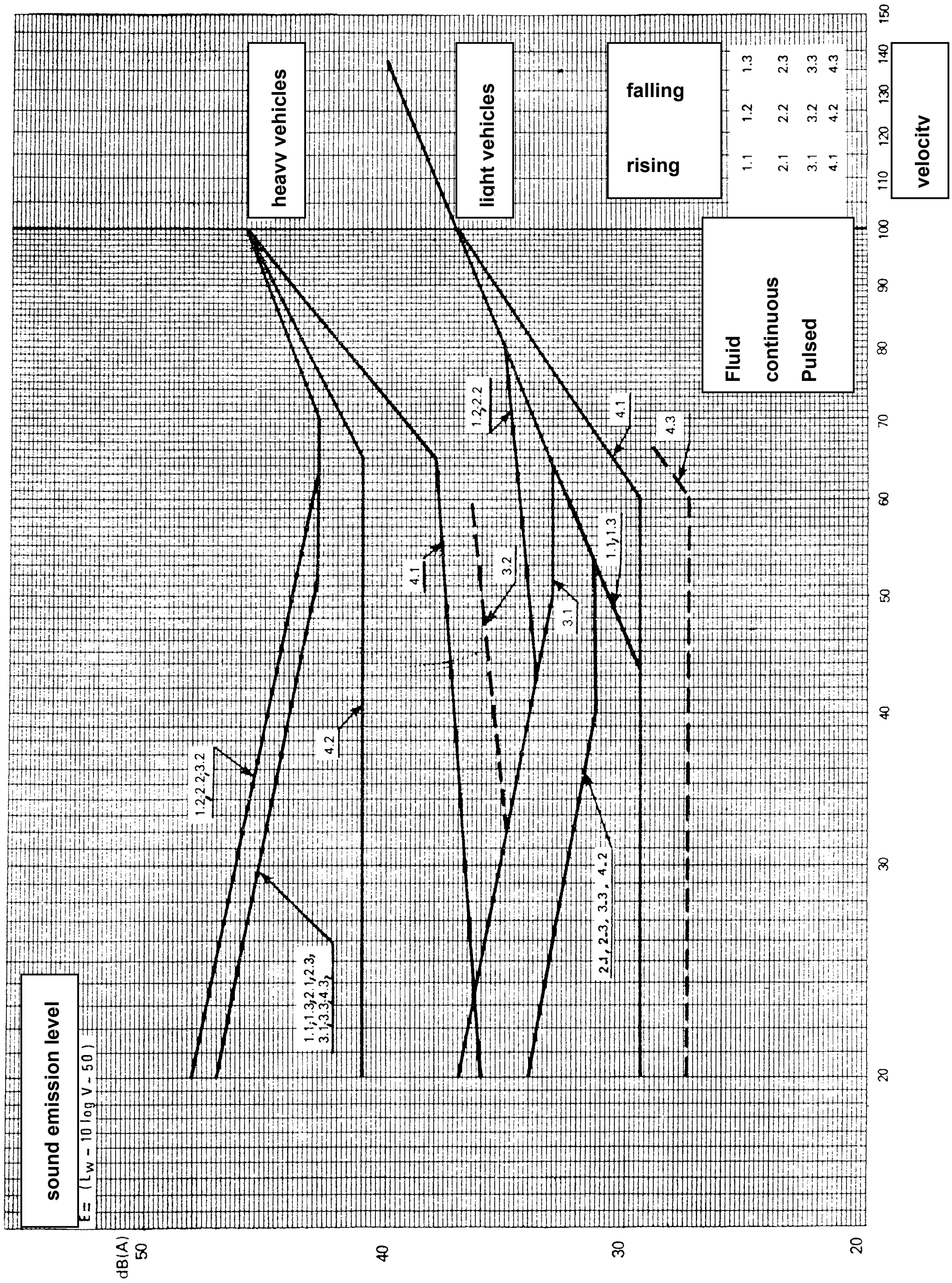

Figure 5 - Nomogram 2[29]

[29] the correction is applied only in the specified low speed range. Figure 5 - Nomogram 2 shows thus some situations where the upper speed limit is within the range of 60-70 km/h

3.1.5. The road surface correction

3.1.5.1. Introduction

Above a certain speed the overall noise emitted by a vehicle is dominated by the noise produced at the road-tyre contact points. This type of noise emission is called road-tyre contact noise. It typically depends on vehicle speed, type of road surface, (in particular porous and sound-deadening surfaces) and tyre type.

The basic noise emission model calculates a standard noise emission for a standard road surface. A correction must be applied for any other road surface. The road surface corrections used here are compatible with EN ISO 11819-1 [14]. The original noise emission model described in [20] does not contain a road surface correction. The following proposal is based on the comparison of all available European correction schemes and ISO 11819-1.

3.1.5.2. SURFACE TYPE DEFINITIONS:

- **Smooth asphalt (concrete or mastic):** is the reference road surface defined in EN ISO 11819-1. It is a dense, smooth-textured, either asphalt concrete or stone-mastic asphalt surface with a maximum chipping size of 11 - 16 mm.
- **Porous Surface:** is a surface with a void volume of at least 20 %. The surface has to be less than 5 years old (the age restriction accounts for the tendency of porous surfaces to become less absorptive over time as the voids fill up. If special maintenance is applied the age restriction may be lifted. However, after the initial 5 years term measurements must be made to determine the acoustics properties of the surface. The sound-reducing effect of this surface is a function of vehicle speed.).
- **Cement Concrete and corrugated asphalt**: includes both the cement concrete and coarse-texture asphalt.
- **Smooth texture paving stones:** paving stones with a distance smaller than 5 mm between the blocks.
- **Rough texture paving stones:** paving stones with a distance greater than or equal to 5 mm between the blocks.
- **Others:** is an open generic category into which each EU M.S. may place corrections for own national surfaces. Any number of aptly named classes of type “Other” can be added to the table or supersede the above proposals. To ensure harmonised use and results, data must be obtained in accordance with EN ISO 11819-1. The data obtained should be entered into Table 10. For all measurements, the passage speeds must be equal to the standard’s reference speeds. The SPBI equation will be used to evaluate the effect of the percentage of heavy vehicles. 10%, 20%, 30% will be used respectively to calculate the SPBI for each of the three percentage ranges defined in Table 10 (0-15%, 16-25% and > 25%).

Table 10 – Proposed complete road surfaces correction scheme

Speed	< 60 km/h			61-80 km/h			81-110 km/h		
% Heavy vehicles	0-15%	16-25%	> 25%	0-15%	16-25%	> 25%	0-15%	16-25%	> 25%
Surface type									

3.1.5.3. CORRECTION SCHEME

Table 11 – Proposed road surface correction scheme

Road Surface Categories	Noise Level Correction		
Porous Surface*	*0-60 km/h*	*61-80 km/h*	*81-130 km/h*
	- 1 dB	- 2 dB	- 3 dB
Smooth asphalt (concrete or mastic)	0 dB		
Cement Concrete and Corrugated asphalt	+ 2 dB		
Smooth texture Paving Stones	+ 3 dB		
Rough texture Paving Stones	+ 6 dB		

(*) Porous surfaces decrease the high frequency components and thereby accentuate the effect of low frequency components in the road traffic sound spectrum.

Road surfacing corrections should be periodically reviewed and adapted to changes in vehicle and tyre technology.

3.1.6. Noise emissions of motorised two-wheelers[30]

In most northern and central EU M.S. motorised two-wheelers do not have a significant impact on noise pressure levels[31]. This is due to the low share they have in the total traffic flow. The situation in southern EU M.S. is different: here the share of motorised two-wheelers is significant (especially in urban centres). Following a decision made during the meeting with WG AEN members on 14 October 2002, the relationship between motorised two-wheelers and motorised light vehicles was determined on the basis of the Dutch noise emission data[32].

3.1.6.1. A-weighted sound emission levels of RMW 1981 [3]

The following relationship between noise emissions of motorised vehicles and motorised two-wheelers can be used to take into account the contribution of motorised two-wheelers on noise pressure levels:

1 motorised two-wheeler = 9 motorised light vehicles

The Dutch road traffic noise calculation method of 1981 [13] provides sound emission data for light vehicles, motorcycles and mopeds. For motorcycles the aforementioned relationship can be shown over the whole speed range. For mopeds the relationship is approximately true for low speeds of 30-

[30] further information on the calculation can be found in [22]

[31] it must be emphasised that the nuisance is significant mainly due to the frequency distribution and high emission of the isolated event of a motorised two-wheeler passing by.

[32] the figures produced here were certified to be correct by the Dutch experts responsible for road traffic noise measurements (email communication by Ton Dassen of 8 January 2003)

40 km/h max. At 40 km/h, the difference for mopeds is about 7 dB. Higher speeds are of no interest for mopeds.

3.1.6.2. A-weighted sound emission levels from RMW 2002 [16]

The following relationship between noise emissions of motorised vehicles and motorised two-wheelers can be used to take into account the contribution of motorised two-wheelers on noise pressure levels:

1 motorised two-wheeler = 1,25 motorised light vehicles

The Dutch road traffic noise calculation method of 2002 [16] provides sound emission data for light vehicles, motorcycles and mopeds. For motorcycles the aforementioned relationship can be shown over the whole speed range.

3.1.7. Comparison with other noise emission data

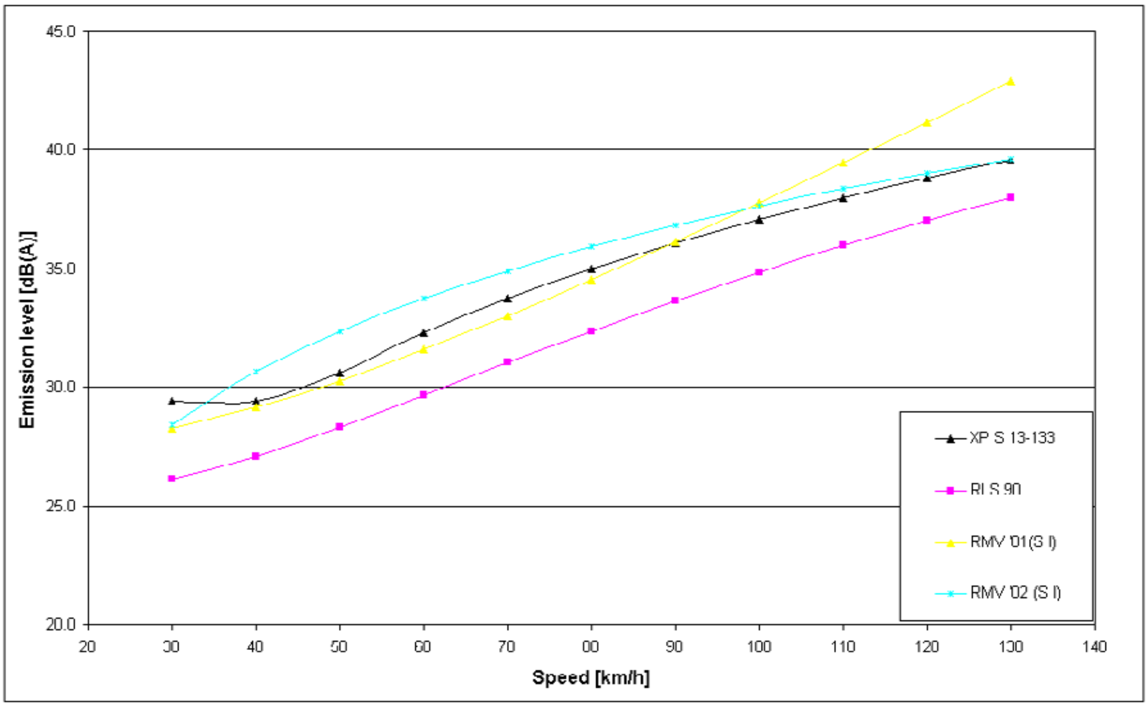

Table 12 – Comparison of road traffic noise emission models from different European M.S.

Table 12 (adopted from a table found in [22]) shows that the noise emission data of Guide du Bruit 1980 compares relatively well to other European noise emission data. The Dutch data has been selected to show the relationship with noise emission data determined at approximately the same period (RMV 1981) and the latest new data from 2002 (RMV 2002). Further comparisons with the Austrian noise emission data showed similar good correlation.

The French emission data is thus considered suitable for use in EU Member States.

3.1.8. Alternate method to determine noise emission data

3.1.8.1. Introduction

The first method presented in the above is based on the noise emission database of the “Guide du Bruit 1980” [20]. Due to the age of the data, the French government has set up a working group to produce updated noise emission data. The work is still in progress at the time of writing this report. The following can thus only be a kind of brief progress report of the new method developed in France (for the complete French report see [21]). The method is scientifically and technically interesting and presents many advantages as compared to the method presented in 3.1.3.

It is hoped that the missing elements of the new French method can be produced in time for inclusion in the EC guidelines on the adapted interim methods. We recommend that WG AEN and EC DG Environment should liase with the French authorities to check for availability of the final method for inclusion in the EC guidelines on the adapted interim computation methods.

3.1.8.2. Measurement method

The measurement method is similar to one defined in EN ISO 11819-1. Noise levels are measured at 7.5m from the lane centreline and 1.2m above the ground. All results will be published in terms of L_{Aeq} or similar. The change from L_{Amax} to L_{Aeq} is based on the assumption that the single vehicle can be modelled as an omni-directional point sound source.

This implies that EU M.S. can produce their emission data reflecting the characteristics of both their specific composition of the car fleet and their specific types of road surfaces by means of measurements in accordance to EN ISO 11819-1.

3.1.8.3. Vehicle categories

The emission data is produced for two vehicle types:

- light vehicles of less than 3.5 t, and
- heavy vehicles of more than 3.5 t.

The emission data for heavy vehicles is based on measurements on heavy vehicles with at least 4 axles. Smaller heavy vehicles will thus be modelled as a heavy vehicle with 4 axles. A study on representative car fleet compositions has shown that the error produced by this approximation is less than 1 dB(A) on roads and highways including urban transit roads. The error will be greater on urban roads that are used by a higher percentage of light heavy vehicles.

3.1.8.4. Road surfaces

Following a statistical analysis, three types of road surfaces are defined. They are called R1, R2 and R3 (for a definition see table below). A fourth class is reserved for pavements.

Table 13 – 3 categories of road surfaces for the new French emission data

Category R1 (the less noisy)	Category R2 (intermediate)	Category R3 (the most noisy)
BBTM 0/6 types 1 et 2 BBUM 0/6 BBDr 0/10 BBTM 0/10 type 2	BBTM 0/10 type 1 BBSG 0/10 ECF BBUM 0/10	BC BBTM 0/14 BBSG 0/14 ES 6/10 ES 10/14

- BBTM : very slim bituminous concrete
- BBUM : ultra slim bituminous concrete
- BBDr : drainage bituminous concrete
- BBSG : half-granulated bituminous concrete
- ECF : cold moulded surfacing
- BC : cement concrete
- ES : superficial seal

Aging of road surfaces is not accounted for. It is considered that aging is an important factor but that the available data is insufficient to determine correction factors for aging. Nevertheless, research for a simple correction is still ongoing.

3.1.8.5. Preliminary considerations

To obtain a suitable and practicable method, a series of simplifications are introduced following a preliminary analysis of the possible combinations of parameters influencing the sound emission of a vehicle (vehicle type, speed, flow, road surface and slope). It was found that three classes of combinations could be identified:

- “base” combinations: a detailed and exhaustive analysis of the measured data is required,
- “derived” combinations: whose emission data can be derived from base combinations without explicit need for further measurements, and
- combinations that are not very probable or without specific interest for which no emission data will be provided.

The following further simplifications are defined:

- low speed range for urban traffic (<50-60 km/h) with motor noise predominant,
- high speed range 50-120 km/h with contact noise predominant,
- acceleration is negligible for heavy vehicles travelling at higher speeds,
- for a given speed in the high speed range, the impact of the slope on the noise emission is considered negligible,
- in the low speed range the contact noise is considered negligible except for pavements.
- the regime of the engine of a vehicle climbing a slope at constant speed is considered identical to the one of an accelerating vehicle on a level road: a numerical relationship can thus be found between the sound emissions for these two driving conditions.

Table 14 - Base and derived combinations

Speed	Surface	longitudinal profile	Flow type	Type
< 50-60 km/h	R1+R2+R3**	horizontal	fluid	Base
			accelerated	Base
			decelerated	Base
		rising or falling slope	*	derived
	Pavement	horizontal	fluid	Base
> 50-60 km/h	R1	horizontal	fluid	Base
		rising or falling slope	*	derived
	R2	horizontal	fluid	Base
		rising slope	fluid	Base
		falling slope	fluid	Base
	R3	horizontal	fluid	Base
		rising slope	fluid	Base
		falling slope	fluid	Base

** for derived combinations, the effect of the slope is similar to the one for acceleration.*

*** The surface (except pavement) is supposed to have no impact on the sound emission.*

The noise emission LAmax for a given vehicle type results from two components that can be assimilated to two distinct sources. It is given by the following formula:

LAmax(V, R, p, a) = Lrolling(V, R) ⊕ Lengine(p, a)

where

V is the vehicle speed

R is the road surface

p is the slope of the road

a is the traffic flow type (fluid, accelerated or decelerated) of the vehicle

⊕ is the energetic addition: $L_1 \oplus L_2 = 10*\log[10\text{^}(L_1/10) + 10\text{^}(L_2/10)]$

Lrolling is called the “rolling component” generated by the contact between the tire and the road. **It is a linear function of log(V).**

Lengine is called the “engine component” or “mechanical component” and is the result of all the mechanical sources of the vehicle. **Lengine is deliberately chosen to be a constant over the whole speed range.**

3.1.8.6. Current results

3.1.8.6.1. Lrolling

Table 15 – New French road traffic noise emission data: rolling noise

surface type	light vehicles	heavy vehicles
R1	73,8 + 30,2 log(V/90)	33 + 26 log(V)
R2	77,7 + 31,5 log(V/90)	26,6 + 31 log(V)
R3	80,2 + 32,2 log(V/90)	24,6 + 32,6 log(V)
pavement	under development	under development

V in km/h

3.1.8.6.2. Lengine

Table 16 - New French road traffic noise emission data: engine noise of light vehicles

LV	**slope**		
	0% ≤ p ≤ 2%	**rising 2% ≤ p ≤ 6%**	**falling 2% ≤ p ≤ 6%**
continuous	**61,6 dB(A)**	**under development (1)**	**under development (1)**
acceleration	**69 dB(A)**	**under development (1)**	**under development (1)**
deceleration	**ongoing**	**under development (1)**	**under development (1)**

(1) the numerical relationship between slope and acceleration still has to be developed.

Table 17 - New French road traffic noise emission data: rolling noise of heavy vehicles

HV	**slope**		
	0% ≤ p ≤ 2%	**rising 2% ≤ p ≤ 6%**	**falling 2% ≤ p ≤ 6%**
continuous	**73 dB(A)**	**73 + 2*(p-2)**	**73 + 1*(p-2)**
acceleration	**ongoing**	**under development (1)**	**under development (1)**
deceleration	**ongoing**	**under development (1)**	**under development (1)**

p in % (absolute value)

(1) the numerical relationship between slope and acceleration still has to be developed.

3.2. Revised Noise Emission Data for the Dutch railway noise calculation method

The following tasks have been carried out:

- Study of rolling stocks and rails used in different EU Member States.
- Liaison with authorities and train companies in the Southern Member States to obtain information on existing noise emission data.
- Study an description of the noise emission model of the Dutch railway noise calculation method.
- Translation of the Dutch railway noise calculation method into non-contextual English.
- Detailed description of the noise emission measurement method from suitable to either assign rolling stock to any of the existing train classes or to generate new classes.

3.2.1. Introduction

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. The Dutch noise emission model can be used in all European Members States:

- The default database contains a sufficiently large number of examples of Dutch and non Dutch rolling stock on Dutch rails to serve as a useful guide for the adaptation of national emission data or the assignment of trains to existing classes.
- The noise emission model is not limited to Dutch national parameters. In fact, the accompanying measurement method effectively enables every EU M.S. to produce its own data for use with the existing Dutch emission model.
- The default database can and should be replaced by more accurate national data. The production of a general European-wide database would require the co-operation of the responsible authorities and private train operators from all Member States. The differences in national rolling stock and rail and the information available on both currently vary heavily between the Member States and are likely to remain different. Parameters like rail roughness cannot be generalised and must be accounted for in each Member State.
- Other databases for railway noise emission do exist. Most of these are specific to the railway traffic in individual EU M.S. (national and foreign rolling stock on national tracks). Not all are sufficiently complete. If at all possible they should be converted by the Member State to fit the Dutch noise emission model (see also procedure A of the measurement method for help in assigning trains to existing groups).

It is most likely that a series of M.S. will adopt their own national method for strategic noise mapping. However, if these or any other EU Member State will adopt the interim method for railway noise, the requirement to either adapt existing noise emission data sets to fit the requirements of the Dutch methods or to produce new data will arise. The Dutch noise emission measurement method provides two different approaches:

- 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.

The noise measurement method is based on a method originally described by DITTRICH/JANSSEN for SRM II 1996 and later adopted for integration with the 2002 release of the Dutch computation method. The noise emission model was revised to permit inclusion of non-Dutch rolling stock on non-Dutch tracks. Finally, a proposal was developed for an European Database of Train Emission Data. The full detail of the reports on these works is available in Part B of this report.

3.2.2. The noise emission model

3.2.2.1. Existing Rail vehicle categories

In 3.2.3, 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 6 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.

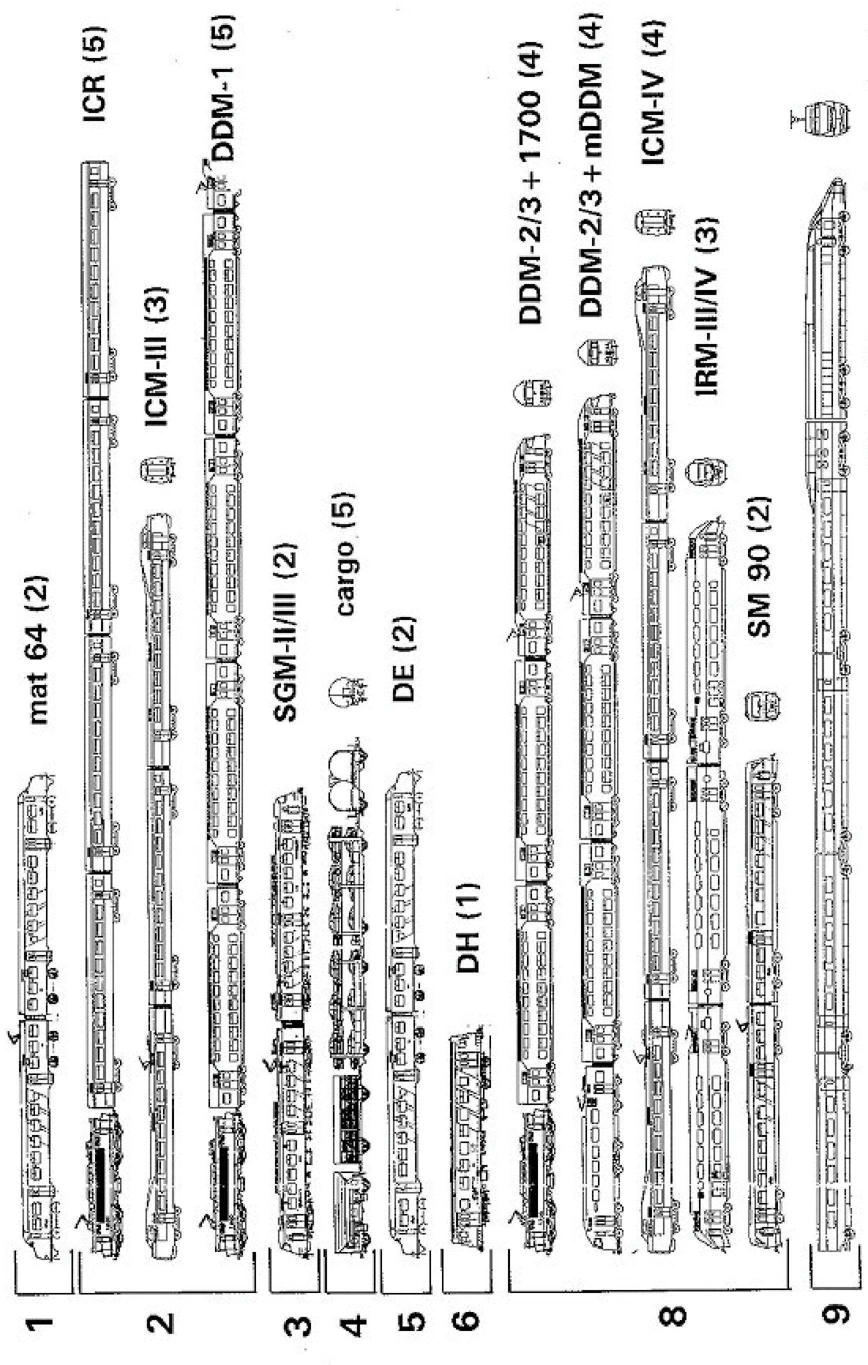

Figure 6 - Train categories for the calculation and measurement guidelines for rail transport noise: type (number of units)

3.2.2.2. Emission Values per Octave Band

3.2.2.2.1. 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.

3.2.2.2.2. Track

In order to determine the emission value per sound source level one uses the categories for railway vehicles given in 3.2.2.1. 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);

3.2.2.2.3. Specifications

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

Q_c the mean number of non-braking units of the railway vehicle category concerned [h^{-1}]

$Q_{br,c}$ the mean number of braking units of the railway vehicle category concerned [h^{-1}]

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]

$C_{bb,i,m}$ correction for to track discontinuities and rail roughness.

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

3.2.2.2.4. Calculation method

3.2.2.2.4.1. Existing train categories

The calculation proceeds as follows:

$$L_{E,i}^{bs} = 10\lg\left(\sum_{c=1}^{8} 10^{E_{bs,nb,i,c}/10} + \sum_{c=1}^{8} 10^{E_{bs,br,i,c}/10}\right) \quad 2.3a$$

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

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

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

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

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

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

$$E_{bs,nb,i,c} = E_{nb,i,c} - 1$$

$$E_{bs,br,i,c} = E_{br,i,c} - 1$$

$$E_{as,nb,i,c} = E_{nb,i,c} - 7$$

$$E_{as,br,i,c} = E_{br,i,c} - 7$$

The following applies for categories 4 & 5:

$$E_{bs,nb,i,c} = E_{nb,i,c} - 3$$

$$E_{bs,br,i,c} = E_{br,i,c} - 3$$

$$E_{as,nb,i,c} = E_{nb,i,c} - 3$$

$$E_{as,br,i,c} = E_{br,i,c} - 3$$

The following applies for category 9:

$$E_{as,nb,i,c} = E_{nb,i,9-as}$$

$$E_{as,br,i,c} = E_{br,i,9-as}$$

$$\mathrm{E}_{\mathrm{2m,i,c}} = \mathrm{E}_{\mathrm{i,9-2m}}$$

$$\mathrm{E}_{\mathrm{4m,i,c}} = \mathrm{E}_{\mathrm{i,9-4m}}$$

$$\mathrm{E}_{\mathrm{5m,i,c}} = \mathrm{E}_{\mathrm{i,9-5m}}$$

with:

$$E_{nb,i,c} = a_{i,c} + b_{i,c} \lg v_c + 10\lg Q_c + C_{bb,i,m} \qquad 2.4a$$

$$E_{br,i,c} = a_{i,c} + b_{i,c} \lg v_{br,c} + 10\lg Q_{br,c} + C_{bb,i,m} \qquad 2.4b$$

$$E_{brake,i,c} = a_{i,c} + b_{i,c} \lg v_{br,c} + 10\lg Q_{br,c} + C_{brake,i,c} \qquad 2.4c$$

for c = 5

$$\mathrm{E}_{\mathrm{diesel,i}} = 10\lg\begin{pmatrix} 10^{\left(\mathrm{a}_{\mathrm{diesel,i}} + \mathrm{b}_{\mathrm{diesel,i}} \lg \mathrm{v}_5 + 10\lg \mathrm{Q}_5\right)/10} \\ + 10^{\left(\mathrm{a}_{\mathrm{diesel,i}} + \mathrm{b}_{\mathrm{diesel,i}} \lg \mathrm{v}_{\mathrm{r,5}} + 10\lg \mathrm{Q}_{\mathrm{r,5}}\right)/10} \end{pmatrix} \qquad 2.4d$$

for c = 3 and c = 6

$$E_{motor,i} = 10\lg\begin{pmatrix} 10^{\left(a_{motor,i} + b_{motor,i} \lg v_c + 10\lg Q_c\right)/10} \\ + 10^{\left(a_{motor,i,c} + b_{motor,i} \lg v_{br,c} + 10\lg Q_{br,c}\right)/10} \end{pmatrix} \qquad 2.4e$$

for c = 9

$$E_{9-2m,i} = 10\lg\begin{pmatrix} 10^{\left(a_{9-2m,i} + b_{9-2m,i} \lg v_9 + 10\lg Q_9\right)/10} \\ + 10^{\left(a_{9-2m,i} + b_{9-2m,i} \lg v_{br,9} + 10\lg Q_{br,9}\right)/10} \end{pmatrix} \qquad 2.4f$$

$$E_{9-4m,i} = 10\lg\begin{pmatrix} 10^{\left(a_{9-4m,i}+b_{9-4m,i}\lg v_9+10\lg Q_9\right)/10} \\ +10^{\left(a_{9-4m,i}+b_{9-4m,i}\lg v_{br,9}+10\lg Q_{br,9}\right)/10} \end{pmatrix} \quad 2.4g$$

$$E_{9-5m,i} = 10\lg\begin{pmatrix} 10^{\left(a_{9-5m,i}+b_{9-5m,i}\lg v_9+10\lg Q_9\right)/10} \\ +10^{\left(a_{9-5m,i}+b_{9-5m,i}\lg v_{br,9}+10\lg Q_{br,9}\right)/10} \end{pmatrix} \quad 2.4h$$

The values for the emission index codes can be taken from tables 2.5 & 2.6.

Table 18 - Emission index codes a_c and b_c as functions of the railway vehicle category c = 1 to 8 inclusive in octave band (i)

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

Table 19 - 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)

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

Table 20 - Correction factor $C_{brake,i.c}$ for brake noise as a function of the railway vehicle category (c) and the octave band (i)

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

3.2.2.2.4.2. New train categories

After the characterisation of the emission of different train categories, the emission of the whole railway line is calculated taking into account the passage of different train categories (considering that not all train categories have sound sources at all heights) and the passage at different conditions (braking or not braking).

$$L^h{}_{E,i} = 10Log(\sum_{c=1}^{n} 10^{E^h_{nb,i,c}/10} + \sum_{c=1}^{n} 10^{E^h_{br,i,c}/10})) \qquad 2.5$$

where h=a_s (0m), b_s (0.5m), 2m, 4m and 5m.

The emission of each train category at different heights: (see 3.2.2.2.3)

h= 0m

$$E^{bs}_{nb,i,c} = a^{bs}_{i,c} + b^{bs}_{i,c} \log V_c + 10 \log Q_c + C_{bb,i,m,c} \qquad 2.6a$$

$$E^{bs}_{br,i,c} = a^{bs}_{i,c} + b^{bs}_{i,c} \log V_{br,c} + 10 \log Q_{br,c} + C_{bb,i,m,c} \qquad 2.6b$$

h=0.5 m

$$E^{as}_{nb,i,c} = a^{as}_{i,c} + b^{as}_{i,c} \log V_c + 10 \log Q_c + C_{bb,i,m,c} \qquad 2.6c$$

$$E^{as}_{br,i,c} = a^{as}_{br,i,c} + b^{as}_{br,i,c} \log V_{br,c} + 10 \log Q_{br,c} + C_{bb,i,m,c} \qquad 2.6d$$

h=2m

$$E^{2m}_{nb,i,c} = a^{2m}_{i,c} + b^{2m}_{i,c} \log V_c + 10 \log Q_c \qquad 2.6e$$

$$E^{2m}_{br,i,c} = a^{2m}_{i,c} + b^{2m}_{i,c} \log V_{br,c} + 10 \log Q_{br,c} \qquad 2.6f$$

h=4m

$$E^{4m}_{nb,i,c} = a^{4m}_{i,c} + b^{4m}_{i,c} \log V_c + 10 \log Q_c \qquad 2.6g$$

$$E^{4m}_{br,i,c} = a^{4m}_{i,c} + b^{4m}_{i,c} \log V_{br,c} + 10 \log Q_{br,c} \qquad 2.6h$$

h=5m

$$E^{5m}_{nb,i,c} = a^{5m}_{i,c} + b^{5m}_{i,c} \log V_c + 10 \log Q_c \qquad 2.6i$$

$$E^{5m}_{br,i,c} = a^{5m}_{i,c} + b^{5m}_{i,c} \log V_{br,c} + 10 \log Q_{br,c} \qquad 2.6j$$

Comment: Note that the different emissions at distinct source heights of a train category under non braking or braking conditions come from both the train speed (V_c for trains running under non-braking conditions and $V_{br,c}$ for braking trains) and the mean number of individual units that roll on the track (Q_c non-braking units and $Q_{br,c}$ braking units). Sources at 0.5 meters are an exception in that their emission index may be different for either of the the two cases non braking conditions ($a^{as}_{i,c}$ and $b^{as}_{i,c}$) and braking conditions ($a^{as}_{br,i,c}$ and $b^{as}_{br,i,c}$).

3.2.2.2.4.3. Track type and track roughness correction

The correction for track type C_{bbi} is given in table 14, but the effect of the track roughness has also been integrated in this correction as function of track discontinuities (m)

The extra noise emission of a rough track or the noise reduction of a smoother track in comparison with the reference rail roughness will be included for existing categories (formulas 2.4.a and 2.4.b) and for new categories (formulas 2.6a, 2.6b, 2.6c, 2.6d) . This is carried out 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 applied for a jointless track (m = 1), because in the other cases, m ≠1, which means rail with junctions, the rolling noise caused by rail roughness can be neglected. This parameter as it will be seen afterwards, is dependent on speed (v) and train category (c).

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

$$C_{bb,i,1,c}(v) = C_{bb,i}+C_{rr,i,c}(v)$$

$$C_{bb,i,1,c}(v) = C_{bb,i}+\{(L_{i,rtr,loc}(\lambda_i)\oplus L_{i,rveh,c}(\lambda_i)) - (L_{i,rtr,ref}(\lambda_i)\oplus L_{i,rveh,c}(\lambda_i))\} \quad 2.7$$

with: $C_{bb,i}$ the track correction from table 14

$C_{rr,i,c}(v)$ correction for rail roughness. Correction is zero when $m\neq 1$

$L_{i,rtr,\mathbf{ref}}(\lambda_i)$ reference rail roughness, according to 3.2.3.3.3.

$L_{i,rtr,loc}(\lambda_i)$ local rail roughness of the track on which the calculation are being carried out. Measured according to pr EN ISO:3095

$L_{i,rveh,c}(\lambda_i)$ wheel roughness of different train categories, according to table 12 and updated with information from the new database (table 2 of New Train Emission Database)

V Train speed.

energetic summation

Note: $C_{rr,i,c}$ (v) is a function of wavelength, but to calculate $C_{bb,i,1,c}(v)$ it has to be added to a parameter that depends on the frequency ($C_{bb,i}$) so first it has to be converted to a function of frequency (formula B.44), and therefore is speed dependent.

Wavelength range for roughness is from 20.2 cm to 0.8 cm, independent of speed. When roughness it is converted to a function of frequency it becomes also a function of speed, for example:

For v=30 km/h the frequency range is about : 50 Hz-1KHz

For v= 250 km/h the frequency range is about: 400 Hz-8KHz

With varying train speed the roughness curve retains its shape but shifts horizontally in the frequency range.

To determine the local wheel roughness, measurements have to be carried out according to annex II at the end of this document.

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 value of rail roughness than average, the track exploitation company has to guarantee that, by monitoring and additional grinding, the low rail roughness level can be maintained.

Determinant for this is that the differences in rail roughness, averaged over the considered part of the track, 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 21 - Data to determine wheel roughness, according to the type of brake system as a function of the wavelength

Wavelength [cm]	wheel roughness as a function of brake system disc brake + blocks	only disc brakes	cast-iron block brake	disc brake + added cast-iron block brake
20.2	-3	8	5	11
16	-4	7	6	11
12.7	-3	7	7	12
10.1	-2	6	9	13
8	-1	6	11	14
6.3	-2	3	13	16
5	-1	1	12	15
4	-2	-1	10	12
3.2	-2	-2	8	11
2.5	-3	-3	6	10
2	-3	-3	5	6
1.6	-3	-4	0	3
1.3	-4	-4	-1	-2
1	-5	-5	-1	-5
0.8	-7	-7	-3	-7

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 according to 3.2.3.2, the average wheel roughness is determined by measurements and should be incorporated in the database.

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:

$$C_{bb,i,m} = C_{3,i} + 10\lg\left(1 + f_m A_i\right) \quad 2.8$$

with: $C_{bb,i}$ the track correction from table 14. (where $C_{3,i}$ is $C_{bb,i}$ with bb=3)

f_m table 13

A_i table 15

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

Table 22 – Values of f_m as a function of track type

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

Table 23 - Correction factor $C_{bb,i}$ as a function of structures above station compounds/railway track condition (bb) and octave band (i)

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

Table 24 - Code index for noise emission in the case of impact A_i as a function of the octave band (i).

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

3.2.2.2.5. Maximum Speeds

In this unit the emission level for train speeds can be determined using a maximum speed per category as shown in Table 25.

Table 25 - Maximum speed per category

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

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

3.2.3. 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, …).

3.2.3.1. 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).

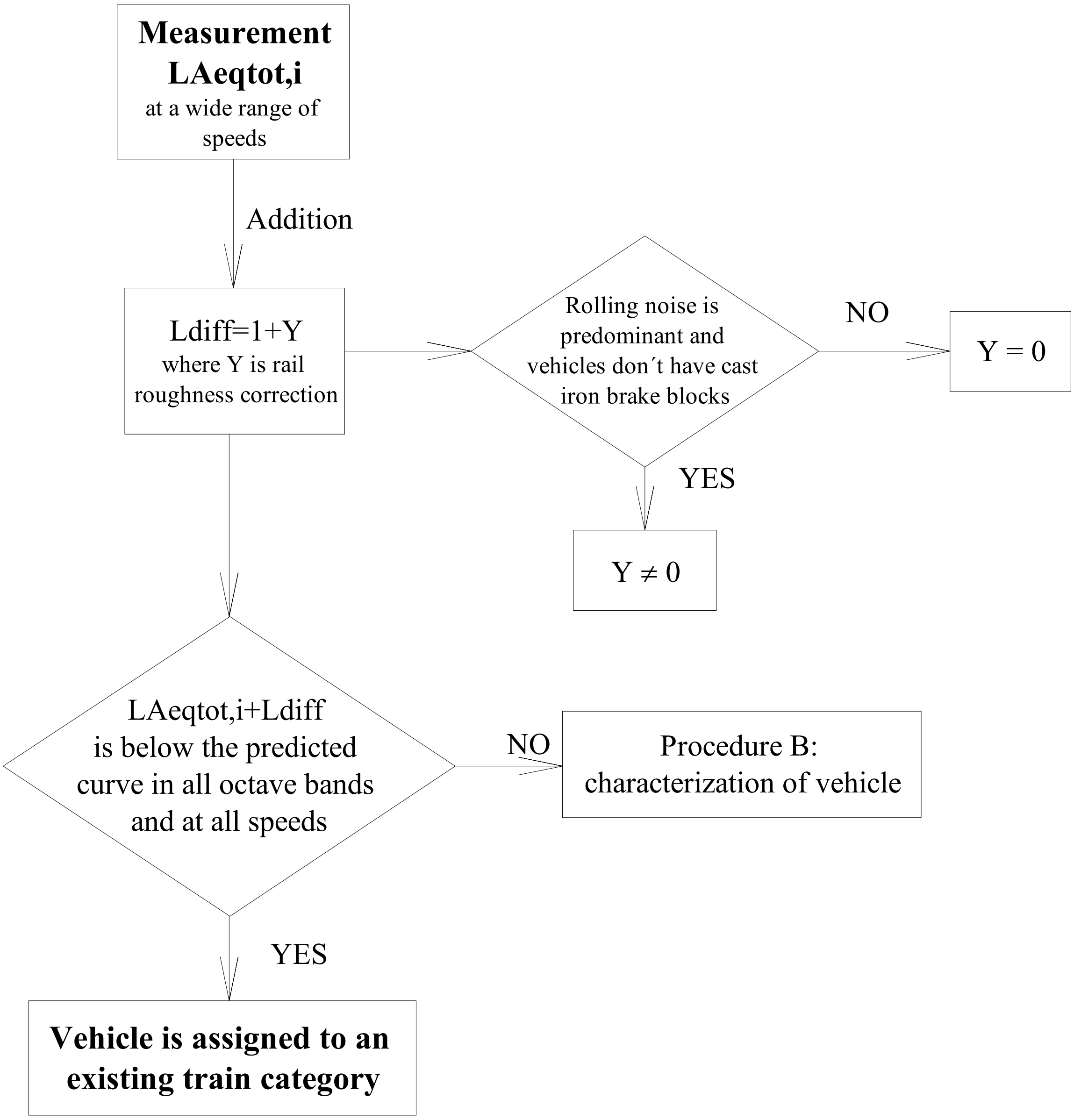

Figure 7 – Dutch railway noise method: Flowchart of measurement procedure A

3.2.3.2. Procedure B: Comprehensive methods for characterisation of vehicle and track

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.

For a flow chart illustrating measurement method Procedure B see ANNEX II at the end of this document.

3.2.3.3. Procedure C:

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.

3.2.3.3.1. 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 $C_{bb,i}$, 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 lose 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.

3.2.3.3.2. 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.

3.2.3.3.3. Other conditions

Task 3-2-2 of Part B of this report gives all the details of the measurement conditions, measurement equipment, meteorological and background noise conditions and other important information on the method.

3.2.3.3.4. Determination of correction values for track characteristics

The track type correction terms of the test track in octave bands $C_{bb,test,i}$ equal:

$$C_{bb,test,i} = \frac{1}{n} \sum_{j=1}^{n} \left(L_{Aeq,test,i,j} - L_{Aeq,ref,i,j} \right) \qquad B.49$$

with:

$L_{Aeq,test,i,j}$	*equivalent noise level during passage of train j in octave band i over test tracks, energetically averaged over the cross-sections*
$L_{Aeq,ref,i,j}$	*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*

3.3. Noise Emission Data for Industrial Noise Sources

3.3.1. Choice of the measurement method

3.3.1.1. Introduction

END lists three possible methods to measure industrial sound emissions: ISO 3744, ISO 3746 and ISO 8297. Although it is clearly noted in Table 0.1 of ISO 3744 & ISO 3746 that there are no restrictions relating to the volume of the sound sources for the application of the two norms, ISO 3744 and ISO 3746 are in fact only suitable for determining the sound power level of individual sound sources of limited dimensions. The inherent requirement for measuring heights of 20 m and more depending on the actual height of on-site sound sources makes noise measurements of source groups or entire companies in accordance with ISO 3744 and ISO 3746 neither realistic nor cost-effective. ISO 3744 & ISO 3746 can be applied to separate sound sources, provided they are not located too close to one another.

To measure the sound power levels of larger installations and entire companies, however, ISO 8297 is highly suitable.

In the following, the application of different norms will be discussed for the determination of the sound power levels of two different types of sound sources: on the one hand, individual discrete sound sources and, on the other hand, parts of - or entire - industrial companies.

Text versions in .DOC-format of the three emission standards are included in Part B of this report.

3.3.1.2. Individual discrete sound sources

Individual sound sources such as equipment used outdoors (see directive 2000/14/EC), air-conditioning installations, compressors, etc., which have been installed separately (which means that they are not located in one another's acoustic field of influence) can be measured with ISO 3744 or ISO 3746.

Both standards are based on the same principle. The sound pressure level is measured on an imaginary hemisphere or parallelepiped around the sound source. This sound pressure level is combined with the size of the surface to be measured in order to obtain the sound power level. Depending on the background noise correction K1 and the environmental correction K2, either ISO 3744 (which is an engineering method) or ISO 3746 (a survey method) can be used. The expected accuracy of the method to determine L_{wA} expressed as standard deviation of reproducibility is less than 1.5 dB for ISO 3744, and between 3 to 4 dB for ISO 3746. An overview of the differences between ISO 3744 and ISO 3746 is given in Table 0.1 of both norms.

3.3.1.3. Parts of (or complete) company sites

If one wants to determine the sound power level of an entire company, it is impossible to do so by means of measurements of all the different individual sound sources. This would never be possible within an acceptable period of time. In addition, in the majority of cases it would not be possible to respect the boundary conditions (K1 and K2) as specified in ISO 3744 and ISO 3746. If the requirement to determine the sound power level of individual sound sources persists despite the aforementioned constraints, then this would have to be done with sound intensity measurements in accordance with ISO9614.

Within the framework of the END, however, it is advisable to determine global sound power levels of entire industrial companies disregarding for the purpose of strategic noise mapping the actual distribution on individual sources. For this purpose, sound pressure measurements can be carried out around the entire installation. ISO 8297 describes a method to carry out these measurements that is derived from a method that is called the "Stuber method" in the literature. Sound pressure measurements are carried out on a previously defined measuring line located at a constant distance of 5 to 35 m from the boundaries of the installation. Depending on the height of the installation under study and the possibilities on site, the measuring height is 5m. The average sound pressure level along the measurement contour is calculated on the basis of these measurements. Art. 10 of ISO 8297 describes in a step-by-step procedure the calculation of the sound power level to evaluate levels in the environment. This sound power level is the combination of the average sound pressure level, the area term for the enclosed measurement surface, and correction terms for proximity, microphone and sound attenuation.

The great limitation of this measurement method are the boundary conditions outlined in Art. 10.2, step 2, which stipulate that the differences in sound pressure level between the measured value and the calculated mean value should not be greater than 5 dB. This is logical, in view of the fact that one is working on a logarithmic scale, which could lead to faulty weighting between quieter and noisier zones of the installations under study. This totally justifiable limitation implies that before the measuring line around the installation is determined, a series of exploratory measurements should already have been carried out for the purpose of being certain afterwards that this min-max limitation will be fulfilled. One solution to this problem is first to carry out a series of measurements on a grid running around – and possibly through – the entire installation. Isocontours of equal sound pressure level are thus obtained by means of interpolation of the measured sound pressure levels. For the rest, the procedure is carried out as specified in ISO 8297. An isocontour is chosen that encloses the entire installation, and the surface area enclosed by the isocontour under study is used for the area term. This is also outlined in the so-called "Colenbrander method". Since the calculation is done with an isocontour, the min-max limitation is automatically fulfilled.

3.3.2. Supplementing ISO 8297

In Belgium these methods have been combined and further developed and republished as the *"EMOLA method"*[17], which can be regarded as a supplement to *ISO8297*. This makes it possible to determine in a reliable manner the contour on the basis of which the sound power level of the entire installation will be calculated. An additional advantage of the "EMOLA method" is that it is possible to double check the calculated L_w by making a comparison of calculations of several subsequent iso-contours (see also figure Figure 8). The English translation is included in this study.

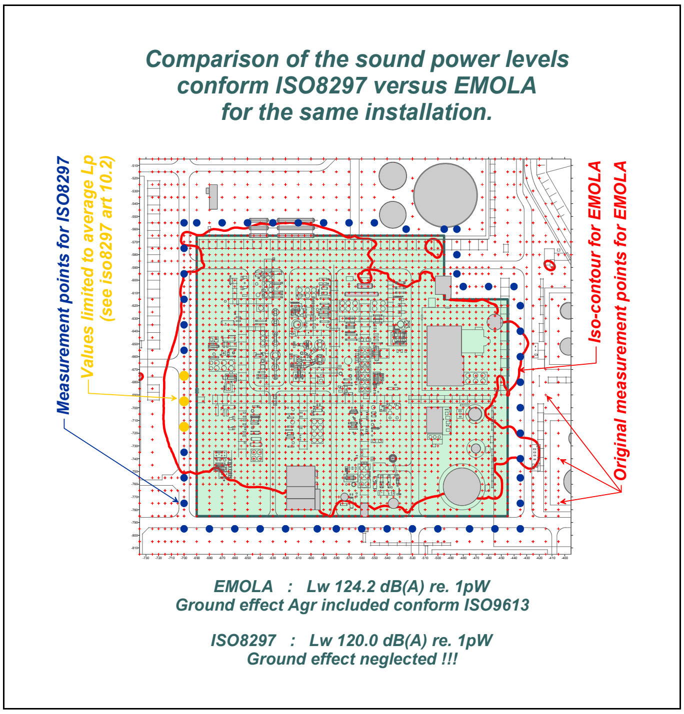

Figure 8 – Comparison of EMOLA vs. ISO 8297

Two differences between both methods could explain the 4.2 dB(A) higher sound power level calculated by the Emola-method.

- ISO8297 does not consider any ground effect inside the installation under study. Sound power calculation by Emola, however, takes into account this ground effect in compliance with ISO9613-2. This is more logical, because the ground effect also has to be considered for the calculation of the L_{den} at the reception points.
- Sound pressure level used for the calculations is obtained in two different ways, for ISO8297 by a “limited” average of measurements on a predefined contour, for Emola by an interpolated contour based on a flexible measurement grid.

3.3.3. Integration into ISO 9613-2

According to Art 4. of ISO 9613-2, the calculations are carried out for point sources. Nevertheless, the possibility exists of dividing extended sound sources (such as industrial sites) into sections (cells), each of which in turn will be represented in the actual calculations by a representatively located point source.

Depending on the type of sound source studied and the type of input data that is available (see Table 26), the source type will be either a point source, a line source or an area source. It is the task of the computer model to ensure proper subdivision of extended sources into component point sources taking into account Art 4, points a, b and c of ISO 9613-2.

Table 26 – Input data types for industrial noise sources

Input Data		Source Type
From	As	
Type 1: Public database	**Lw"for entire company**	Area source, **to be distributed evenly over the entire plant surface area of the company under study**
	L_W, Lw' for individual source	Area source, line source or point source, **depending on the details available**
Type 2: Theoretical operating conditions	**Lw", Lw' or Lw**	Area source, line source or point source, **depending on the details available**
Type 3: Environmental Impact Assessment (EIA)	**Lw", Lw' or Lw**	Area source, line source or point source, **depending on the details available**
Type 4: Noise measurements of the actual situation	**Lw", Lw' or Lw**	Area source, line source or point source, **depending on the details available**

In general it is advisable to start with area sources, and to switch to line or point sources only if reliable detailed information is known about the lay-out of the sources. This prevents the overestimation of screening effects that could be caused by coincidental geometrical combinations of point sources and reception points.

In principle, the calculations are done per 1/1 octave band. In practice, however – and certainly in the first phase – often only a global A-weighted sound power level will be known. For these cases, the attenuation terms for 500 Hz are used in accordance with Note 1 of ISO 9613-2 to estimate the resulting attenuation. For ground effect, the alternate formula 7.3.2 is preferred for overall A-weighted calculations.

3.4. Noise Emission Data for ECAC.CEAC Doc.29

3.4.1. Introduction

A study on existing databases resulted in the selection of the emission data set that is proposed below as the default recommendation. The justification background information and validation figures are included in Part B of this report.

The default recommendation does not preclude the use of other suitable databases if available.

3.4.2. Default recommendation

The recommended default noise-power-distance and performance data are the ones used in Germany [8] and in Austria [6]. The noise-power-distance tables are given in a digital form on the accompanying CD-ROM. These data are readily available. They are backed by extensive research and the report is publicly available [8]. The data have been used at numerous airports in both aforementioned EU M.S. (and some others). They are chosen as default noise emission database because they are complete: they provide noise power distance data and performance data for all types of aircraft and of the new low noise aircraft generation.

During the development phase of the Austrian aircraft noise calculation guideline, a study was conducted comparing L_{Amax} and SEL from the selected dataset with both the data from INM and the Swiss data (based on a completely different system [7]) for all frequently used fixed-wing aircraft types. It was shown that the data compare quite well. In addition, the data have been compared with the $L_{A,max}$ and SEL-values measured at the aircraft noise monitoring stations around the Vienna airport. For most measurement positions the measured values are somewhat lower than the calculated values. The dispersion is considerable and is due to the differences in the fixed-wing aircraft types, the dispersion on the flight track and the detailed conditions chosen by the pilots.

The data are based on a grouping of aircraft and contain $L_{A,max}$-levels. The following formula allows calculation of SEL-values[33] using pass-by duration as an additional parameter.

SEL is calculated from $L_{A,max}$ by

$$\mathrm{SEL} = L_{A,\max} + 10.\lg\frac{T}{T_0} \quad \text{in dB} \quad \text{with}$$

$$T = \frac{A.s}{V + (s/B)} \quad \text{in s and } T_0 = 1 \text{ second}$$

A and B are constants which are different for take-off and approach and for different fixed-wing aircraft; they are given in the tables; s is the slant distance in m and V is the speed in m/s. For the following tables V is set to 80 knots = 41,1 m/s for the groups of aircraft with MTOW up to 5700 kg (groups 1.x) and 160 knots = 82,3 m/s for the groups with MTOW > 5700 kg (groups 2.x, 3.x, 5.x, 6.x and 7)

The sound levels are given for take-off thrust and for landing thrust; to consider the thrust reduction after take-off sound level reductions ΔL_{ξ} are given at certain heights H and certain speeds V.

[33]) The calculations have to be based on $L_{A,max}$ only as given in the relevant formula; the SEL-values are shown in the tables for information and comparison only.

For each of the groups a default take-off-profile is given with speed V and height H versus distance σ on the ground track from start-off-roll point and for greater distances with $dH/d\sigma$.

The sound level data and the performance data are normalized for temperature 15^0C, humidity 70% and pressure 1013,25 HPa. They may be used for temperatures up to 30^0C and whenever the product of relative humidity and temperature is greater than 500.

The groups of aircraft and the assignment of different types of fixed-wing aircraft to these are given in table Table 27.

Table 28 shows fixed-wing aircraft frequently observed on major European airports and how they are assigned to aircraft groups.

Table 27 - Groups of aircraft

P 1.1	power glider
P 1.2	Propeller aircraft with a maximum take-off weight (MTOM) up to 2 t or power glider as tow plane
P 1.3	Propeller aircraft with a maximum take-off weight (MTOM) up to 2 t
P 1.4	Propeller aircraft with a maximum take-off weight (MTOM) > 2 up to 5,7 t
P 2.1	Propeller aircraft with a maximum take-off weight (MTOM) > 5,7 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3 or Chap. 10
	DASH 7, SF 34, DASH 8, ATR 42
P 2.2	Propeller aircraft with a maximum take-off weight (MTOM) > 5,7 t, which can not be assigned to group P 2.1
	SAAB 2000, L 188
S 1.0	Jet aircraft with a maximum take-off weight (MTOM) up to 34 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 2
S 1.1	Jet aircraft with a maximum take-off weight (MTOM) > 34 t up to 100 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 2 (without types Boeing 737 und Boeing 727).
S 1.2	Aircraft of type Boeing 737, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 2
S 1.3	Aircraft of type Boeing 727, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 2
S 3.1	Jet aircraft with two or three engines and a maximum take-off weight (MTOM) > 100 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 2 or complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3 and not assigned to the groups S 6.1 or S 6.2 respectively
S 3.2	Jet aircraft with four engines and a maximum take-off weight (MTOM) > 100 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 2 or complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3 and not assigned to the group S 6.2 respectively
S 5.1	Jet aircraft with a maximum take-off weight (MTOM) up to 50 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3
	Canadair RJ, RJ 70, BAE 146, BA46-2, LEAR35, FK 10, LR 30
S 5.2	Jet aircraft with a maximum take-off weight (MTOM) > 50 t up to 120 t and a by-pass ratio > 3, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3
	F 100, FK 70, B 737-300...500, EA32
S 5.3	Jet aircraft with a maximum take-off weight (MTOM) > 50 t up to 120 t and a by-pass ratio up to 3, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3
	MD 80,
S 6.1	Jet aircraft with two engines and a maximum take-off weight (MTOM) > 120 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3 The types must be included in the current register of low noise jet aircraft with a maximum take-off weight > 120 t (see the following register)
	EA31, B767, B777

S 6.2	Jet aircraft with three or four engines and a maximum take-off weight (MTOM) > 120 t up to 300 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3 (without type Airbus A340). The types must be included in the current register of low noise jet aircraft with a maximum take-off weight > 120 t (see the following register)
	MD11, IL-76, B727, DC10
S 6.3	Type Airbus A340.
S 7	Jet aircraft with three or four engines and a maximum take-off weight (MTOM) > 300 t, complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3
	B747

Register of low noise jet aircraft with a maximum take-off weight (MTOM) > 120 t	
(only groups S 6.1 and S 6.2)	
Airbus A300	(all models complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3)
Airbus A310	(all models)
Airbus A330	(all models)
Boeing 767	(all models)
Boeing 777	(all models)
Lockheed 1011	(all models complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3)
McDonnell Douglas DC 8-70-Serie	(all models complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3)
McDonnell Douglas DC 10	(all models complying with the requirements of Appendix 16 of the Convention on International Civil Aviation, Vol. I, Chap. 3)
McDonnell Douglas MD-11	(all models)

Table 28 - Frequent fixed-wing aircraft types and their assignment to the aircraft groups described in table1.1

ICAO design	**%**	**group**			
unknown or unregistered	**0.953**				
A124	**0.003**				
A306	**0.471**	**S 6.1**			
A30B	**1.854**	**S 6.1**			
A310	**0.279**	**S 6.1**			
A320	**16.798**	**S 5.2**			
A330	**1.808**	**S 6.1**			
A340	**0.611**	**S 6.3**			
A748	**0.144**	**S 5.1**			
AC95	**0.003**				
AN12	**0.026**	**P 2.2**			
AN24	**0.011**	**P 2.2**			

AN26	**0.007**	**P 2.2**			
AS50	**0.034**	**H**			
AS65	**0.003**	**H**			
AT43	**1.761**	**P 2.1**			
AT44	**0.145**	**P 2.1**			
ATP	**0.006**				
B190	**0.297**	**P 2.1**			
B222	**0.016**				
B721	**0.027**	**S 2**			
B722	**0.000**	**S 1.3**			
B727	**2.573**	**"-200 S 1.3**	**"-100 S 2**	**with Hushkit S 5.3**	
B737	**25.367**	**"300-800 S5.2**	**"-200 S 1.2**	**"-100 S 2**	**with Hushkit S 5.3**
B741	**0.806**	**S 7**			
B752	**1.598**	**S 5.2**			
B762	**1.938**	**S 6.1**			
B772	**0.006**	**S 6.1**			
BA11	**0.005**	**S 1.1**			
BA46	**22.029**	**S 5.1**			
BE99	**0.010**				
BN2P	**0.008**	**P 1.4**			
C130	**0.690**	**P 2.2**			
C500	**0.757**	**S 5.1**			
CL60	**0.160**	**S 5.1**			
CN35	**0.017**				
CRJ1	**2.884**	**S 5.1**			
CVLT	**0.127**	**P 2.1**			
D228	**0.006**				
D328	**0.024**	**P 2.1**			
DC10	**0.511**	**S 6.2**			
DC3	**0.001**				
DC6	**0.001**				
DC8	**0.037**	**S 4**	**"-70 S 6.2**		
DC9	**0.621**	**≤ 34t S 1.0**	**>34t S 1.1**		
DH8C	**0.013**				
DHC6	**0.001**				
DHC8	**2.242**	**P 2.1**			
E110	**0.011**				
E120	**0.027**				
E145	**3.078**	**S 5.1**			
F100	**0.061**	**S 5.1**			
F27	**0.043**	**P 2.1**			
F2TH	**0.815**	**S 5.1**			
F50	**1.199**	**S 5.1**			
F70	**0.704**	**S 5.1**			
GULF	**0.187**	**G2 S 1.0**	**G3-5 S 5.1**		
H25C	**0.164**	**S 5.1**			

HPR7	**0.001**					
IL62	**0.004**	**S 4**				
IL76	**0.003**	**S 3.2**				
IL96	**0.001**					
JS31	**0.014**					
JS41	**0.020**					
JU52	**0.004**					
L101	**0.064**	**S 6.2**				
L188	**0.175**	**P 2.2**				
L410	**0.009**					
LR55	**0.398**	**S 5.1**				
MD11	**0.713**	**S 6.2**				
MD80	**3.096**	**S 5.3**				
MD90	**0.022**	**S 5.2**				
MU2	**0.003**					
MU30	**0.001**					
N262	**0.025**					
P68	**0.057**	**P 2.2**				
S601	**0.009**					
S61R	**0.009**	**H**				
S76	**0.003**	**H**				
SB20	**0.530**	**P 2.2**				
SF34	**0.264**	**P 2.1**				
SH33	**0.001**					
SH36	**0.004**					
SW4A	**0.350**	**P 2.1**				
T134	**0.004**	**≤ 34t S 1.0**	**>34t S 1.1**			
T154	**0.200**	**S 1.3**				
WW24	**0.001**					
YK40	**0.037**	**S 1.0**				
YK42	**0.003**	**S 5.3**				

3.4.3. Validation of the proposed noise emission data

An intensive study was carried out in Austria to validate the proposed noise emission data. Two figures from these studies are shown hereafter. In this study the L_A and SEL of all frequently used types of aircraft have been compared with both the INM data and the Swiss data. It was found that the data compare quite well. It is therefore considered suitable for use in EU Member States. For more details refer to Task 3-3-3 of Part B of this report.

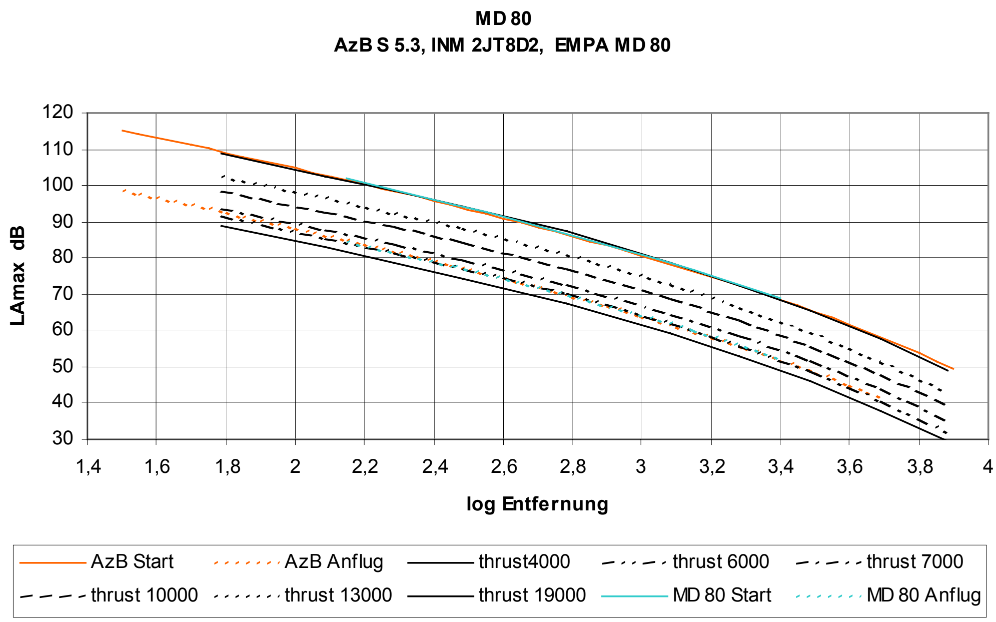

Figure 9 – Comparison of noise emission data for aircraft: MD80

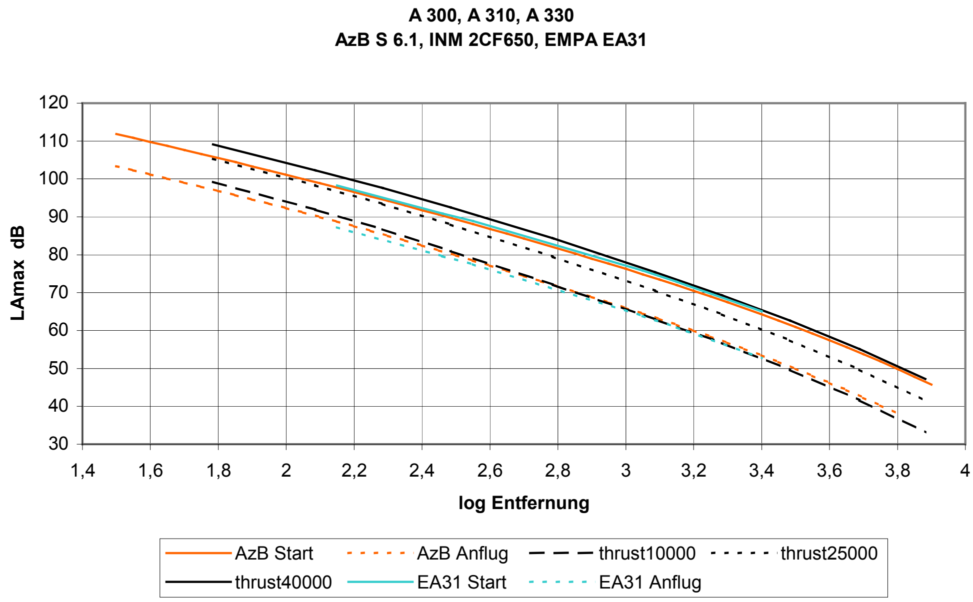

Figure 10 - Comparison of noise emission data for aircraft: A300, A310, A330

3.4.4. Alternate recommendation

As reported by Peter HULLAH during a meeting at EC DG Environment on 10th of October 2002, EUROCONTROL (in co-operation with international aircraft institutions and manufacturers) is currently busy setting up a new aircraft noise emission database for modelling purposes. The database should be publicly available in the future on the internet. If available on time, the data might be considered a valid alternative to the default proposal.

4. Guidelines on a basic software package

4.1. General considerations

4.1.1. Introduction

These guidelines will identify modules of a software package suitable for the calculation of noise contours for L_{den} and L_{night}.

A software for strategic noise mapping according to article 7 of the *Directive of the European Parliament and of the Council relating to the assessment and management of environmental noise* (hereafter END) shall comprise facilities for the following components:

- Site modelling;
- Source emission model;
- Calculation of the noise propagation;
- Mapping of information.

Each of these modules will be described in terms of technical specifications as stipulated in Article 7 “Strategic Noise Mapping”, in ANNEX I “Noise Indicators” and in ANNEX IV “Minimum requirements for Strategic Noise Mapping”.

These guidelines are not meant to be a blueprint for software development but a checklist of features and facilities to integrate into a suitable software package. The checklist can serve both potential manufacturers of software packages and potential users. It will help potential manufacturers to make basic software design and development decisions. It will help potential users to verify whether a commercial or in-house software is suitable for strategic noise mapping.

4.1.2. Guidelines on Data Input Facilities

A suitable software should feature at least the following data input facilities:

- keyboard input;
- on-screen drawing;
- interface to digitising tablet;
- import of digital data.

Input facilities shall cover the whole range from digitising and manual input of attributes to importing of existing digital data. The software must be able to handle both geo-referenced (as is the case of site geometry and attributes, site description) and non geo-referenced data (as is the case of boundary conditions). In addition to data influencing the noise propagation, additional geo-referenced data for both the mapping and the computation stage are required. Input of geo-referenced data must respect the scales of the original map-based information.

4.1.3. Guidelines on Data Output Facilities

The sound propagation calculation provides numerical results. The software must be able to provide the numerical results in graphical form, in tables and in digital form. Both the mapping and the computation part of the software share the same data presentation facilities. The graphical mapping part of the software requires graphical possibilities (at least 2D). All input data and calculated results must be geo-referenced.

A basic requirement stated in Article 9 of the END concerns the information to be provided to the public by Member States. According to the same article, "this information shall be clear, comprehensible and accessible"[34]. However, the public is not the only recipient of strategic noise maps which will have to be presented to technicians, administrators and political decision makers. The plethora of recipients is reflected by the wide range of graphical and numerical output facilities required to make a given software suitable for the task. Point 4 of Annex IV of the END lists the objectives which are to be served by strategic noise maps. The END clearly states in this article, that "Each of these applications requires a different type of strategic noise map".

The presentation can be manifold but should at least include:

- cartographic presentation of the site with and without overlaid result-data;
- tabular presentation of numeric data including co-ordinates of the calculated results;
- colour and grey-scale noise maps with associated colour scale, graduated X-Y axis and relative grid height.

The presentation of numeric result data shall satisfy the following: the Noise Mapping Software must be able to display, print-out and export into digital files all calculated noise levels and/or assessment levels. For both single reception point calculation and grid calculations (maps), the minimum requirements include:

- X, Y and Z co-ordinate of the reception point,
- the calculated L_{den} and L_{night} assessment level.
- The presentation of graphical results shall satisfy the following: coloured, textured, grey- or other scale noise maps[35] from calculated grids of reception points. The minimum requirements for the graphics are:
- graduated X and Y axis and relative grid height;
- presentation of the noise indicators in the form of noise contour plots (isophones);
- graduated colour scale;
- position of sources and obstacles and other relevant graphical information describing the site (i.e. the limits of the land-use areas/zones used in conflict maps);
- respect of the original map scale of all map-based geo-referenced input and output data.

A suitable software package must document single reception point calculations in a way that enables the user to verify the results.

[34] It must be noted here that information provided to the public must be clear and comprehensible and should be free of complex technical notations. In addition, the need to provide suitable information to disabled citizens is an implicit requirement of the EU legislation on equal treatment of citizens.

[35] see footnote 34

4.1.4. Guidelines on site modelling

4.1.4.1. Introduction

A scheme of the site is composed of both the geometrical objects found on the site and their specific acoustic and non-acoustic attributes. In addition to its geometrical properties and aforementioned attributes, all objects are geo-referenced. This includes the position and geometry of the noise sources. The result of the site modelling is a scheme. It is a central set of information in the noise prediction and mapping process.

The site modelling shall follow the rules as defined by the computation methods according to Article 6 and Annex II of the END and shall satisfy the needs for the presentation of the data as defined below.

4.1.4.2. Input data

The software provides suitable input dialogues to describe the source with all the input data required by the computation method.

4.1.4.3. Site geometry and description

Digitising the site geometry results in a 3D scheme of the site of interest. The scheme includes at least the following types of objects to describe the site:

- terrain level contour lines or altitude points to describe changes in the terrain level
- roads
- artificial obstacles: buildings and walls

An absolute z specifying the elevation of the actual terrain above sea level is assigned to each single terrain level contour line and altitude point. The suitable software package uses the information to calculate the digital terrain model of the site. Elevated parts of the terrain are obstacles to sound propagation and the suitable software package must be able to take care of them as such.

4.1.4.4. Source emission model

The source emission modelling shall be in accordance with the definitions and rules provided by the computation methods as defined in Article 6 and Annex II of the END.

4.1.5. Noise propagation model

Determination of the transfer function from source to receiver taking into account all effects on the propagation pathway imposed by:

- the site description given in the scheme, including geometry and attributes as defined above
- the boundary conditions for the calculation and the propagation conditions specified by the user.

The calculation of the transfer function shall be done with the computation method for road traffic noise as defined in Article 6 and Annex II of the END.

The calculation of the transfer function shall be combined with sound emission levels delivered by the sound emission model or by measurement. The result is post-processed in such a way that the value of a noise indicator as defined in Article 5 and Annex I of the END at one or several geo-referenced reception points or in a grid of reception points, is determined.

4.1.6. Mapping

The mapping component includes all possibilities to present the information related to outdoor sound levels, exceedance of limit values, noise exposure, number of affected people or economic data. The result of the mapping are either graphical or numerical output of the geo-referenced calculated results.

The output covers screen display, printed or plotted graphs, printed or plotted tables and digital files in graphics, text or binary formats. The minimum possibilities of output from mapping are:

- graphical presentation of the scheme as site maps;
- graphical presentation of the value of the noise indicators;
- graphical presentation of the value of noise indicators as difference maps;
- graphical presentation of the value of the noise indicators as conflict maps;
- graphical presentation of the effects of noise (number of annoyed people, number of sleep disturbed people) as noise exposure maps;
- numerical presentation of the above in tables;
- character-based presentation of the input data in lists.

The presentation shall satisfy the minimum requirements of Annex IV.

4.1.7. Quality Assurance

4.1.7.1. Accuracy of strategic noise maps

The accuracy of a strategic noise map depends on:

- The accuracy of the input data (site modelling, see 4.1.4).
- The accuracy of the emission data (source emission model, 3 and 4.1.4.4).
- The accuracy of the propagation calculation (see 2 and 4.1.5).

The accuracy of the calculation depends on:

- The distance between the computation methods and the physical laws of sound propagation.
- The quality of the implementation of the computation method in software.
- The effect of efficiency techniques on the calculation.
- The professional experience of the user in the use of both the computation method and the software.

It is considered that the quality of the interim computation method has been asserted by Working Group 3. The quality of national computation methods is asserted by the requirement to produce results equivalent to the results of the interim methods. A suitable software package for strategic noise mapping must provide a robust, coherent and reliable implementation of the interim or national computation method.

4.1.7.2. Quality of the noise mapping software

A suitable noise mapping software for strategic noise mapping must provide a reliable calculation kernel, i.e. the interim or national computation method must be properly implemented.

To assess the quality of the implementation of the interim or national computation methods in software, separate standardised test cases developed, documented and maintained by an independent body must be made available.
In the absence of standardised test cases for a given calculation method, a suitable software package must provide means to check the reproducibility of results, i.e. run test calculations on schemes of varying complexity to enable the user to compare results that are known to be correct. The general settings in the software that are used to reproduce the known results within a predefined small confidence range are called hereafter the reference settings.

4.1.7.3. Efficiency techniques

The calculation time rises with the complexity of the large scale projects. Reference settings may lead to unreasonable calculation times. A suitable software package will provide efficiency techniques that will speed up the calculation at the expense of accuracy. This is acceptable as long as the inaccuracy due to the use of efficiency techniques does not exceed the inevitable inaccuracy in the input data (both geometry and emission). A suitable software package will provide

- Statistical means to assess the inaccuracy introduced by efficiency techniques.
- Estimation techniques to predict calculation times for a given combination of efficiency techniques.

4.2. NMPB/XP S 31-133

4.2.1. Introduction

The present chapter gives Guidelines on a Basic Software Package for Calculation of Noise Contours for L_{den} and L_{night} for the interim computation method: "NMPB-Routes-96 (SETRA-CERTU-LCPC-CSTB)" referred to in "Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10 mai 1995, Arcticle 6" and in the French standard "XPS 31-133" and "Guide du bruit des transports terrestres, fascicule prévision des niveaux sonores, CETUR 1980".

4.2.2. Input data

The software provides suitable input dialogues to describe the source with at least the following input data. These are independent of the three assessment periods day, evening and night.

- road surface category
- slope (either user-specified or determined by the software from digital terrain model)
- total width of the road infrastructure
- longitudinal profile of the road

4.2.3. Source

4.2.3.1. General considerations

NMPB/XP S 31-133 defines the source with respect to geometrical aspects and sound power level. The implementation of the noise emission model is described in a separate chapter above.

The sound emission is described as the A-weighted octave band sound power per meter length.

NMPB provides a formula to transform overall A-weighted noise emission data from "Guide du Bruit" into an octave-band spectrum using the road traffic noise reference spectrum of EN 1793-3.

4.2.3.2. Source positioning and division into component sound sources

The height of the actual source line is 0,5 m above the upper edge of the road surface.

Actual source lines must be located on the centreline of lanes.

At least one of the three methods to divide the source line into component point sound sources must be implemented:

- equiangular subdivision (generally steps smaller or equal to 10^o),
- subdivision with a constant step independent of the actual position of the reception point (step length is less than half of the orthogonal distance between lane and reception points and rarely exceeds 20 m),
- variable subdivision as a function of the relative distance between the reception point and the source line.

It must be emphasised that a suitable software package will use the most accurate division into component point sources. Fixed step divisions can lead to both

- insufficient accuracy if the step size is selected on a reception that is too far from the source, and
- slow calculation times, if the same fixed step required for the nearest reception points is used for reception points that are far from the source.

The fixed step method can be used. However, the implementation must ensure that all propagation conditions between the source and the reception point are taken into account.

4.2.4. Site geometry and description

Depending on the actual programming of a suitable software package, a road is a line element that either corresponds to the fixed position of the source or to a reference line from which the software calculates the actual source position, or is a complex element that corresponds to the entire road infrastructure on which the software positions the source line(s). Depending on the choice of the programmer different input data is requested. It must be noted that NMPB/XP S 31-133 considers the road platform as reflecting for the purpose of propagation (this is not to be confused with surfacing correction for emission data!). It is thus necessary to provide a means to define the entire reflecting width of the platform.

Artificial obstacles are all obstacles to the propagation of sound other than the actual terrain. NMPB/XP S 31-133 takes into account both diffraction and reflection. For the latter, the software package must provide a means to assign an absorption coefficient to a reflecting obstacle. It must be noted that by default NMPB/XP S 31-133 calculates reflections on vertical obstacles. Calculation of reflections on other obstacles requires a 3D scanning algorithm.

4.2.5. XP S 31-133: Meteorological average conditions

4.2.5.1. Introduction

In order to take into account meteorological influences in calculating a long-term sound level, NMPB/XP S 31-133 calculates sound levels for two conventional propagation conditions, namely

favourable and homogeneous conditions.

The software package must make provisions to enter and manage either of the following[36]:

- lists of occurrences of favourable conditions in each directional sector for the three assessment periods day, evening and night
- overall fixed estimates for the three assessment periods day, evening and night.

4.2.5.2. occurrences of favourable conditions

The tables reproduced in XP S 31-133 may not be used as they are limited to two assessment periods day and night as defined in the French legislation. They should thus not be implemented for the purpose of strategic noise mapping.

[36] There is no requirement to handle meteorological data files. There is no harmonised file format available for all of Europe. In addition, it is the occurrences of favourable conditions rather than the actual meteorological data that is of interest for the computation. Finally, the instruction of Annex B of XPS 31-133:2001 is insufficient on its own to determine occurrences without ambiguity.

The user should, however, have the possibility to enter his own data determined for the site of interest in accordance with the aforementioned annexes. The software package must ensure that occurrences of favourable conditions are specified for all three assessment periods day, evening and night.

4.2.5.3. overall fixed estimates

Suggested overall fixed estimates for each of the three assessment periods are:

- 100 % of favourable occurrence for the night period,
- 50 % of favourable occurrence for the daytime period, and
- 75 % of favourable occurrence for the evening period.

The software package must allow for correction of these defaults as the END allows shortening of the evening period and consequently readjustment of the length of the day and the night.

4.2.6. Noise propagation computation

4.2.6.1. Introduction

The computation method is designed to be used with road traffic sources only. The propagation algorithm stays close to ISO9613-2 with modifications to account for road infrastructure specifics and enhanced meteorological correction (calculation in homogeneous conditions).

The propagation computation is frequency-dependent in the octave band range from 125 Hz to 4 kHz (mid-band frequencies).

4.2.6.2. Noise indicator

In summary, the noise indicators of the END are based on the equivalent continuous A-weighted sound pressure level, averaged over the year with respect to variations in both sound source activity and meteorological conditions influencing the sound propagation. This is, however, the same mathematical and physical basis for noise indicators as the one defined in NMPB/XP S 31-133.

The software should provide a means to enter the data compatible with the requirements defined in 2.1.2.

4.2.6.3. Height of reception points

For the purpose of strategic noise mapping, and here especially for the computation of L_{den} and L_{night}, the software package should impose in accordance with **END** the reception point height at

4 m above the ground[37].

L_{den} is derived from the three other indicators described in the END. The aforementioned receiver height is thus compulsory for all these indicators.

Note that the reception point height does not conflict with the requirement of respecting a minimum height of 2 m[38] expressed in **NMPB/XP S 31-133**.

[37] END, ANNEX I, 1. Definition of the Day-evening-night level L_{den} and 2. Definition of the night-time noise indicator

Caution: the French requirement of placing reception points at a distance of 2 m in front of a façade is not compatible with the requirements of END. The END simply requires to ignore reflections in proximity of a façade. The software package must make provisions to handle this requirement even in complex situations with several close-by walls.

4.2.6.4. Sound propagation

4.2.6.4.1. Introduction

The software package needs to calculate sound propagation in the octave bands with nominal midband frequencies in the range from 125 to 4000 Hz.

NMPB/XP S 31-133 calculates the long-term indicator.

The long term-level $L_{longterm}$ is then calculated by the following formula:

$$L_{longterm} = 10\,.\lg\left[p.10^{L_F/10} + (1-p).10^{L_H/10}\right]$$

where

L_F is the sound level calculated for favourable sound propagation conditions,

L_H is the sound level calculated for homogeneous sound propagation conditions, and

p is the long term occurrence of meteorological conditions favourable for the propagation of sound.

The sound level for favourable conditions is calculated for each octave band and for each path from one point source on the road to the receiver by

$$L_F = L_w - A_{div} - A_{atm} - A_{grd,F} - A_{dif,F}$$

The sound level for homogeneous conditions is calculated for each octave band and for each path from one point source on the road to the receiver by

$$L_H = L_w - A_{div} - A_{atm} - A_{grd,H} - A_{dif,H}$$

Attenuation due to geometrical divergence A_{div} and air absorption A_{atm} are the same in both formulas. The difference is in the attenuation due to ground effect $A_{grd,x}$ and in the attenuation due to diffraction $A_{dif,x}$: diffraction and ground effect are influenced by propagation conditions. For more details on these terms, please refer to the text below.

[38] XP S 31-133:2001, 1 Domaine d'application, p. 5

4.2.6.4.2. Geometrical divergence

The equation for geometrical divergence must be implemented in the software package.

4.2.6.4.3. Atmospheric absorption

The software package should allow the user to chose from the set of temperatures and relative humidity published in ISO 9613-1:1993. The software package must then implement the coefficients of ISO 9613-1:1993 in the NMPB.

4.2.6.4.4. Ground effect

The software package must implement the calculation of ground effect for two conditions: homogeneous and favourable. The attenuation for homogeneous conditions $A_{grd,H}$ is calculated taking into account the ground coefficient G. If G = 0 (reflecting ground) $A_{grd,H}$ = - 3 dB. The site relief on the propagation pathway is taken into account by means of an equivalent height calculated from actual terrain levels.

4.2.6.4.5. Diffraction

The software package must implement the calculation of ground effect for two conditions: homogeneous and favourable.

Caution: Ground effect is taken into account directly by the equations dealing with diffraction. Hence the requirement to neglect ground effect calculation in the presence of diffraction on an obstacle.

Terrain level changes are taken into account by means of an equivalent height.

Prior to calculating diffraction, the path length difference atop the obstacle is compared with $-\lambda/20$ (where: λ is the wave length at 500 Hz and thus $-\lambda/20$ = -0,034 m). Attenuation due to diffraction is not calculated, if the path length difference is found to be smaller than this value[39].

The software package should implement diffraction on vertical edges according to XP S 31-133[40].

4.2.6.4.6. Reflection

The software package should use image sources to take into account reflections on vertical obstacles.

A software package operating in 2D or 2½D has to check the criterion for a vertical obstacle: inclination of less than 15°.

A software package that takes into account other reflecting obstacles in addition to vertical obstacles has to operate in full 3D.

Obstacles with dimensions small compared to the wavelength are neglected.

The sound power level of the image source has to take into account the absorption coefficient of the reflecting surface.

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39 XP S 31-133:2001, 7.4.2 Calcul de la différence de marche, p.25, first sentence below Figure 12.

40 XP S 31-133:2001, 7.4.6 Cas particulier des diffractions sur arêtes verticales

4.3. SRM II

The present chapter[41] gives Guidelines on a Basic Software Package for Calculation of Noise Contours for L_{den} and L_{night} for the interim computation method: "Reken- en Meetvoorschrift Railverkeerslawaai '96, Ministerie Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 20 November 1996'".

4.3.1. Input data

The Dutch statutory calculation-scheme for Rail-traffic Noise requires a description of the situation in terms of:

- Co-ordinates, in a user defined rectangular co-ordinate system of:
    - tracks;
    - obstacles like buildings,
    - sound barriers;
    - observation point(s).
- Track type.
- Passing trains:
- Numbers and types of passing trains.
- Driving speeds of the trains.
- Braking actions.
- Sound absorbing surfaces:
- The fraction of the ground between track and observer that is sound absorbing.
- Other surfaces, like sound barriers.

4.3.1.1. Track type and density of rail joints

A suitable software package should allow at least for the 9 track types and the 4 rail joint densities defined in the original calculation method. Provision must be made for the user to add further tracks and rail joint densities to cope with national non Dutch tracks.

4.3.1.2. Vehicle specifications

A suitable software package should allow at least for the 10 train categories defined in the original calculation method. Provisions must be made for the user to add further train categories to cope with national non Dutch rolling stock.

- For each category:
    - Vehicle intensity (number of passing trains per hour) [1/h].
    - Driving speed (for trains that are passing at constant speed) [km/h].

[41] this chapter relies on an internal communication made available to WG 4 "Noise Mapping" in 2000: OUDE LANSINK, D.F./ VAN DER TOORN, J.D.: Input data for the Dutch-EU-calculation-scheme Rail-traffic Noise, TNO wegtransportmiddelen Adviesgroep Transport Emissies, 16 November 2000

  - Percentage of braking vehicles [-].
- Sound power levels of non-standard vehicles (not fitting within categories 1-7). The sound power levels in decibels re 1 pW, at track height and at 0,5 meter above railhead, for the octave bands with mid-band frequencies 63 – 8000 Hz.

4.3.2. Source

SRM II defines a line sound source. The sound emission is described as the octave band (mid-band frequencies 63 – 8000 Hz) sound power level L_E, in decibels, for up to 4 different source heights. If the characteristics of the track, of the rolling stock or of driving conditions depend on the position along the track, different straight track sections are defined by the positions of their outer points. The characteristics and conditions should be virtually homogeneous along a section. Track type and density of rail-joints are specified for each section.

4.3.3. Site geometry and description

4.3.3.1. Buildings

A suitable software makes provisions to enter the following data for a building:

- co-ordinates of the corners,
- Heights (including ridge height in case of a peaked roof) [m]
- Reflection factors or absorption coefficients of façades.

4.3.3.2. Sound barriers

A suitable software makes provisions to enter the following data for a barrier:

- Heights [m].
- Shape types: sharp or obtuse top (angle between 0°-70° or between 70°-165°).
- Reflection factors or absorption coefficients of barrier surface (standard or customised).

4.3.3.3. Ground

A suitable software makes provisions to enter the following data for a barrier:

- The fraction of sound absorbing ground surface between track and observer is specified [-] or hard and sound absorbing areas are specified separately by stating the character of each area (reflecting or absorbing) and the positions of the border lines.
- Heights of ground surfaces are specified [m].

4.3.3.4. Reception points

A suitable software package for strategic noise mapping will ensure that the reception point is located according to END **4 m above the ground[42].** In addition, the suitable software should prohibit the use of façade reflection for the purpose of strategic noise mapping.

[42] END, ANNEX I, 1. Definition of the Day-evening-night level L_{den} and 2. Definition of the night-time noise indicator

4.3.4. Sound propagation

The software package needs to calculate sound propagation in the octave bands with nominal midband frequencies in the range from 63 to 8000 Hz.

4.3.4.1. Computation

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

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

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

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

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

with L_E emission value per source type and octave band

ΔL_{GU} attenuation due to distance

ΔL_{OD} attenuation due to propagation

ΔL_{SW} screening effect, if present

ΔL_R attenuation due to reflections, if present

4.3.4.2. Number of sources

The emission value is expected to be determined for each section. The number of sources is defined as a function of the position of the reception point.

Summation over index n (from 1 through N) describes the (energetic) superposition of the separate contributions of the source type. Summations over the indices i (from 1 through 8) and j (from 1 through J) are the numeric integration over frequencies (octave bands) and the total opening angle of the reception point (sectors). In most cases, it is enough to appoint to each sector an opening angle of 5°. Sectors with an opening angle smaller than 5° may be needed when discontinuities occur in the geometry (corners of buildings, extremities of screens, …) and in the traffic data (changing of the emission number) in order to lay down limiting surfaces. Minimum sector angle is 0.5°.

The total opening angle of the reception point can have two values:

- 180° when L_{Aeq} is used to determine the sound pressure at a façade;
- 360° when L_{Aeq} is used to determine the sound pressure in an open space.

4.3.4.3. Attenuation by distance ΔL_{GU}

4.3.4.3.1. Data

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

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

4.3.4.3.2. Calculation

The calculation of ΔL_{GU} is as follows:

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

4.3.4.4. Attenuation by propagation ΔL_{OD}

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

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

where D_L air attenuation

D_B ground attenuation

C_M meteorological correction factor.

4.3.4.4.1. Air attenuation D_L

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

In order to calculate D_L the following data is necessary:

- r the distance between source and receiver, measured at the shortest connection line [m]

4.3.4.4.2. Ground attenuation D_B

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

4.3.4.4.3. Meteorological correction factor C_M

A suitable software will calculate C_M as outlined in 2.1.2.2 and 2.3.2 of this document.

4.3.4.5. Attenuation factor for screening ΔL_{SW}

If objects found inside a sector have at least a viewing angle that corresponds with the opening angle of the sector concerned and if it is assumed that these objects interfere with sound transmission, the attenuation factor ΔL_{SW} is taken into account, along with reduced ground attenuation. The formula for calculating the attenuation contributed by an object of variable shape contains two factors. The first factor describes the screening by an equivalent idealised barrier (a thin, vertical plane). The height of the equivalent barrier corresponds to the height of the obstructing object. The upper edge of the barrier corresponds to the highest edge of the obstacle. If it is possible to place the barrier in various positions, the position at which the highest attenuation occurs is chosen.

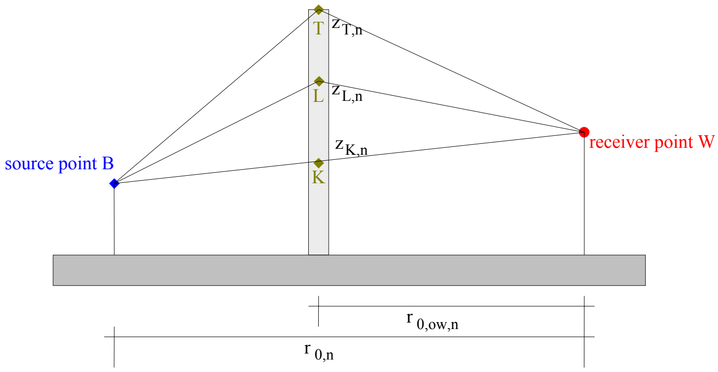

Figure 11 - Calculation with an idealised barrier: points K, T and L are shown

For the calculation, three points on the barrier are determined (see Figure 11)

- K point of intersection between the barrier and the direct line of sight (source to receiver)
- L point of intersection of the barrier and a curved sound ray in downwind conditions
- T upper edge of the barrier

The broken line BLW is a schematic representation of the curved sound ray under downwind conditions. The second factor is only of importance if the profile deviates from that of the idealised barrier. The profile is defined as the cross-section of the sector plane of the attenuating object. The attenuation of the object is equal to the attenuation of the equivalent barrier minus a correction factor C_p depending on the profile. If several attenuating objects are present in a sector, only the object that - in the absence of the others - would cause the most attenuation is taken into account.

4.3.4.6. Determining rail specific absorption

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

4.3.4.7. Reduction of levels as a result of reflections ΔL_R

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

N_{ref} number of reflections (see also § 1.3 of the interim computation method) between source point and reception point [-]

- type of reflecting object

4.4. ISO 9613-2

The present chapter gives Guidelines on a Basic Software Package for Calculation of Noise Contours for L_{den} and L_{night} for the interim computation method: “ISO 9613-2: ‘Acoustics — Abatement of sound propagation outdoors, Part 2: General method of calculation’”.

4.4.1. Input data

The software provides suitable input dialogues to describe at least three types of sound sources: point, line and area sound source.

- sound power level
- geometry of the source

4.4.2. Source

ISO 9613-2 defines the source with respect to geometrical aspects and sound power level. By default, ISO 9613-2 defines a propagation algorithm for a point source. Extended sound sources (line and area) must be subdivided into small segments each of which is represented by a sound source at its centre.

The sound emission is described as the octave band sound power level L_w, in decibels.

The standard provides a distance criterion to subdivide extended sources into component point sources. This distance criterion is accompanied by the requirement to cover all occurring propagation conditions by individual component point sound sources.

4.4.3. Site geometry and description

Figures 3 and 4 of ISO 9613-2 provide useful information on the use of site data in the propagation algorithm and should be studied carefully by the programmer. Special attention should be brought to the definition of mean height from actual terrain level information.

The software must provide means to enter all obstacles acting as screens. Diffraction for both barriers and buildings is described in ISO 9613-2. Figures 4, 5, 6 and 7 should be studied carefully.

4.4.4. Meteorological average conditions

From the outset ISO 9613-2 is designed to account for meteorological influences to calculate long-term sound levels. A suitable software must support this feature. The software package should be able to cope with the equation provided in 2.4.2 for both wind data measured on the site of interest and overall fixed estimates as defined in 2.1.2.2. The software package must allow for corrections for shortened evening period and consequently to readjust the length of the day and the night.

4.4.5. Noise propagation computation

The propagation computation is in octave bands with mid-band frequencies from 63 Hz to 8 kHz.

4.4.5.1. Noise indicator

In summary, the noise indicators of the END are based on the equivalent continuous A-weighted sound pressure level, averaged over the year with respect to variations in both sound source activity and meteorological conditions influencing the sound propagation. This is, however, the same mathematical and physical basis for noise indicators as the one defined in ISO 9613-2.

The software should provide means to enter the data compatible with the requirements defined in 2.1.2.

4.4.5.2. Height of reception points

For the purpose of strategic noise mapping, and here especially for the computation of L_{den} and L_{night}, the software package should impose in accordance with **END** the reception point height at

4 m above the ground[43].

L_{den} is the derived from the three other indicators described in the END. The aforementioned receiver height is thus compulsory for all these indicators.

4.4.5.3. Sound propagation

The software package needs to calculate sound propagation in the octave bands with nominal midband frequencies in the range from 63 to 8000 Hz.

The sound level at the reception point is calculated for each octave band and for each path from one (component) point source to the receiver by $L_{fT}(\mathrm{DW}) = L_W + D_c - A$

where $A = A_{\mathrm{div}} + A_{\mathrm{atm}} + A_{\mathrm{gr}} + A_{\mathrm{bar}} + A_{\mathrm{misc}}$.

The overall A-weighted down-wind sound pressure level at the reception point is the energetic sum of all partial contributions from all component point sources and all octave bands and is calculated by:

$$L_{AT}(\mathrm{DW}) = 10 \lg \left\{ \sum_{i=1}^{n} \left[\sum_{j=1}^{8} 10^{0,1\left[L_{fT}(ij) + A_f(j)\right]} \right] \right\}$$

[43] END, ANNEX I, 1. Definition of the Day-evening-night level L_{den} and 2. Definition of the night-time noise indicator

To transform this downwind level into a long-term level in accordance with ISO 1996-2:1987, the following must be observed:

$$L_{AT}(\mathrm{LT}) = L_{AT}(\mathrm{DW}) - C_{met}$$

Cmet is the meteorological correction and is calculated according to 2.4.2.

4.4.5.3.1. Geometrical divergence

The equation for geometrical divergence must be implemented in the software package.

4.4.5.3.2. Atmospheric absorption

The software package should allow the user to chose from the set of temperatures and relative humidity published in ISO 9613-1:1993. The software package must then implement the coefficients of ISO 9613-1:1993 in the ISO 9613-2.

4.4.5.3.3. Ground effect

The software package must implement the calculation of ground effect. for two conditions: homogeneous and favourable. The site relief on the propagation pathway is taken into account by means of a mean height calculated from actual terrain levels.

4.4.5.3.4. Diffraction

The software package must implement the calculation of ground effect. Caution: Ground effect is taken into account directly by the equations dealing with diffraction, hence, the requirement to neglect ground effect calculation in the presence of diffraction around an obstacle.

Terrain level changes are taken into account by means of a mean height.

A suitable software package will check the three conditions that an obstacle must meet to be considered a screening obstacle described in 7.4 of ISO 9613-2.

In addition to diffraction on horizontal edges, the software package should implement diffraction on vertical edges according to ISO 9613-2.

4.4.5.3.5. Reflection

The software package must use image sources to take into account reflections on vertical obstacles.

For each octave band, a suitable software must check for each octave band the three requirements of 7.5 of ISO 9613-2.

The sound power level of the image source has to take into account the absorption coefficient of the reflecting surface.

4.5. ECAC.CEAC Doc. 29

4.5.1. Introduction

The present chapter gives Guidelines on a Basic Software Package for Calculation of Noise Contours for L_{den} and L_{night} for the interim computation method: "ECAC.CEAC Doc. 29 'Report on Standard Method of Computing Noise Contours around Civil Airports', 1997".

4.5.2. Calculation Grid

Aircraft sound sources are positioned at a considerable elevation above the ground compared to the surface sound sources road, rail and industry. With the requirement to calculate noise indicators close to the ground (at 4 m above the ground), the angular dispersion due to the lateral projection must be accounted for. This is especially true if different reference co-ordinate systems are used at the airport and for the map of the surrounding area. If the aircraft sound contours cross national borders the problem will be of an even higher magnitude as differences in reference co-ordinate systems between EU M.S. are frequent. The use of unified co-ordinates to define source and receiver positions and the reference of the underlying map is compulsory. Several EU initiatives are under way to develop harmonised methods. It is recommended to obtain latest information from the INSPIRE initiative.

The choice of a coarse mesh can lead to significant errors in estimating the number of people exposed to sound levels in certain sound level bands as defined in the Annexes of the Directive.

4.5.3. Source description

4.5.3.1. Source Segmentation

In geometrical terms, the basic sound source is a straight line segment. The flight paths, whether straight or curved, are divided into straight line segments of a minimum length of 3m, each of which must have constant (or maximum allowed difference) thrust settings and constant (or maximum allowed difference) speeds. For each segment or - if necessary - its straight extension the slant distance (reception point to perpendicular closest point of approach PCPA) is determined; this defines the sound level to be read from the NPD-curve. The relevant speed and the relevant change in sound level for the thrust has to be read for the closest point of the segment (CPA) to the reception point.

The slant distance to the PCPA defines both the horizontal distance and the elevation angle for the calculation of the lateral attenuation.

A suitable software has to implement equations and boundary conditions outlined in 7.5 SEGMENTATION.

The sound exposure level is calculated for each segment and corrected for the finite length of the segment and its position relevant to the reception point before the contributions from all segments are added. The use of segmentation solves many of the computational problems as e.g. the effect of change in power setting and the effect of changed duration in connection with a turning flight track. The costs for high degree of segmentation are increased computer time compared to the ordinary method.

4.5.3.2. Velocity V and Change in Sound-Level Δ_ξ due to Change in Thrust

The sound levels are for groups of aircraft. They are given for take-off thrust and for landing thrust; to consider the thrust change after take-off or during approach sound level corrections are stated at certain heights H and certain speeds V. For each of the aircraft groups a default take-off-profile is given with speed V and height H versus distance σ on the ground track from start-off-roll point and for greater distances with dH/dσ. For each aircraft group, the quantities V, H and Δ_ξ are linearly interpolated.

4.5.3.3. Lateral Dispersion of Segments into 5 Corridor Paths

If the corridor width of the beginning or end of the segment is > 0 each segment will be substituted by 5 paths. The number of movements is split over all 5 paths using a dispersion function for the number of flight operations described in table 1 of chapter 10.1 (ECAC.CEAC Doc. 29).

4.5.4. Site Geometry and Description

A suitable software package must not provide provisions to enter either site geometry or terrain level as the computation does not take either of them into account.

4.5.5. Meteorological Average Conditions

The operation of take-off and landing runways on airports is subject to wind conditions. In general, aircraft take off into a head-wind. Changes in wind direction will thus have a direct impact on calculated sound contours.

4.5.6. Sound Propagation Computation

The sound level data are given as A-weighted sound level versus the logarithm of the slant distance. Additionally the lateral attenuation has to be taken into account.

4.5.6.1. Noise Indicator

In summary, the noise indicators of the END are based on the equivalent continuous A-weighted sound pressure level, averaged over the year with respect to variations in sound source activity (including the influence of meteorological conditions).

4.5.6.2. Height of Reception points

Since ECAC Doc. 29 does not take into account the terrain level and the source height is “on the ground” or “according to the given profile” the calculation is done for the reception point at airport level.

4.5.6.3. Calculation of the Sound Level L_A

The slant distance d between the reception point and the PCPA is determined. Using this distance the sound level L_A has to be looked up in the sound emission tables as a function of lg(d). Here, a logarithmic interpolation is used.

4.5.6.4. Calculation of Lateral Attenuation

According to chapter 7.4 (ECAC.CEAC Doc. 29) the lateral attenuation depending on the horizontal distance l and the elevation angle ß from the reception point to the PCPA is calculated.

4.5.6.5. Calculation of Take-off Roll Noise Behind the Take-off Point

According to chapter 8.2 (ECAC.CEAC Doc. 29) the directivity function Δ_L is determined. For both reception points in front of the take-off point – i.e. all points east of the take-off point for starts into the eastern direction – and approaches this value is 0.

4.5.6.6. Calculation of the Noise Duration

The duration-allowance Δ_A will be calculated for each aircraft group according to chapter 7.3 (ECAC.CEAC Doc. 29) with the relevant speed V and the relevant slant distance. The constants A and B have to be taken from the tables in annex 1.

4.5.6.7. Calculation of the Correction Term Δ_F for the Segment Length and Position

If the flight path is segmented a correction Δ_F has to be applied to correct for the finite length of the segment and its position relevant to the reception point (ECAC.CEAC Doc. 29, chapter 7.5). From the sound energy fraction $F_{1,2}$ calculated for the segment with the end points P_1 and P_2 the correction term is calculated by

$$\Delta_F = 10 \cdot \lg(F_{1,2})$$

4.5.6.8. Calculation of the Maximum Sound Level $L_{A,max}$ for Calculation of SEL for a Segment

The maximum sound level $L_{A,max}$ will be calculated for each aircraft group in each corridor path of each segment of each flight track as follows:

$$L_{A,max} = L_A - \Lambda(\beta,l) + \Delta_L + \Delta\xi$$

where

$\Lambda(\beta,l)$: lateral attenuation $\Lambda(\beta,l)$has to be set G(ℓ) if the aircraft is on the ground

Δ_L : directivity function for the region behind the start-of-roll

$\Delta\xi$: change in sound level due to change in thrust.

4.5.6.9. Calculation of the Sound Exposure Level $SEL_{i,j,k,m}$ and $SEL_{i,j}$

For each component (flight track i, aircraft group j, corridor path k, segment m) the sound exposure level $SEL_{i,j,k,m}$ is calculated as follows:

$$SEL_{i,j,k,m} = L_{A,max,\, i,j,k,m} + \Delta_{A,i,j,k,m} + \Delta_{F,i,j,k,m}$$

where

Δ_A duration allowance

Δ_F correction term for the finite length and the position of the segment

From this the sound exposure level for one flight track i with the movement of one aircraft of group j is calculated by:

$$SEL_{i,j} = \sum_{k,m} SEL_{i,j,k,m}$$

4.5.6.9.1. Calculation of the Noise Indicators L_{den} und L_n

L_{den} and L_n will be calculated according to chapter 9 (ECAC.CEAC Doc. 29) using the $SEL_{i,j}$ values for each aircraft group j and for each flight path i respecting the number of flight operations N for daytime, evening and night time:

$$L_{den} = 10 \cdot \lg\left(\frac{\tau_0}{T_{den}} \sum_{i,j} (N_{d,i,j} + 3{,}16 \cdot N_{e,i,j} + 10 \cdot N_{n,i,j}) \cdot 10^{SEL_{i,j}/10}\right)$$

$$L_{night} = 10 \cdot \lg\left(\frac{\tau_0}{T_n} \sum_{i,j} N_{n,i,j} \cdot 10^{SEL_{i,j}/10}\right)$$

where

T_{den} duration of day + evening + night (24h = 86400s)

T_n duration of night (8h = 28800s)

N_d, N_e, N_n are the number of movements during one day (12h), one evening (4h) and one night (8h), respectively. The number of movements depends on the flight path and the aircraft group.

The above numbers for duration of day, evening and night are default values and may be altered by the M.S. (for all sources in the same way) according to END.

5. Guidance on the application

5.1. NMPB/XP S 31-133

5.1.1. Introduction

The method for calculating road traffic noise according to XP S 31-133, as illustrated by the flow chart on the next page, may be divided into two parts: **noise emission** and **noise propagation**. This chapter is primarily focused on determining sound emissions in practice and seeking to answer any questions users may ask.

5.1.2. Overview of the method

The French calculation method can be divided into two steps: road traffic sound emission modelling and noise propagation. The dotted red line marks this separation in Figure 12, a flow chart summarising the method. Main tasks are in yellow rounded boxes and secondary tasks are in blue rounded boxes. Input information is in green trapeziums.

Each of the operations involving sound emissions are shown below in the form of tables featuring the following information:

- General formulas with a background colour equal to one of the rounded boxes;
- Formulation, definitions and meanings of the parameters;
- References to the value of the parameters (proposal, advice or comments).

5.1.3. Division by uniform segments and periods of time

In order for a road to be modelled, it first of all has to be divided into uniform segments in the light of the traffic characteristics. This does not mean the characteristics are constant but only minor variations are reported with the same segment throughout the day. Consequently, a road, with an intersegment and traffic lights will be divided into four specific segments:

- Upstream from the traffic lights, a segment where the speed is constant,
- Approaching the traffic lights, a segment where vehicles are decelerating,
- Leaving the traffic lights, a segment where vehicles are accelerating,
- Downstream from traffic lights, a segment where the speed is constant once more.

This example is considered in greater detail later on in the chapter.

For each of the segments, the traffic characteristics have to be determined for at least one of the three reference periods (day, evening, night). If the characteristics vary too much during one or more of these periods, there has to be a division into elementary periods. Consequently, in the case of a road that does not feature any obstacles and where the traffic is concentrated between 7 am and 9 am and between 5 pm and 7 pm (therefore during the daytime), with a change in the flow type (from fluid to pulsed), the 5 periods to take into consideration are: day – 7 am to 9 am, day – 9 am to 5 pm, day – 5 pm to 7 pm, evening and night. Should the variation apply solely to the number of vehicles passing in transit on the segment under review, there is no need for a division into elementary periods and the total number of vehicles will be taken into consideration.

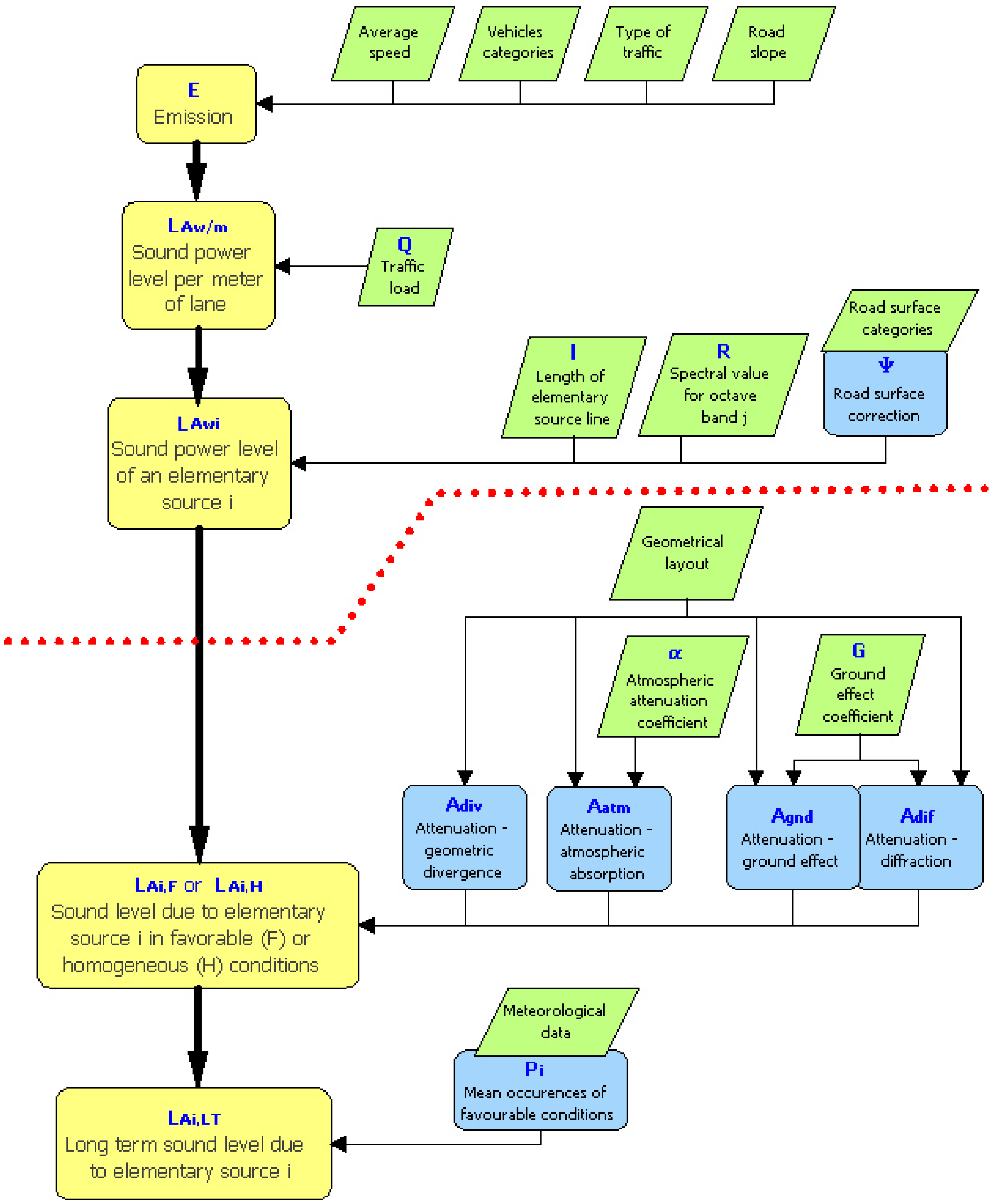

Figure 12 – Flow chart: Overview of the French calculation method XP S 31-133

5.1.4. E : Emission

The traffic emission must be determined at the very least for each reference period (day, evening and night), based on a typical year's average traffic characteristics.

- If average traffic characteristics are **constant** during these periods, the emission is calculated according to the average traffic conditions.
- If the traffic characteristics **fluctuate** during these periods, a finer time interval with the same traffic characteristics (i.e. same type of traffic, same traffic composition and negligible speed difference in regard to the required precision) must be applied. For each of these time periods, the sound emission is calculated according to the general method. In this case, the average noise power level is determined after the road surface corrections are applied.

Table 29 – Tabular summary of Guide du bruit parameters

Emission	**E**	**Determined according to nomogram 4.2 from "Guide du bruit" or with the proposed formula below (formula 1). This shows the emission rated per vehicle.**	
Vehicles category	**lv**	**Light vehicles**	**Loaded weight < 3,5T**
	hv	**Heavy vehicles**	**Loaded weight $\geq$ 3,5T**
Speed		**lv : [20-130 km/h]**	**Determined by measurements or estimated from speed limits and driver behaviour. The latter proposal is maybe the easiest and most convenient one.**
		hv: [20-100 km/h]	
Road slope		**Down**	**Road gradient > 2% downward**
		Up	**Road gradient > 2% upward**
		Flat	**Road gradient $\leq$ 2%**
Type of Traffic		**Fluid continuous**	**- Motorway - Interurban road - Urban expressway (outside rush hours) - Major roads in urban environment - …**
		Pulsed continuous	**- Urban city-centre roads - Major roads close to saturation - Dispatching or connecting roads with numerous crossings, car parks, pedestrian crossings, junctions to dwellings - …**
		Pulsed accelerated	**- Expressway after a crossing - Motorway entrance - Tollbooth - …**
		Pulsed decelerated	**- Expressway before a crossing - Motorway exit - Approach of tollbooth - …**

The following formula may be deduced from the calculation chart number 4.2 from "Guide du bruit", where parameters E_0 and a are shown in the tables below in accordance with the traffic characteristics and where v_0 = 20 km/h. The column $\Delta_{10\ km/h}$ shows the noise emission variation for <u>one vehicle</u> with a change of speed of 10 km/h.

$$E = E_0 + a \lg\left(\frac{v}{v_0}\right) \qquad (1)$$

Table 30 – Parameters to calculate Guide du Bruit road traffic noise emission data for light vehicles

Light vehicles									
	Slope	v	E_0	a		Slope	v	E_0	a
Continuous fluid	Flat or Down	v < 44	29.4	0	Non-differentiated pulsed	Flat or Down	v < 40	34.0	- 9.3
		v / 44	22.0	21.6			40 ≤ v < 53	31.2	0
							v / 53	22.0	21.6
	Up	v < 43	37.0	- 10.0		Up	v < 43	37.0	- 10.0
		43 ≤ v < 80	32.1	4.8			43 ≤ v < 80	32.1	4.8
		v / 80	22.0	21.6			v / 80	22.0	21.6
Pulsed Accelerated	Flat	v < 50	37.0	- 10.0	Pulsed Decelerated	Flat	v < 60	29.4	0
		50 ≤ v < 64	33.0	0			60 ≤ v < 100	13.0	34.3
		v / 64	22.0	21.6			v / 100	22.0	21.6
	Up	v < 32	37.0	- 10.0		Up	v < 40	34.0	- 9.3
		v / 32	34.0	5.2			40 ≤ v < 53	31.2	0
	Down	v < 40	34.0	- 9.3			v / 53	22.0	21.6
		40 ≤ v < 53	31.2	0		Down	v < 60	27.4	0
		v / 53	22.0	21.6			v / 60	11.3	33.8

Table 31 - Parameters to calculate Guide du Bruit road traffic noise emission data for heavy vehicles

Heavy vehicles									
	Slope	v	E_0	a		Slope	v	E_0	a
Continuous fluid	Flat or Down	v < 51	47.0	-10.3	Non-differentiated pulsed	Flat or Down	v < 51	47.0	-10.3
		51 ≤ v < 70	42.8	0			51 ≤ v < 70	42.8	0
		v / 70	32.3	19.4			v / 70	32.3	19.4
	Up	v < 63	48.0	-10.4		Up	v < 63	48.0	-10.4
		63 ≤ v < 70	42.8	0			63 ≤ v < 70	42.8	0
		v / 70	32.3	19.4			v / 70	32.3	19.4
Pulsed Accelerated	Flat or Down	v < 51	47.0	-10.3	Pulsed Decelerated	Flat	v < 65	36.0	3.9
		51 ≤ v < 70	42.8	0			v / 65	16.7	41.7
		v / 70	32.3	19.4		Up	v < 65	41.0	0
	Up	v < 63	48.0	-10.4			v / 65	27.9	25.7
		63 ≤ v < 70	42.8	0		Down	v < 51	47.0	-10.3
		v / 70	32.3	19.4			51 ≤ v < 70	42.8	0
							v / 70	32.3	19.4

5.1.5. $L_{Aw/m}$: Sound power level per meter of lane

Table 32 - $L_{Aw/m}$: Sound power level per meter of lane

Sound power level per meter of lane	$L_{Aw/m} = E_{lv} + 10\lg(Q_{lv}) + E_{hv} + 10\lg(Q_{hv})$
Traffic Load Q	Number of vehicles (lv and hv) during the period under consideration (reference period or elementary period in case of varying traffic characteristics)

5.1.6. $L_{Aw/m,\Psi}$: Average sound power level per meter of lane, corrected with the road surface

Parameter Ψ, the road surfacing correction, is the last one in the calculation method that may depend on vehicle speed, and therefore traffic conditions. The average sound power level may be determined at this stage.

Table 33 – Calculation of $L_{AW/m}$

Average sound power level per meter of lane, corrected in the light of the road surface – Variable traffic conditions during the reference period (k > 1)		$L_{Aw/m,\Psi} = 10\lg\sum_k 10^{\frac{(L_{Aw/m,k}+\Psi)}{10}} \cdot \frac{h_k}{h_p}$
Sound power level per meter of lane, corrected in the light of the road surface – Same traffic conditions during the reference period		$L_{Aw/m,\Psi} = L_{Aw/m} + \Psi$
Correction for road surface	Ψ	see **Table 11 – Proposed road surface correction scheme**
Length of the elementary period	h_k	**Length of the elementary period under consideration, expressed in hours**
Length of the reference period	h_p	**Length of the reference period under consideration (day, evening or night), expressed in hours**

5.1.7. L_{Awi} : Sound power level of elementary source i

As a reminder, the elementary sources i originated from dividing each segment into point sources i for the purposes of the calculation.

Table 34 – Sound power level of elementary source i

Sound power level of an elementary source i in a given octave band j		$L_{Awi} = L_{Aw/m,\Psi} + 20 + 10\lg(l_i) + R(j)$							
Length of elementary source line	**Li**	**Length of the elementary source line resulting from the segmentation used for the calculation**							
Spectral value for octave band j	**R(j)**	**j**	**1**	**2**	**3**	**4**	**5**	**6**	**Normalised A-weighted octave band traffic noise spectrum calculated from third octave spectrum of EN 1793-3**
		Octave band (Hz)	**125**	**250**	**500**	**1000**	**2000**	**4000**	
		Value of R(j) in dB(A)	**-14.5**	**-10.2**	**-7.2**	**-3.9**	**-6.4**	**-11.4**	

5.1.8. Preliminary remarks on the noise propagation model

- The hands-on examples assume a professional (commercially available) software package for sound propagation calculations.
- The calculation will be carried out according to the requirements of the *Directive of the European Parliament and of the Council relating to the assessment and management of environmental noise* (hereafter called “END”).
- The hands-on examples assume the use of the recommended *Interim Method for Road Traffic Noise* (*IM-RT*: merge of *NMPB* and *Guide de Bruit*).
- The explanatory pictures are not to scale.

5.1.9. Hands-On Examples

5.1.9.1. Example 1: Preparation of calculation

5.1.9.1.1. Introduction

The first example provides the basic information and describes preparatory steps required for all examples.

5.1.9.1.2. Indicators

The noise indicators according to the END are:

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

An additional indicator is defined for strategic noise mapping. It is calculated from the other three indicators to represent the whole 24 hours period (see END Annex I).

L_{den} day-evening-night level

According to the END at least L_{den} and L_{night} have to be provided.

5.1.9.1.3. Time periods

According to the END the computations are made for the time periods "day", "evening" and "night". The start and the end of those periods can vary from country to country. If there are no national regulations, the following values (see END Annex I) have to be applied:

Table 35 - Time periods according to END

Time period	Duration	
day	12 hours	7am – 7pm
evening	4 hours	7pm – 11pm
night	8 hours	11pm – 7am

Advice: It is possible that national regulations will shorten the evening period by one or two hours. These hours may be added to the day or night period. Please, check your national regulations!

5.1.9.1.4. Attenuation due to ground effect (G)

For calculations according to the IM-RT it is necessary to know the attenuation by ground (G) for the whole area of sound propagation. Most of the software packages use a default value for G, which will apply to all areas without explicitly defined G-values. In the IM-RT are defined G values shown in Table 36.

Table 36 - Ground surface types

Ground surface type	G
absorbing ground (grassland, prairie, woodland, ballast, etc.)	1
reflecting ground (road surfacing, concrete, etc.)	0

If the ground surface type differs from the values mentioned above, G may be set to values between 0 and 1. In cases of strategic noise mapping according to the END the following G-values are suggested:

Table 37 - Proposed values of G

Area to be calculated	Suggested G
countryside (only few buildings)	1
residential areas (one-family houses, semi-detached houses and a lot of green)	0,5
urban areas (blocs with little green)	0

5.1.9.1.5. Atmospheric conditions

The atmospheric conditions according to the IM-RT are defined for France with a humidity of 70 % and an average temperature of 15°C. From these values, which can be different from country to country, are determined the atmospheric-absorption attenuation coefficients α (see ISO 9613-1, Table 1).

Software packages usually offer the possibility to change the values for humidity and temperature. If they do not, it could be possible to change the atmospheric-absorption attenuation coefficients α directly.

The following table shows the original values of the IM-RT for France for the conditions mentioned above.

Table 38 - Atmospheric-absorption attenuation coefficient α for each octave band

Nominal midband frequency (in Hz)	125	250	500	1000	2000	4000
α (in dB/km)	0.38	1.13	2.36	4.08	8.75	26.4

5.1.9.1.6. Meteorology

The sound propagation according to the IM-RT has to be calculated separately for homogeneous and for favourable atmospheric conditions.

The probability of occurrence of these conditions can vary between sites of interest. The average yearly probabilities of occurrences for discrete wind directions (usually in 20° steps) are required. The final long-term sound levels are obtained by adding and weighting the partial sound levels in both conditions.

For the most areas detailed meteorological data is not available. In this cases the following values are suggested to use for every direction distinguished after time periods:

Table 39 – Proposed default values for occurrences of atmospheric conditions

Time period	Probability of occurrence during the year in average
day	50% favourable atmospheric conditions
evening	75% favourable atmospheric conditions
night	100% favourable atmospheric conditions

Advice: If detailed meteorological data is available it is strongly recommended to use it. For this case the correct adjustment to the north is essential.

Advice: If you use detailed meteorological data a wrong adjusted map can have a huge impact on the results. This is why, for some software packages it is impossible to start calculations without the above mentioned adjustment.

5.1.9.2. Example 2: Road with free flowing traffic

5.1.9.2.1. Introduction

This example is based on a road with free traffic flow (e.g. a motorway) affecting a building. The road has two lanes with a width of 4 m and a length of 1 km. The front of the building is positioned 20 m from the centreline of the road.

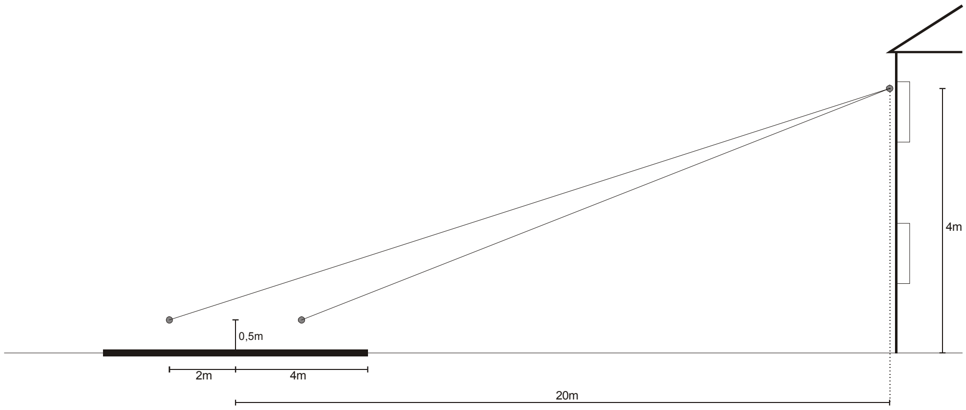

Figure 13 - Road with free flowing traffic - cross-sectional view

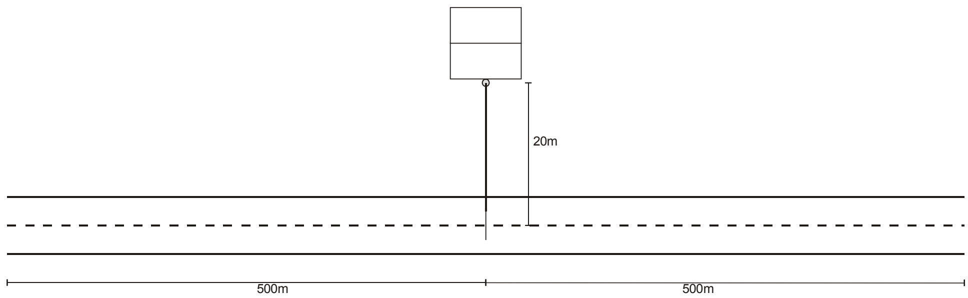

Figure 14 - Road with free flowing traffic - ground plan

5.1.9.2.2. Traffic lanes

For calculation, the software package has to know the exact position (in x-, y- and z-coordinates) of each traffic lane. Different software packages can show differences in how to handle this.

However, the sound source has always to be positioned 0,5 m above the surface of the road in the middle of the lane.

Advice: Usually software package are positioning the sound sources automatically (e.g. when the axis of the road is given).

5.1.9.2.3. Road surfaces

See 3.1.5.3 for a road surface correction scheme.

Advice: Use the possibility to produce your own national road surface correction factors!

5.1.9.2.4. Traffic load (Q)

The traffic load is usually given as the number of vehicles for the whole road. Most software packages distribute the traffic load equally to all traffic lanes. Some software packages offer the option to input the traffic density per lane. In others this information is mandatory.

However, values must distinguish between

- light and heavy vehicles (heavy vehicles ≥ 3.5 t net load) and
- time periods (day, evening and night).

Advice: Traffic load is usually provided in vehicles per hour (in this case speeds have to be input in km/h). In addition to this the IM-RT allows calculation with vehicles per second (in this case speeds have to be input in m/s).

5.1.9.2.5. Speed (V)

For reasons of simplicity, the parameter "vehicle speed" is used in this method for the whole average speed range (from 20 to 120 km/h) for both light and heavy vehicles (≥ 3.5 t net load).

All average speeds determined with either of these methods that turn out to be below 20 km/h are set to 20 km/h.

5.1.9.2.6. Reception point

The IM-RT is valid for reception point heights ≥ 2 m above the ground. The END stipulates a reception point height of 4 m (± 0,2 m) above the ground for strategic noise maps (see Annex I par. 1).

If reception points are calculated for a building (e.g. to represent the most exposed façade) reflections from this building are <u>not</u> taken into account.

5.1.9.3. Example 3: Noise barriers

5.1.9.3.1. Introduction

In this example noise barriers are situated on both sides to the road. The left one is sound reflecting.

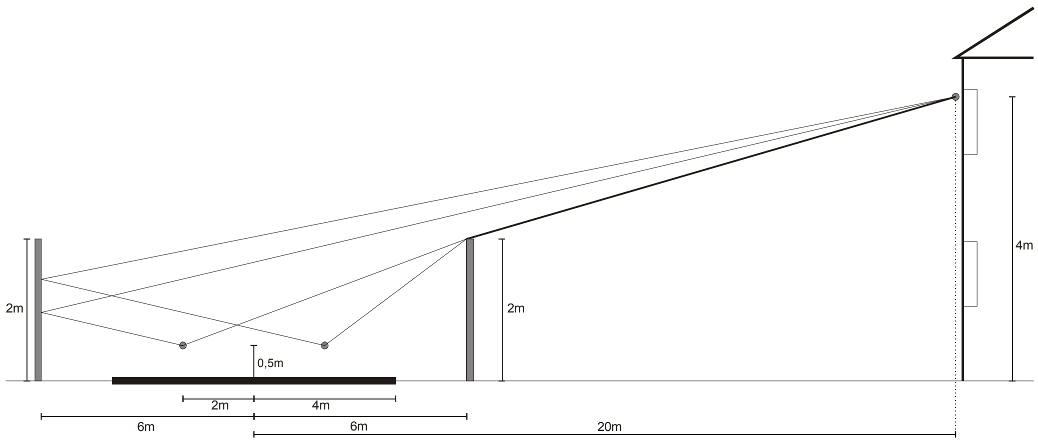

Figure 15 - Noise barriers – cross-sectional view

5.1.9.3.2. Reflection and absorption

In general, if sound is reflected by an obstacle some sound energy is absorbed. The sound absorbing character of a barrier or other obstacle is described by the sound absorption coefficient α_r.

In case sound absorption coefficients are not available it is suggested to use one of the following:

Table 40 - Suggestion for sound absorption coefficients α_r; based on table 7 of the German "Richtlinien für den Lärmschutz an Straßen – Ausgabe 1990 – RLS-90"

Material	Suggested α_r
completely reflecting wall	**0,0**
plane wall, reflecting noise barrier	**0,2**
structured wall (e.g. building with balconies)	**0,4**
absorbing wall or noise barrier	**0,6**
highly absorbing wall or noise barrier	**0,8**

<u>Advice:</u> Buildings can also reflect sound. So for buildings sound absorption coefficients have to be determined too.

5.1.9.4. Example 4: Road in a cutting

The road is positioned in a cutting. This example requires topographical data.

In principle this is a mixture of Examples 2 and 3. The only difference is that the geometry is a little bit more complicated than in the previous examples.

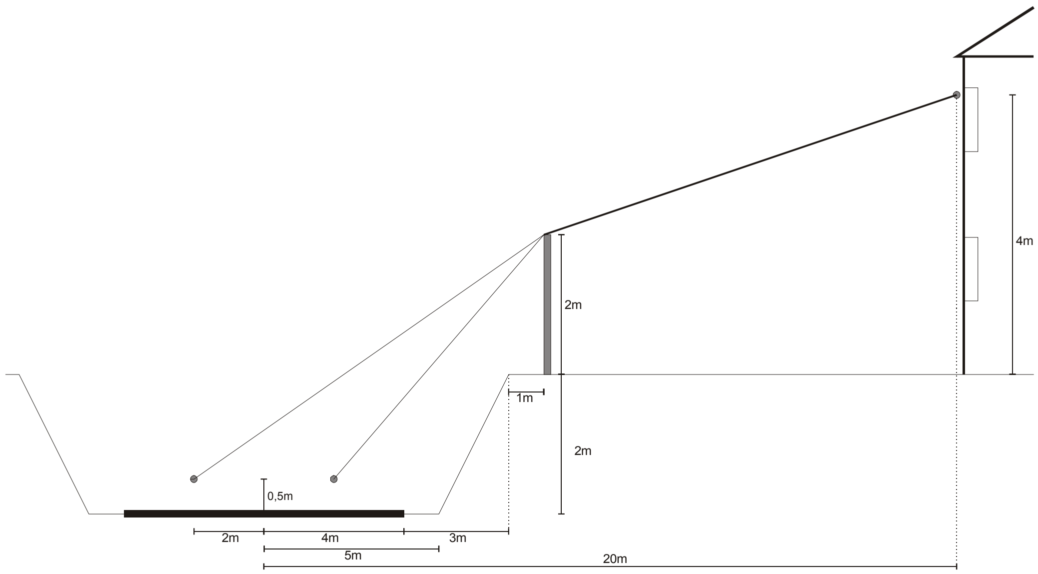

Figure 16 - Road in a cutting – cross-sectional view

<u>Advice:</u> Situations like these have to be dealt with very carefully using geometrical data. Accurate input of the coordinates of all elements is essential, otherwise computations could be highly erroneous.

5.1.9.5. Example 5: Road on an embankment

5.1.9.5.1. Introduction

The road is situated on an embankment with a slope.

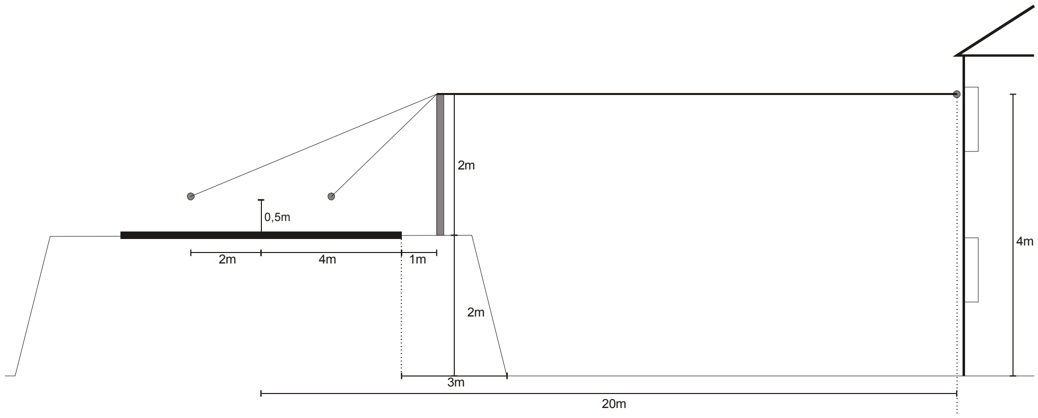

Figure 17 - Road on an embankment - cross-sectional view

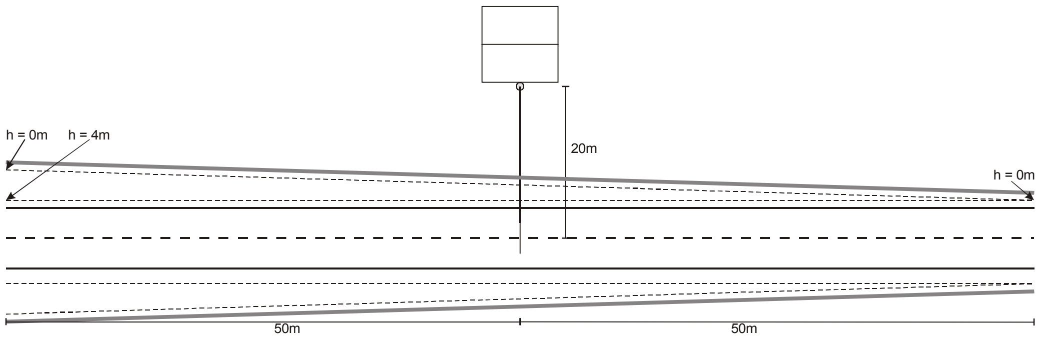

Figure 18 - Road on an embankment - ground plan (compared with the previous examples the length of the road under consideration is reduced to 100 m)

5.1.9.5.2. Gradients

The IM-RT distinguishes between three longitudinal profiles:

- horizontal carriageway (- 2% ≤ gradient ≤ 2%)
- rising carriageway (gradient > 2%)
- falling carriageway (gradient < - 2%)

In this example the road is situated on an ascending embankment (gradient = 4%). It is necessary to take into account how the software package deals with gradients.

In the best case the software package calculates the gradient based on the topographical model automatically. But there are also software packages which require the gradient explicitly and whether it is "falling" or "rising".

5.1.9.6. Example 6: Ground effects

5.1.9.6.1. Introduction

An extensive asphalt area is situated between road (sound source) and reception point.

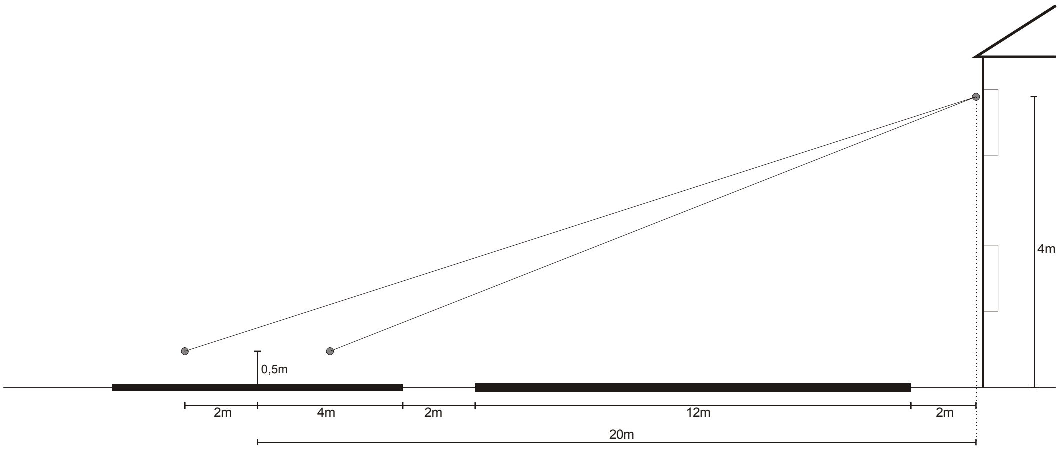

Figure 19 - Ground effects – cross-sectional view

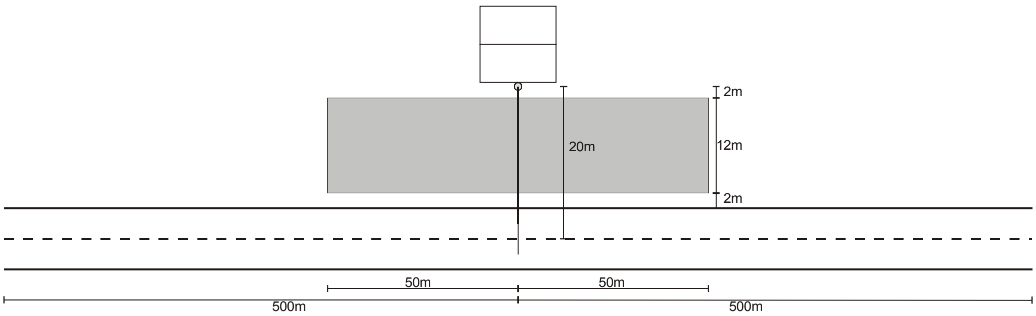

Figure 20 - Ground effects - ground plan

5.1.9.6.2. Attenuation by ground (G)

If a larger area of the sound propagation path is covered with a surface different from the default ground surface (e.g. a parking area in the countryside or a park in an urban area) this has to be taken into account. Suggested values for the attenuation by ground can be found in Table 36: Ground surface types on page 102.

A road as a sound source is always assumed as "reflecting" (G = 0). But, if there are any other roads on the sound propagation path, it would depend on the software package whether these other roads are considered "reflecting" automatically.

It may be possible to switch this handling in the settings of the software package.

<u>Advice:</u> Please check the manual of your software package!

5.1.9.7. Example 7: Crossroads

5.1.9.7.1. Introduction

In this situation we will look at crossroads with special attention to the traffic flow.

5.1.9.7.2. Traffic flow

The IM-RT distinguishes between 4 flow types:

- fluid continuous … means: steady traffic flow, constant speed (e.g. on motorways and on roads connecting cities without traffic lights)
- pulsed continuous … means: vehicles are driving in groups, constant speed (e.g. on urban roads with traffic lights, between crossroads, but not too close to traffic lights)
- pulsed accelerated … means: vehicles are driving in groups, vehicles are accelerating (e.g. moving away from traffic lights)
- pulsed decelerated ... means: vehicles are driving in groups, vehicles are decelerating (e.g. approaching traffic lights)

According to Guide du Bruit 1980 [20] the V50 speed should be used. If the data is available is available or can be produced it should be used. In all other cases the maximum allowed speed should be used for each road segment. A new road segment must be defined whenever the speed (either V50 or V_{max}) changes. The four traffic flow types are used as a correction for the lower speed range (lower than 60 to 70 km/h)[44] only. All speeds below 20 km/h are set to 20 km/h.

For strategic noise mapping, the use of “continuous flow” for all roads except road junctions with traffic lights where the simple method outlined in “Guidance on the application” should be used to determine “pulsed accelerated” and “pulsed decelerated” flows is considered sufficiently accurate.

If the software package does not support variations in traffic flows in proximity to crossroads, these have to be determined for every street (and every lane of the street). In this case the lanes have to be divided into segments according to the flow types.

When determining the length of the segments (especially those with accelerating and decelerating vehicles) it must be noted that r_a and r_d depend on the vehicle speed (see Figure 21).

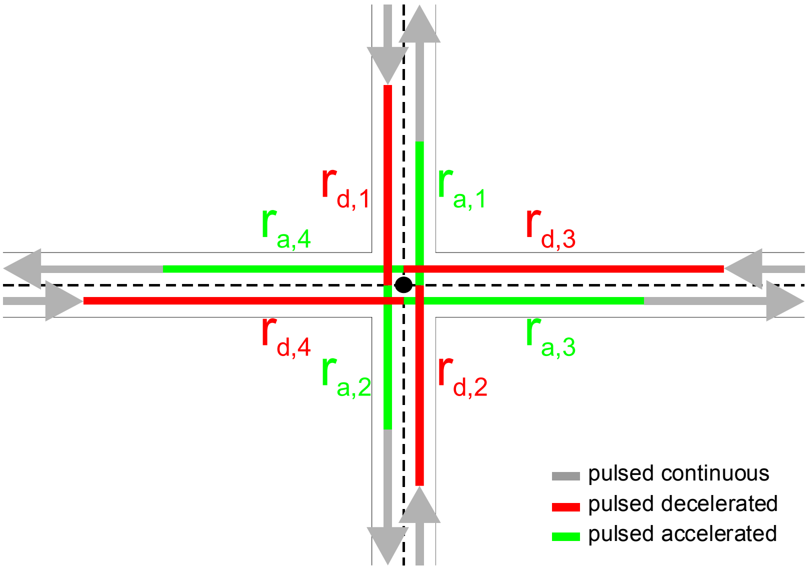

Figure 21 - Crossroads - ground plan (for right hand side traffic)

[44] the correction is applied only in the specified low speed range. Figure 5 - Nomogram 2 shows thus some situations where the upper speed limit is within the range of 60-70 km/h

5.1.9.7.3. Proposal for an automatic handling of traffic flows near crossings

A modern software package should be able to provide assistance on the input of traffic flows types. If no information concerning traffic flows is available the following rule of thumb (see Table 41) for the segment length can be applied:

Table 41-Suggested segment length for traffic flow types around crossroads

Traffic flow type	Suggested segment length
accelerated	$r_a = V_{max} * 7$ s
decelerated	$r_d = V_{max} * 11$ s

where:

V_{max} is in m/s

s is seconds

The values 7 an 11 are suggestions. They can be adapted by the user to suit his needs.

For a Vmax of 50 km/h, the above rule of thumb defines the following segment lengths:

for accelerated flow: 97.22 m (can be rounded to 100 m), and

for decelerated flow: 152.77 m (can be rounded to 150 m).

6. SRM II

6.1.1. Guidance on the application of the propagation model

6.1.1.1. Modelling the situation

6.1.1.1.1. Source Lines

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

6.1.1.1.2. Composition of the ground

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

6.1.1.1.3. Ground Height Differences

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

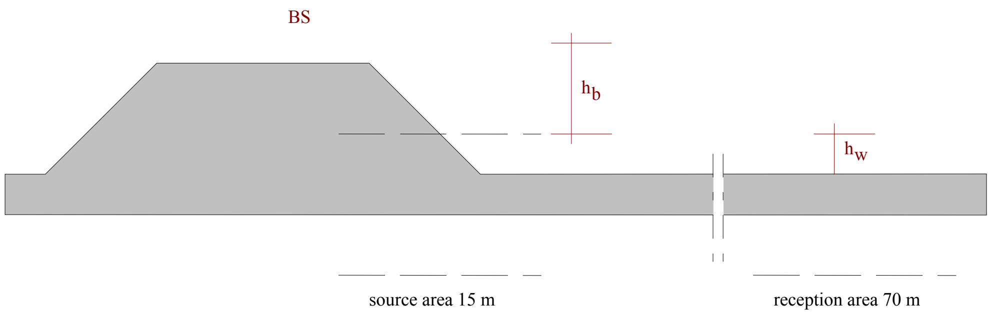

Figure 22 - Height in relation to the average terrain level. As a result of the raised tracks the average terrain level is situated in the source area slightly above the upper edge of the terrain, near the embankment.

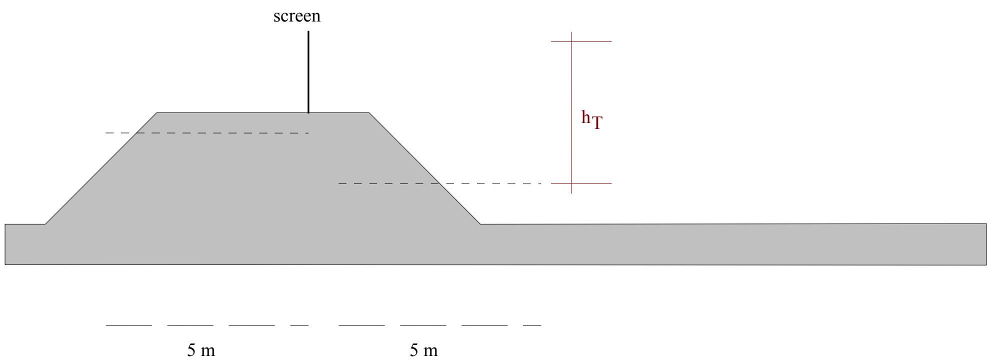

Figure 23 - Barrier set upon an embankment; the average terrain level to the left is slightly lower than the upper edge and to the right slightly higher than close to the embankment. The situation to the right is a determining factor for h_T.

6.1.1.1.4. Standard Embankment

Figure 24 shows a cross–section of an actual track embankment. Figure 25 shows the corresponding model. The following rules apply when establishing a model:

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

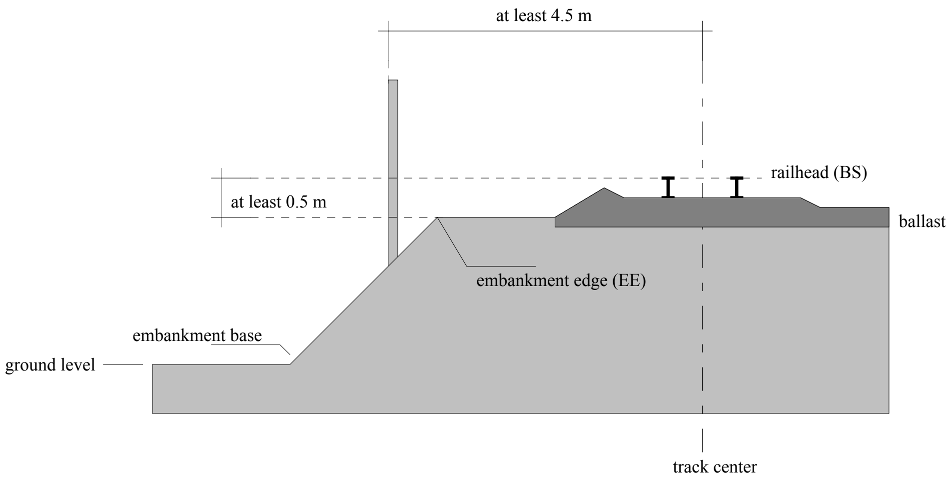

Figure 24 - Cross-section of a standard embankment.

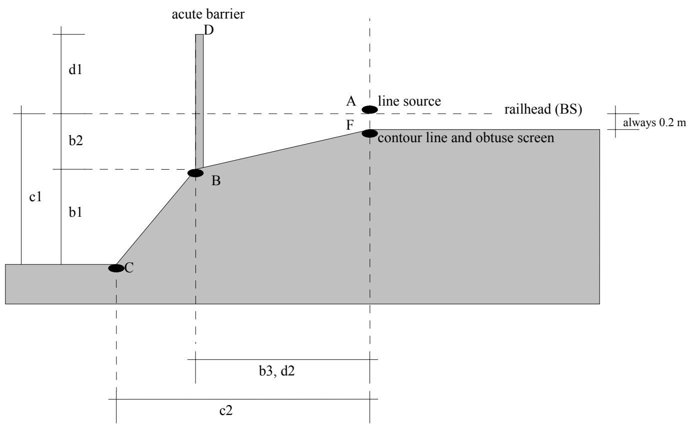

Figure 25 - Model of a cross-section of a standard embankment

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

6.1.1.1.5. Level crossing

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

6.1.1.1.6. Screening slabs (U-type slabs)

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

In the case of U-type slabs with absorbing wall lining (see 6.1.1.1.10) the source lines are found at the specified height above railhead.

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

No line sources are modelled for the actual tunnel section.

6.1.1.1.7. Barriers and screening objects

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

- have sufficient noise insulation, i.e the mass must be at least 10 kg/m² and have no recognizable columns or openings,
- have a viewing angle corresponding at least to the opening angle of the sector in question.

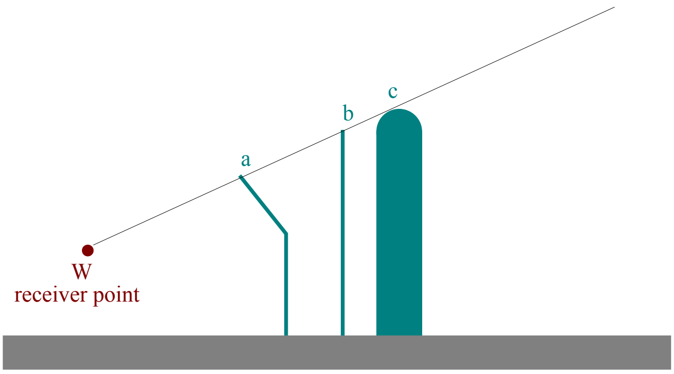

Figure 26 - Idealised barrier: (a) inclined barrier, (b) thin barrier, (c) thick barrier

Reflecting barriers near the track path which show no gradient can be modelled as an absorbing barrier.

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

The side of the barriers close to the track must be either absorbing (see 6.1.1.1.7.) or have a gradient of at least 15° relative to the vertical. Barriers close to the track that are not completely reflecting may be modelled as absorbing barriers. The effective height (= $h_{s,eff}$) of such a barrier is calculated $\boldsymbol{h_{s,eff} = h_s(1+a)/2}$, where a is the absorbing proportion of the barrier.

In order to calculate the effectiveness of noise barriers which are mounted at the edge of embankments, a 100% absorbing barrier is presumed for octave band calculation methods. In the case of absorbing barriers the actual height above railhead is modelled; in the case of noise reflecting or partially noise reflecting barriers the above-mentioned formula for calculating the effective barrier height can be used. The conditions when a real barrier can be considered absorbing are described in 6.1.1.1.10.

In the case of barriers with a relative height of more than 4 m above railhead, the real attenuation by diffraction is probably lower than the calculated one. The calculation method is not well suited for barriers at a distance closer than 4.5 m to the track path.

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

A barrier is always modelled as a vertical barrier, even if in reality the barrier is curved, or mounted at an angle. The top of the barrier has to be modelled at the exact same position of the diffraction edge of the real barrier. The method described above is then used to determine the effective height.

6.1.1.1.8. Platforms

The height of the platform is set at 0.8 m above railhead. Platforms are modelled with two obtuse absorbing barriers at each side of the platform and the side facing the tracks is situated 0.2 m from the centre of the tracks. In the case of the barrier near the tracks, the ground under the track (0.2 m below railhead) and the relevant height of the upper edge of the terrain apply. The applicable profile dependant correction factor Cp is determined by considering whether an absorbing lining is present or not (see table 1.4 and § 1.3.10). Platforms which are open on both sides (i.e. lack of a side wall on the track side and the outer side) are not modelled as barriers. Platforms which are open on the track side only are to be considered absorbing.

6.1.1.1.9. Bridge constructions

In the case of bridge constructions, the actual heights and distances are modelled. The type is defined in accordance with § 2.3.5. If the construction is not absorbing, the entire bridge floor is modelled as hard. In the case of tracks set on ballast or poured–in tracks with at least 15 cm of ballast the whole bridge flooring is modelled as absorbing ground, unless hard sections of the bridge floor are wider than 1 m. In this case the sections concerned are modelled as hard ground elements. In the case of steel bridges the bridge body is modelled as an absorbing ground element.

In the case of steel girder bridges, T-beam bridges and solid plate web bridge, the bridge is modelled as an absorbing obtuse barrier (see table 1.4 and § 1.3.10).

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

The profile dependent correction factor Cp is determined by considering whether an absorbing lining is present or not (see table 1.4 and § 1.3.10).

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

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

6.1.1.1.10. Noise absorbent construction

Linings or constructions of screening objects, platforms, and tunnel walls are to be considered absorbing if the track specific absorption is larger than or equal to 5 dB(A). This absorption is referred to in further detail in § 1.7.

6.1.1.1.11. Reflections

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

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

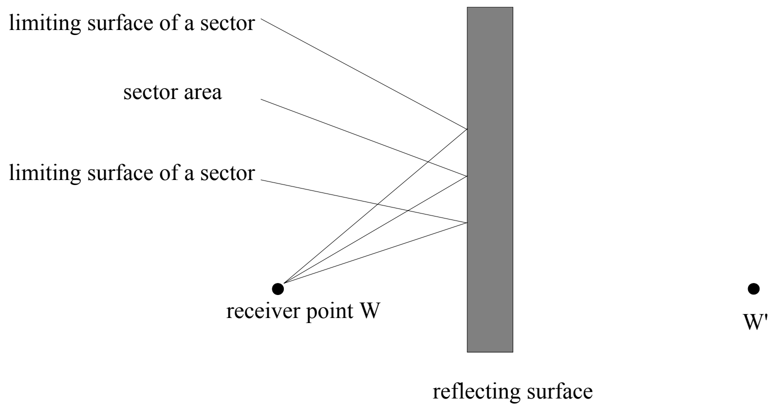

Figure 27 – Reflecting surface

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

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

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

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

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

6.1.1.1.12. Residential buildings and reception points

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

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

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

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

6.1.2. Hands-on examples

6.1.2.1. Modelling basic situation

Figure 28 shows a standard situation of two railway lines, one building and one barrier. Railway line 1 has two sections with homogeneous emission data. The equation of § 3.2 results in a minimum of 8 sectors needed to describe the situation. Each of these sectors has to be divided into smaller sectors when the opening angle is larger than 5°.

Table 42 - Sectors

sector 1	**one source (two or four source lines as a function of train types; each source line can contain 1 to 9 train types)**
sector 2	**one source, one building (screening)**
sector 3	**one source (but different section of previous section), one building (screening)**
sector 4	**two sources, one building**
sector 5	**two sources**
sector 6	**one source without barrier; one source with barrier**
sector 7	**two sources**
sector 8	**one source**

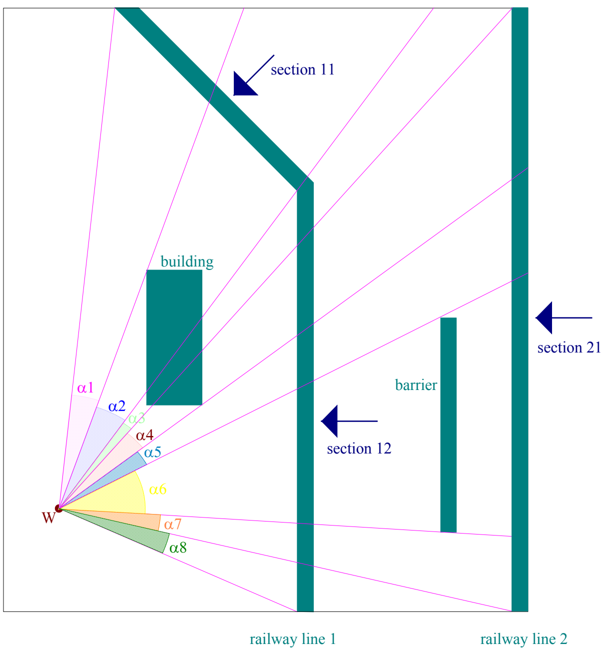

Figure 28 - Modelling standard situation

6.1.2.2. Reflections

Figure 29 shows the construction of a sector to calculate the influence of reflections. The part of the non reflecting sector at the right of the reflecting surface is replaced by the its mirror image with regard to the reflecting surface. The mirrored sector part seems to belong to reception point W', which is the mirror image of the real reception point W.

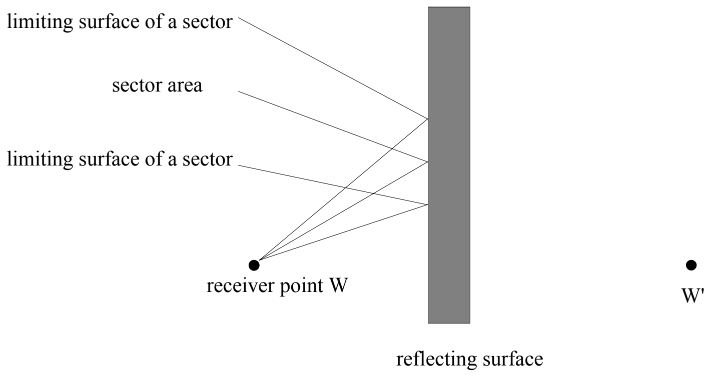

Figure 29 – Reflecting surface

6.1.2.3. Double crossing of railway by reflection

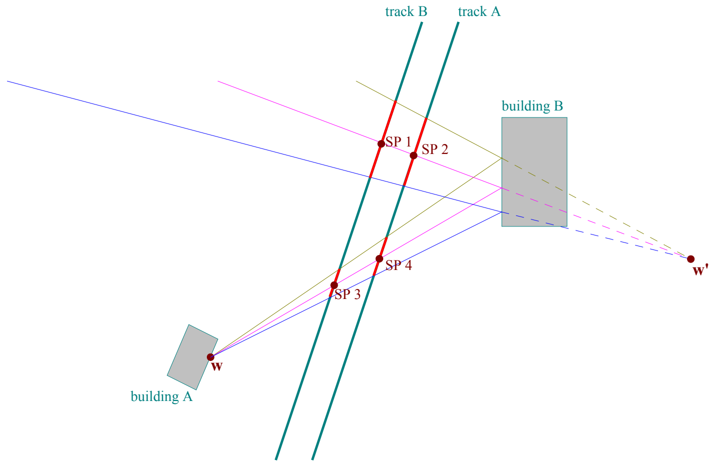

Figure 30 – Double crossing of railway by reflection

Figure 30 shows a sector that crosses the railroad a second time because of reflections. The contribution of the considered sector to the equivalent sound level L_{Aeq} must be calculated by superposing the contribution of source points 3 & 4 (direct) and source points 1 & 2 (via reflection modelled by additional reception point W'). For reflecting surfaces with an angle of ≥ 5° to the vertical, it is not a priori sure whether the reflected sound will reach the reception point. In this case, a closer study is required to show to which degree the sound reflections influence the L_{Aeq} of the considered sector. The contribution of reflecting surfaces with an angle of ≥ 30° to the vertical and thus reflecting sound upward (sloping roofs, …) can be neglected making closer investigation in this case unnecessary.

Balconies, galleries, staircases, … are to be considered as irregularities of the reflecting surface. When the source or reception point are close to such irregularities, their diffusing effect may lead to noise levels that do not correspond to the calculation results. A closer investigation, e.g. by measurements on site or on a scale model, may offer a solution. If the reception point is on a façade, (this is the case when the sound pressure on a façade must be determined), the above is not applicable to the reception point. Per sector, the surface of an object is approximated by a flat plane. If this approximation is not a good description of the real situation, dividing the surface over several sectors with a smaller opening angle may solve this problem. If this is not the case, closer investigation is necessary, e.g. by measurements on site or on a scale model.

6.2. ISO 9613-2

6.2.1. General considerations

This guidance on the application will consider the various parameters of the basic equations in *art 6* of *ISO 9613-2*. It involves the format for the sound power levels used in *equation 3*, on the one hand, and the attenuation terms referred to in *equation 4,* on the other.

The accuracy of strategic Noise Maps for Industrial Noise depends, on the one hand, on the nature of the sound power levels utilised for the industrial sound sources and, on the other hand, on the accuracy with which the geometry of the industrial zone and its surroundings have been digitised. Naturally, the greatest accuracy is obtained on the basis of actual measured sound power levels of entire industrial installations or, if possible, even of discrete individual sound sources.

In practice, however, there will not be enough time to determine all sound power levels in this manner – certainly not for the first phase of the END. Moreover, the measurements for determining the intended sound power levels should be carried out on the different company sites in the industrial zone. Here the practical problem arises that these companies are not accessible to the public, and therefore the company or agency that does the strategic noise mapping is simply not in a position to carry out the required measurements on its own initiative. It is therefore advisable that alternative input data be available, such as databases of sound power levels for different types of industrial installations.

In the following, we will first discuss the different possible types of input data and then the potential applications of the selected methods of measurement. In the final section, we will take a look at the integration of the sound power levels into ISO 9613-2.

The highest accuracy is obtained when sound power levels are specified in octave bands. ISO 9613-2 provides formulas to calculate the levels in octave bands with mid-band frequencies ranging from 63 Hz to 8000 Hz. Most data in public databases is in overall A-weighted levels. For overall A-weighted levels and in accordance with Note 1 of ISO 9613-2, all formulas should be applied for the octave band with a mid-band frequency of 500 Hz. There is one exception to this rule: ground effect. ISO 9613-2 provides an alternate formula 7.3.2 for overall A-weighted calculations of ground effect.

6.2.2. Choice of the type of "Input Data"

6.2.2.1. Introduction

The choice of input data from the set of available data can be based on

- the desired accuracy,
- the practical possibilities and
- the established time frame.

Table 43 - Different data types in ascending order of complexity and accuracy.

Input Data		Accessibility	Precision
From	As		
Type 1: Public database	**Lw" for entire site** **L_w for individual source**	**Public**	**Rudimentary estimate**
Type 2: Theoretical exploitation conditions	**ditto**	**Public**	**Pre-established limit**
Type 3: Environmental Impact Assessment (EIA)	**ditto**	**Public**	**Estimate after calculation**
Type 4: Noise measurements of the actual situation	**ditto**	**Usually not public**	**Best possible approach to actual situation**

6.2.2.2. TYPE 1: PUBLIC DATABASES

The most rudimentary strategic noise mapping is achieved when sound power levels per unit of surface area are input for the industrial zones of interest.

This $L_{w"}$ depends naturally on the type of company: chemical or petrochemical installations, haulage companies, open or closed installations, steel companies, scrap processing, etc. The great advantage of this method is the fact that the sound power levels should be publicly available and thus uniform for all of Europe. This should facilitate the mutual comparison of strategic noise maps across Europe. On the other hand, the agreement between strategic noise mapping and the actual acoustic situation remains absolutely unpredictable. In some less complex cases, sound power levels for individual sound sources such as cooling towers, power plants, compressors, etc. can also be used.

Table 44 - Non-comprehensive list of available databases.

Sound power levels for entire companies.		
Database	**Description**	**Address**
Kentallen Industrie	**Mean value of Lw" on the basis of a large number of situations**	**i-kwadraat** **c/o DCMR Milieudienst Rijnmond** **Postbus 843** **3100 AV SCHIEDAM** **The Netherlands** **E-mail : si2@DCMR.nl** **http://www.xs4all.nl/~rigolett**
DGMK Project 209	**Specific A-weighted Sound Power Level of Refineries and Petrochemical Works**	**DGMK** **Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e.V** **Kapstadtring 2** **D-22297 Hamburg** **Germany**
DGMK Project 308	**Evaluation of the immission-relevant A-weighted sound power level of an open plant from sound measurements inside the plant.**	
DGMK Project 446	**Community noise levels of existing refineries and petrochemical plants.**	

Report UBA-94-102	**Noise emission Measurement – Limit values – State of the art Chapter 2.2.2**	**Umweltbundesamt (federal environmental agency) Spittelauer Lände 5 A-1090 Wien Austria**
Monographien Band 154	**Schallemission von Betriebstypen und Flächenwidmung**	
DIN18005 Part 1	**Noise abatement in town planning; calculation methods**	
AV-Ecosafer	**LW measured on site for different types of open chemical and petrochemical installations**	**AV-Ecosafer nv Koningslaan 157 B-1190 Brussels Belgium**

Table 45 – Sample databases for individual industrial sound sources

Sound power levels for individual sound sources		
Database	**Description**	**Address**
Directive 2000/14/EEC	**Sound power levels of equipment used outdoors: Art 12, limiting values for different types of machines.**	
Report UBA-94-102	**Noise emission Measurement – Limit values – State of the art** **Chapter 2.2.1**	**Umweltbundesamt** **(federal environmental agency)** **Spittelauer Lände 5** **A-1090 Wien** **Austria**
Lärm Bekampfung 88	**Tendenzen – Probleme – Lösungen**	**Umweltbundesamt** **(federal environmental agency)** **Bismarckplatz 1** **D-14193 Berlin** **Germany**
British Standard 5228 part 1 – 1997	**Noise and vibration control on construction and open sites.**	**BSI** **389 Chiswick High Road** **London** **W4 4AL** **Great Britain**
Eurovent Directory of Certified products	**Certified Lw for Air Conditioners and Cooling Equipment.**	**Eurovent Certification Company** **62, boulevard Sébastopol** **F-75003 Paris** **France**

No recently updated official database on sound power levels of entire companies has been found. A rudimentary estimate of the sound power level of an industrial installation can be made, by using the proposed values in the table below.

Table 46 – Approximate estimates of area sound power levels (illustrative)

Noise emission classification	**Sound power level $L_{w''}$**
Low	**< 65 dB(A)**
Medium	**65 to 75 dB(A)**
High	**> 75 dB(A)**

6.2.2.3. Type 2: Input data based on (theoretical) operating conditions

Greater accuracy and differentiation is obtained in determining sound power levels by starting from the legal operating conditions fixed in permissions for either of the following: entire industrial zones, separate companies or even individual sound sources. For instance, the Dutch assigns maximum permissible sound power levels ("Kentallen") per unit of surface area to particular industrial sites. These assigned sound power levels could be used as input data. It is also possible to calculate maximum permissible sound power levels per unit of surface area on the basis of limiting values for the maximum noise levels in the surroundings and to use them as input data. For a series of individual sound sources used outdoors, Directive 2000/14/EC provides limiting values that can also be used as input data. All this data is available to the public. The agreement with the actual acoustic situation is better, but naturally it depends on the degree to which the operating conditions or limiting values are realised in practice.

6.2.2.4. Type 3: Input data based on EIA (Environmental Impact Assessment)

For many industrial installations, an EIA was established in the permitting phase before the installation was put into operation. The sound power levels adopted in or calculated for this study can also be used as input data, whether as Lw" or as Lw of individual sound sources. In principle, the EIA is a publicly accessible document. Naturally, the agreement with the actual acoustic situation depends totally on the accuracy with which the EIA was established and the correctness of the basic theoretical data.

6.2.2.5. Type 4: Input data from noise measurements of the actual situation.

It is obvious that the greatest accuracy will be achieved by using input data obtained from noise measurements of the actual situation at the different industrial sites being studied. Depending on the situation on site, these can be measurements of sound power levels of entire industrial zones, separate companies or individual sound sources. The measurement methods that apply in these cases are discussed elsewhere.

The main problem in all of this, however, is the accessibility of the data. Various large companies have such measurements carried out for internal use, but in principle the results of these measurements remain their own private property. Moreover, there will still be a great deal of companies that do not know their sound power levels.

No matter which measurement method is chosen, noise measurements for determining the total sound power level of entire companies are labour-intensive. Due to the relatively short period of time allocated to the first phase of the END, it is unlikely that all this data can be collected for all companies. In addition, there is the fact that the intended measurements need to be carried out on site at the private companies. Should the company or agency doing a strategic noise mapping nevertheless want to carry out these measurements itself, then this must always be done in consultation with the companies.

6.2.3. Sound power level format

6.2.3.1. Introduction

The sources for the sound power levels Lw, referred to in *equation 3* of *ISO 9613-2 art 6* were already considered in 3.4.2. The details for the attenuation term A are examined in further detail in 6.2.4. The directivity correction is, however, dependent on the format used for the sound power levels considered below.

Although *ISO 9613-2* was theoretically developed to calculate the attenuation of sound from point sources, a calculation model should nonetheless enable the area or line sources to be entered. The final calculations are then made for point sources, but the area or line sources may be distributed automatically in this way. This is also referred to in *ISO 9613-2 art 4: Source description.*

If a global source should be entered as a point source, the choice of where the point source is located may cause serious inaccuracies when calculating the screening effects of buildings. This is why it is generally best to start from an area source, and let the computer model determine the correct distribution of this in point sources, depending on the location of the reception point in relation to the area source and potential barriers. In this way, any barrier effects are distributed more uniformly and realistically.

Depending on the grade of detail that is known for the sound power levels of industrial plants, a distinction can be made according to the format for the sound power levels, as described below.

6.2.3.2. Format 1 : GLOBAL SOURCES.

If only one global sound power level Lw is known per industrial plant, without any further details about the internal distribution, an area source is used. The area source then covers the surface area actually covered by the facilities.

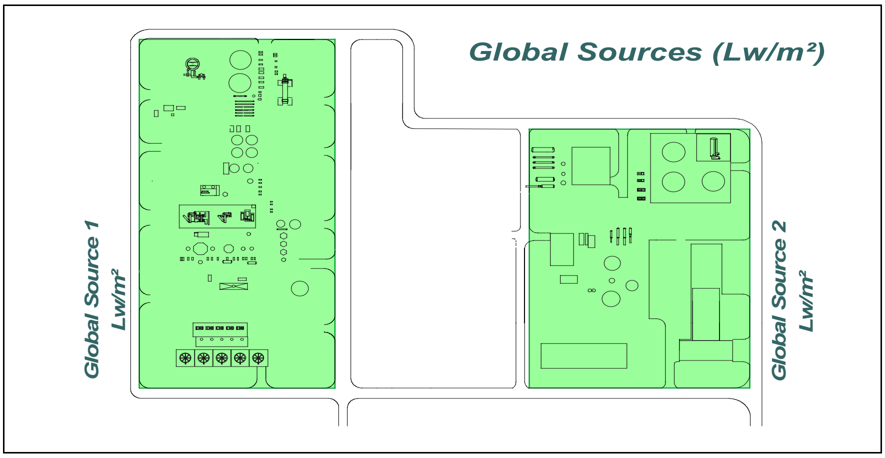

Figure 31 – Global sources

As no further details are known, no account is taken of the directivity correction D_c nor of the building or barriers within this area.

The source height may be assumed to be 4m unless more appropriate values are known.

6.2.3.3. Format 2 : ZONAL SOURCES.

Sound source registers, detailed engineering studies and noise maps measured to determine sound emission provide a further level of detail without necessarily distinguishing between individual items of equipment. Sound power levels $L_{W''}$ can be assigned to several distinct area sources each of which encloses a group of emitting sources.

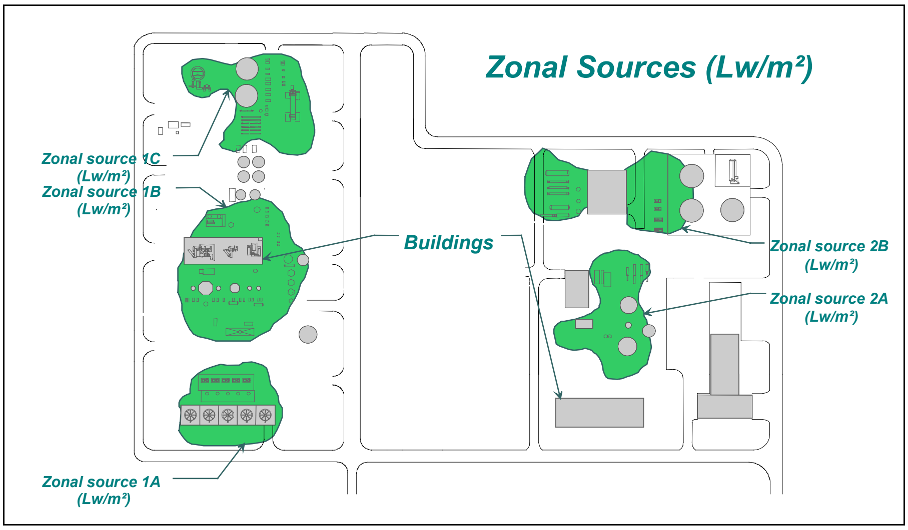

Figure 32 – Zonal sources

No account is taken of the directivity correction D_c. In this case, the effect of buildings and barriers is dependent on their location, inside or outside the zonal sources.

The source height may be assumed to be 4m unless more precise values are known.

6.2.3.4. Format 3 : INDIVIDUAL SOURCES.

Individual sources can only be used when sufficiently detailed information on sound power levels and location of the individual equipment exists **and** when the exact positions of buildings and potential barriers on the industrial plant are known.

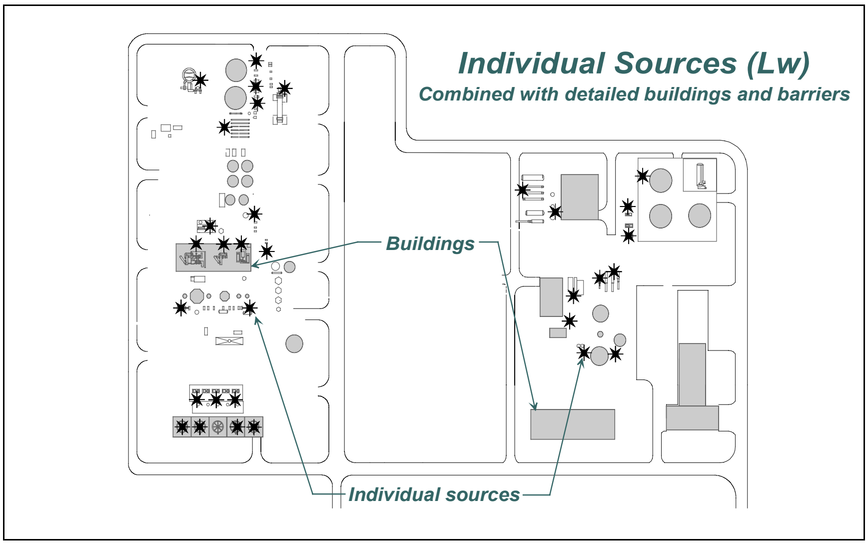

Figure 33 – Individual sources

In this case, account may be taken of the directivity correction D_c for the various sound sources. The effect of buildings and barriers is very significant in this case. The sound sources have to be carefully positioned in relation to the buildings.

If the information about the buildings and potential barriers is not detailed enough, it is better to add the sound power levels from individual sources together, and to take into account zonal sources or global sources for further calculation.

The actual source height is of course recorded as the source height in this case.

6.2.4. Attenuation Terms.

Equation 4 of *ISO 9613-2 art 6* indicates the structure of the total attenuation term.

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc.}$$

$\mathbf{A_{div}}$ (geometrical divergence) and $\mathbf{A_{atm}}$ (atmospheric absorption) are clearly defined in *ISO 9613-2 equation 7 & table 2.*

$\mathbf{A_{gr}}$ (ground effect).

Table 47 – Suggested values of G

Area to be calculated	Suggested G
Countryside (only a few buildings)	1
Residential areas (one-family houses, semi-detached houses and a lot of greenery)	0.5
Industrial areas	0.5
Urban areas (blocs with little greenery)	0

The parameters h_s (source height) and h_r (receiver height) are important for the further calculation of A_{gr}. For strategic noise mapping according to the END the receiver height is assumed to be h_r 4.00 m. For source height h_s we also propose opting for 4.00 m, or the average source height $h_{sAVG,}$ as long as this is higher than 4.00 m.

For $\mathbf{A_{bar}}$ (attenuation due to a barrier) and $\mathbf{A_{misc}}$ (attenuation due to miscellaneous other effects : *industrial sites*) a distinction needs to be made according to the location of potential barriers and buildings in relation to the sound sources.

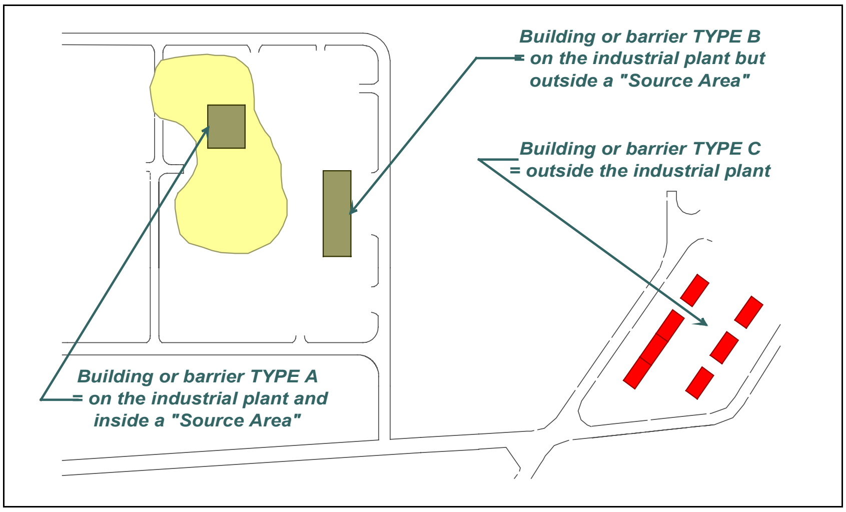

Figure 34 – Classification of buildings and barriers

The unbiased screening effect of buildings is taken into account by A_{bar} (attenuation due to a barrier). In the case of chemical and petro-chemical facilities, this does not always involve genuine buildings but complete facilities comprising pipes, valves boxes, structural elements, etc. that screen each other. Consequently, this cannot be regarded as an unbiased screen effect but is a combination of absorption and screening. It is better to use the term A_{site} (attenuation due to industrial sites) for sound sources that are located within the industrial site itself.

The terms A_{fol} and A_{hous} (annexe A of ISO 9613-2) are not taken into account since there are no other similar methods or standards that refer to these attenuation effects. They are therefore neglected.

6.2.5. Reflections.

Reflections may be calculated according to *ISO 9613-2 art 7.5. and table 4.* Nonetheless, a distinction has to be made according to the location of the receiver. See 2.1.3.

6.2.6. Overview

Below is a summary of all the parameters in keeping with the “sound power level format” and in combination with the “building and barrier type”.

Table 48 – Overview of industrial noise sound emission data

$L_{fT}(DW) = L_w + D_c - A$ equation (3)		**Sound Power Level FORMAT**		
		Global Source	**Source per Zone**	**Individual Source**
Input data for Lw		**Area source See 3.3.3**	**Area source See 3.3.3**	**Point, Line, or Area source See 3.3.3**
D_c Directivity correction		**Neglected**		**Optional**
$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}$ equation (4)		**Sound Power Level FORMAT**		
		Global Source	**Source per Zone**	**Individual Source**
A_{div} geometrical divergence		**Conform ISO 9613-2 art 7.1.**		
A_{atm} atmospheric absorption		**Conform ISO 9613-2 art 7.2.**		
A_{gr} ground attenuation	**Principle**	**Conform ISO 9613-2 art 7.3.1.**		
	G ground factor	**Countryside : G = 1 Residential areas : G = 0.5 Industrial areas : G = 0.5 Urban areas : G = 0**		
	h_r receiver height	**h_r = 4.00 m above ground**		
	h_s source height	**H_s = 4.00 m or Average source height if this is more than 4.00 m**		
A_{bar} attenuation due to a barrier	**Buildings TYPE A**	**Neglected**	**Neglected but see A_{site}**	**ISO 9613-2 art 7.4.**
	Buildings TYPE B or C	**Conform ISO 9613-2 art 7.4.**		
A_{misc} attenuation due to miscellaneous other effects	**A_{fol} Foliage**	**Neglected**		
	A_{site} Industrial sites	**Neglected**	**ISO 9613-2 annex A2**	**Neglected**
	A_{hous} Housing	**Neglected**		
		Sound Power Level FORMAT		
		Global Source	Source per Zone	Individual Source
Reflections	**Buildings TYPE A**	**Neglected**		**ISO 9613-2 art 7.5.**
	Buildings TYPE B or C	**Conform ISO 9613-2 art 7.5. Reflection inhibited 3m in front of reflecting surface**		
C_{met} **meteorological correction**		$C_{0\ day}$ **= 1.4 dB** $C_{0\ evening}$ **= 0.7 dB** $C_{0\ night}$ **= 0 dB**		

3.4.3.6. Example.

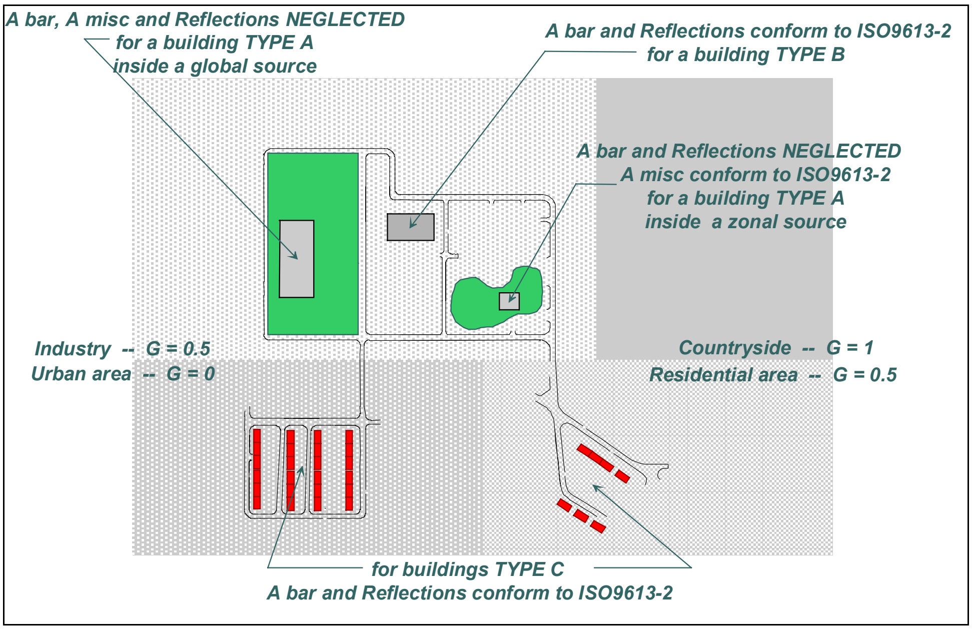

Figure 35 – Comprehensive example

6.3. ECAC.CEAC Doc.29

6.3.1. OVERALL GUIDANCE ON THE COMPUTATION OF THE NOISE CONTOURS

This section is based on the chapter of same title of [12]. Necessary adaptations are made.

For an airport noise study, the following information is required :

- the aeroplane types which operate from the airport;
- noise and performance data for each of the aeroplane types concerned, supplied in accordance with the specifications of Chapter 4;
- the routes and/or procedures followed by arriving and departing aircraft including dispersion across ground tracks;
- the numbers of movements per aeroplane type on each route within the year chosen for the calculations including the time of day for each movement;
- the operational data and flight procedures relating to each route (including aeroplane masses, power settings, speeds and configurations during different flight segments); and
- airport data (including number and alignment of runways, displaced threshold etc.).

From the respective data on noise and performance, the aircraft are assigned to the aircraft groups (see chapter 3.4) and representative data are selected. The calculation grid is arranged and the calculations of SEL at the grid points, for the individual aircraft movements, proceed according to the specifications given here. The sound exposure levels at each grid point are summed or combined according to the formulation of the indicator. Finally, interpolations are made between noise indicator values at the grid points to locate the contours.

In a number of detailed respects, the computation procedures remain at the discretion of the user, since they may be specific to the airport or there might be constraints due to computational capability. Such detailed aspects include the following :

- The optimum number of aeroplane groups to be selected.
- The method of interpolation to be used between grid points to locate the noise contours. An iterative process can be used to find the exact location of a contour, subject to the limitation of the cost of computer running time. It is possible for iterations to proceed to an accuracy of 0.005 dB in order to keep the positional accuracy of the contours to within 1 m. Such accuracy might be necessary with respect to financial compensation or other action to deal with the noise problem.

It should be noted that there can be an extremely low rate of change of noise indicator value with distance, especially far away from the runway, possibly leading to a positional uncertainty of up to 1 km for a tolerance of 1 dB.

A further point to note is that there are a number of noise-making activities by aircraft for which no method of calculation is given here. These include taxiing, engine testing and use of auxiliary power units.

6.3.2. Calculation of a Sample Scheme

6.3.2.1. Introduction

The practical application of ECAC.CEAC Doc. 29, 1997 adapted to the requirements of the END is shown in the following sample scheme calculation. All working steps from input data to calculated noise levels are described.

6.3.2.2. Flow Chart

The following flow diagram shows the different steps required to calculate SEL for one operation of one type j of aircraft on one flight path i at one reception point.

Flow chart on next page!

define segments 1-K of the flight path i

with respect to the reception point rp

determine segment geometry for the first segment k=1

position of segment ends P_1 and P_2

position of CPA on segment (if segment is ahead or behind rp)

position of PCPA on segment or on straight extension of segment

σ for segment at CPA and PCPA

d distance of PCPA to reception point rp

ℓ and β from rp to PCPA

determine physical parameters for segment k

read from table for relevant aircraft type j

the constants A and B and V at σ for CPA (if segment is ahead or behind rp) or at σ for PCPA if segment is astride rp by linear interpolation

and calculate Δ_A

Δ_ξ at σ for CPA (if segment is ahead or behind rp)

or
at σ for PCPA if segment is astride rp by linear interpolation

L_A for d by logarithmic interpolation

calculate $\Lambda(\beta,\ell)$ or G (ℓ) for PCPA

calculate Δ_L if segment is behind take off roll acc. to 8.2

calculate fraction $F_{1,2}$

and $\Delta_F = 10.\lg F_{1,2}$

calculate $SEL_{i,j,k} = L_A + \Delta_\xi + \Delta_A + \Delta_L + \Delta_F + \Lambda(\beta,\ell)$

or $SEL_{i,j,k} = L_A + \Delta_\xi + \Delta_A + \Delta_L + \Delta_F + G(\ell)$

next segment

after segment k = K

calculate $SEL_{i,j} = 10.\lg \Sigma 10^{SELijk/10}$

continue for next aircraft group

6.3.2.3. General Airport Data

Model:

- Plain terrain, elevation 0 m.
- Airfield reference point at [1604486, 5641235].
- Runway west-east-direction, length of 4000m, runway reference point = middle of runway = [0m, 0m].
- Number of departures: 36000/3600/1800 (day/evening/night) of aircraft group S5.3, starting in east direction within a year (cf. chapter 9).
- Take-off position (i.e. start-of-roll position) at [-2000m, 0m].

6.3.2.4. Data Acquisition System

6.3.2.4.1. Airport

Table 49 – Airport data acquisition system

1.1. Designation	**Fictive Airport**
1.2. Airfield reference point **Geo-reference coordinates** **Absolute Easting and Northing**	 **4°29‘6“ East 50°53‘49“ North** **E 1604486 N 5641235**
1.3 Elevation	**0 m**

6.3.2.4.2. Runways

Table 50 – Runway data acquisition system

	I	**II**	**III**	**IV**
1. Designation	**9L/27R**	**/**	**/**	**/**
2. existing / planned	**Planned**			
3. Heading	**90º/270º**			
4. Overall length (m)	**4000**			
5. Coordinates of runway reference point (N/E)	**[0,0]**	**/**	**/**	**/**
6. Distance of take-off position to runway reference point (m)	**-2000/-2000**	**/**	**/**	**/**
7. Distance of runway threshold to runway reference point (m)	**2000/2000**	**/**	**/**	**/**

6.3.2.5. Departure Routes

Table 51 – Departure routes data acquisition system

2.1. Designation	Departure
2.2. Runway:	9R

2.3. Description of departure route

1	2	3	4	5	6	7
Section no.	**Straight flight /m**	**Curve**			**Width of corridor at**	
		L/R	**Change of heading /°**	**Radius of turn /m**	**beginning of segment /m**	**end of segment /m**
1	**10000**	**-**	**-**	**-**	**0**	**0**

Flight corridors, approach routes and traffic circuits are not included in this sample scheme.

6.3.2.6. Aircraft Classes and L_A

In Part B “Calculation method for aircraft noise around airports, Annex 1, Noise-Power-Distance-data and performance data” the noise level L_A(dB) as a function of the distance d for air-to-ground sound propagation are given for the groups of aircraft of interest.

A and B are constants which are different for take-off and approach and for different aircraft; they are given in the tables; d is the slant distance, in meters, and V is the speed, in m/s. The sound levels are given for take-off thrust and for landing thrust. The change of thrust itself is represented by the additional sound level $\Delta\xi$ which accommodates the thrust-related changes of emission levels. During the take-off the thrust is reduced after reaching a certain level of height H and speed V.

For aircraft group S5.3 (take-off) the following parameter settings are valid (see Part B “Calculation method for aircraft noise around airports, Annex 1, Noise-Power-Distance-data and performance data”):

Table 52 – Parameter settings for aircraft group S5.3 at take-off

σ' /m	**V /(m/s)**	**H /m**	**Δξ /m**
0	**40**	**0**	**0**
2000	**85**	**0**	**0**
4400	**85**	**-**	**0**
4900	**85**	**460**	**-**
5400	**-**	**-**	**-2**
8100	**115**	**610**	**-2**
11600	**135**	**830**	**-2**
>11600	**135**	**dH/dσ = 0,117**	**-2**

use linear interpolation!

A = 1.5; B = 50

Remark: The flight velocity V, height H and additional sound level $\Delta\xi$ (see Part B “Calculation method for aircraft noise around airports, Annex 1, Noise-Power-Distance-data and performance data”) are defined by piecewise linear functions of arc length σ'. The numerical values in column σ' indicate the break points of these functions. The values which the functions reach at a break point are given in the respective line. A dash in this line means that this value σ' is not a break point for the respective functions. Between two neighbouring break points the functions have a constant slope. For values below the first value of arc length σ' the functions are constant and have the values stated in the first line. For values of arc length σ' exceeding the last numerical value in column σ', the slopes of the three functions are given in the last line of the table.

6.3.2.7. Calculation of Significant Noise Parameters

As an example the calculation of sound level at the reception points P1 [2000m,-100m] and P2 [6500m,-2000m] will be shown.

The maximum noise level $L_{A,max}$ of an aircraft flying past the reception point is calculated by:

$$L_{A,max} = L_A - \Lambda(\beta,\ell) + \Delta_L + \Delta_\xi$$

where

L_A sound level from table annex 1

$\Lambda(\beta,\ell)$ lateral attenuation

Δ_L directivity function for the area behind the start-of-roll position.

Δ_ξ additional sound level representing changes of thrust

SEL is calculated from $L_{A,max}$ by

$$SEL = L_{A,\max} + 10 \cdot \lg \frac{\tau}{\tau_0} + \Delta_F$$

where

$$\tau = \frac{A \cdot d}{V + (d/B)} \text{ in s}$$

τ_0 1s

Δ_F correction for finite length of the segment

Using the above SEL the noise indicators L_{den} and L_{night} become

$$L_{den} = 10 \cdot \lg(\frac{\tau_0}{T_{den}}(N_d + 3{,}16 \cdot N_e + 10 \cdot N_n) \cdot \sum_m 10^{SEL_m/10})$$

$$L_{night} = 10 \cdot \lg(\frac{\tau_0}{T_n} N_n \sum_m 10^{SEL_m/10})$$

where

T_{den} duration of day + evening + night (24h = 86400s)

T_n duration of night (8h = 28800s)

τ_0 1s

m index of segment.

Remark: Note that the indices i, j and k have been omitted in the formulas above because in this example only one flight track with one aircraft group with corridor width 0 has been modelled.

6.3.2.8. Segmentation

6.3.2.8.1. Input Data

Take-off position	x = -2000.00	y = 0.00	Flight direction along y axis toward east
Reception point 1:	x = 2000.00	y = -100.00	
Reception point 2:	x = 6500.00	y = -2000.00	
Aircraft category S5.3:	A = 1.50	B = 50.00	
Δ_L:	0.00 dB		
N_d:	36000/365d = 98.63/d		
N_e:	3600/365d = 9.86/d		
N_n:	1800/365d = 4.93/d		

6.3.2.8.2. Collection of Calculation Parameters and Formulas

σ'/m	arc length of position within flight path measured from the reference point of aircraft groups
L/m	length of segment
V/(m/s)	aeroplane speed from table in Annex 1 (depending on aircraft group)
$\Delta\xi$/dB	additional sound level from table in Annex 1 (depending on aircraft group)
l/m	horizontal distance of the flight path to reception point
d/m	slant distance of the reception point to PCPA on flight path
β/°	elevation angle between a line from reception point to PCPA on flight path and the reference plane
$\Lambda(\beta,l)$/dB	lateral attenuation
τ/s	duration of flypast (section 7.3 of ECAC Doc. 29)
Δ_A	duration allowance due to the speed of the aircraft
F_{12}	noise exposure fraction for the segment
Δ_F	correction for segment length

6.3.2.9. Results of Calculation (detailed)

6.3.2.9.1. Reception Point 1

Table 53 – Results calculated at reception point 1

Segment	σ' /m [1)]	L /m	V /(m/s) [2)]	$\Delta\xi$ /dB [2)]	l /m	d /m	lg(d)	β /°	$\Lambda(b,l)$ /dB	τ /s	Δ_A /dB	F_{12}	Δ_F	L_A /dB	$L_{A,max}$ /dB	SEL_k /dB	
1	2000	2000	85,00	0,00	100,00	100,00	2,000	0,00	3,62	1,72	2,37	0,0000	-57,23	104,7	101,1	46,3	
2	4000	2400	85,00	0,00	111,40	111,40	2,047	0,00	3,97	1,92	2,82	0,9966	-0,01	103,7	99,8	102,6	
3	4400	500	85,00	0,00	111,40	396,65	2,598	73,69	0,00	6,40	8,06	0,0594	-12,26	91,0	91,0	86,8	
4	4900	500	85,00	-1,00	101,89	471,15	2,673	77,51	0,00	7,48	8,74	0,0108	-19,66	89,2	88,2	77,3	
5	5400	2700	89,68	-2,00	101,89	494,06	2,694	78,10	0,00	7,44	8,72	0,0051	-22,92	88,7	86,7	72,5	
6	8100	3500	115,00	-2,00	102,40	618,54	2,791	80,47	0,00	7,28	8,62	0,0004	-34,15	86,2	84,2	58,6	
															SEL =	**102,7**	**dB**
															Lden =	**75,9**	**dB**
															Lnight =	**65,0**	**dB**

6.3.2.9.2. Reception Point 2

Table 54 – Results calculated at reception point 2

Segment	σ' /m [1)]	L /m	V /(m/s) [2)]	$\Delta\xi$ /dB [2)]	l /m	d /m	lg(d)	β /°	$\Lambda(b,l)$ /dB	τ /s	Δ_A /dB	F_{12}	Δ_F	L_A /dB	$L_{A,max}$ /dB	SEL_k /dB	
1	2000	2000	85,00	0,00	2000,00	2000,00	3,301	0,00	13,86	24,00	13,80	0,0003	-34,66	71,7	57,9	37,0	
2	4400	2400	85,00	0,00	2006,35	2006,35	3,302	0,00	13,86	24,05	13,81	0,0011	-29,73	71,7	57,8	41,9	
3	4900	500	85,00	-1,00	2006,35	2042,15	3,310	10,74	5,70	24,34	13,86	0,0020	-27,05	71,4	64,7	51,5	
4	5400	500	89,69	-2,00	2000,22	2052,43	3,312	12,95	4,94	23,55	13,72	0,0029	-25,37	71,4	64,4	52,8	
5	8100	2700	115,00	-2,00	2000,22	2057,81	3,313	13,59	4,76	19,77	12,96	0,0143	-18,44	71,3	64,6	59,1	
6	8500	3500	117,29	-2,00	2000,40	2091,33	3,320	16,96	3,93	19,72	12,95	0,6327	-1,99	71,1	65,2	76,1	
															SEL =	**76,2**	**dB**
															Lden =	**49,4**	**dB**
															Lnight =	**38,6**	**dB**

Remarks:

1) If PCPA lies within the segment σ' refers to the arc length of PCPA, otherwise σ' refers to the arc length of the end of segment which is nearer to the reception point.

2) If PCPA lies not within the segment the quantities V, H and $\Delta\xi$ are calculated for the end of the segment which is nearest to the reception points [2000,-100] and [6500, -2000] respectively (cf. chapter 7.5).

7. References

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ANNEX I

EU prevention and precautionary principle and the use of overall estimates for meteorological correction

A more elaborate version of the following text can be found in the "Miscellaneous" section of Part B of the report.

Introduction

EU Directive 2002/49/EC (END) defines the "year" for strategic noise mapping as follows:

— a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances; [45]

The average "meteorological circumstances" of a given site can be established only on the basis of long-term on-site meteorological measurements. Taking into account the current rather crude density of meteorological measurement stations, and the variations in density between EU M.S. it is very unlikely that suitable data for all major sources and agglomerations defined in the END do either exist or can be produced by 2007 (the deadline for the first round of mapping).

It must also be noted that the definition of the average meteorological year is virtually impossible for mountainous regions. Major transportation links complying with the requirements of the END for major roads and major railways can be found in mountainous regions in several EU M.S. such as Austria, Spain, Italy, Germany and France.

Finally, the restriction on the applicability of a meteorological correction in the selected interim computation method for strategic noise mapping of road traffic noise NMPB/XP S 31-133 [3] precludes the use of met-correction for a series of agglomerations and transport links.

The selected interim computations methods for strategic noise mapping of surface sources (road, rail, industry) rely on met-correction to compute the long-term equivalent sound level in accordance with ISO 1996-2:1987. In the definition of its noise indicators, the END refers to this long-term equivalent noise level computed over all daytime, evening and night time periods of a year.

To resolve this conflict, the AR-INTERIM-CM project team produced a proposal for a simplified site-independent meteorological correction that would yield long-term equivalent noise levels estimated with the precautionary principle in mind.

The following text will try to show that this approach is both justified and does not entail any unjust or unfair consequences for the "balanced economic and sustainable development of economic activities"[46].

The prevention principle in EU environmental legislation

The prevention principle was first introduced in the context of the First Environmental Action Programme and then again in the Second Environmental Action Programme.

"While neither Action Programme gave the EEC legal competence in the area of environmental policy, they established several principles that are still at the core of EU environmental policy, including the following:

Because prevention is better than cure (a statement that marked a shift in Community priorities away from remediation), environmental impacts should be considered at the earliest possible stage in decision-making."

EU legislation based on the prevention principle started to appear in the mid-eighties and include amongst others the environmental assessment directive (85/337).

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[45] END, ANNEX I, 1. Definition of the day-evening-night level L_{den}

[46] From the amendment to Article 2 the EC Treaty introduced by the Treaty of Amsterdam, quoted from p. 23 of [4]

The precautionary principle in EU environmental legislation

The precautionary principle is prescribed in the EC Treaty to protect the environment. No formal definition is given. Therefore the EC was charged by the Council to help develop a clear understanding of the principle and a basis for its application. In 2000, the EC published the "Commission Communication on the precautionary principle".

Commission Communication on the precautionary principle

It is quite clear that the Commission wishes to prevent the arbitrary use of the precautionary principle. The risk factor mentioned in both the above quotations and the scientific evidence (or lack thereof) must be provided before the precautionary principle can be applied.

The Commission Communication defines three preliminary conditions necessary to invoke the precautionary principle. These three preliminary conditions according to are:

- identification of potential adverse effects,
- evaluation of available scientific data, and
- the extent of scientific uncertainty.

The question then is whether this applies to noise.

The END and the protection of the citizen

From the outset, the END pursues the protection of the citizen against "noise in the environment as one of the main environmental problems in Europe." In the next paragraph, the END notes the "lack of reliable, comparable data regarding the situation of various noise sources". The END explicitly supports the Commission Green Paper, a document based on extensive scientific evaluation of evidence for noise as a potential threat to human well-being. Hence, all three preliminary conditions to justify the application of the precautionary principle as defined in "*Commission Communication on the precautionary principle*" are thus incorporated in the preamble to the Directive 2002/49/EC.

The END goes on by referring to the Treaty quoting the intention of "a high level of protection of the environment" and invokes the principle of subsidiaritity. Finally, the END calls for the application of "the principle of prevention".

The above evidence alone would justify employing a simplified meteorological correction term that would yield long-term noise levels in accordance with the prevention principle and the precautionary principle. The prevention principle is at the basis of previous efforts by the EC to manage noise. It is applied to the source. Again, this principle puts forward the protection of the citizen as the ultimate goal. The standards developed to control noise at the source do however respect the aforementioned requirement of sustainable economic growth. A conflict between sustainable economic growths and the application of the prevention and precautionary principles can thus not be seen.

Evidence of scientific data evaluation and risk uncertainty

The following is a partial list of evidence for the three preliminary principles essential to the application of the precautionary principle.

- The Dobris report
- The EAA homepage

- The WHO report on Community Noise

Chapter 3 of the WHO report on Community Noise identifies 7 distinct adverse effects of noise on humans. The text refers extensively to scientific publications from several EU M.S. The last paragraph of the introduction to Chapter 4 explains the uncertainty linked to the current state of scientific evaluation of the health effects of noise. In Chapter 5, the report asserts the use of both the prevention and the precautionary principle in noise management. EC Directive 2002/49/EC is concerned with the assessment and the management of environmental noise.

Potential legal arguments

Application of the prevention and precautionary principles could cause the reaction of EU M.S. to perceive the implications of these principles as either difficult to meet or in conflict with local and economic interest groups.

It must be noted that objections to an EC Directive based on the difficulty of its implementation were dismissed in Court in previous cases (see Commission v United Kingdom Case C-56/90). The quoted text book on European law goes on to explain that objections of M.S. based on demands of special local circumstances or economic interest groups have been dismissed by the Court in the past.

Technical appreciation of the impact of simplified met-correction

Of all 4 interim computation methods, NMPB/XP S 31-133 provides the most advanced method to account for meteorological influences. In France, a study was conducted to illustrate the effect of different settings of “favourable” conditions. The study clearly show that the spread between 40% favourable and 100% favourable is less than 2 dB in most cases, with some exceptional conditions reaching 5 dB (that is a situation where all of the following is simultaneously asserted: 40% of favourable conditions, worst case ground effect and worst case diffracting edges).

Errors introduced by lack of accuracy in source and topological data are expected to be significantly higher.

It must be noted that the use of meteorological correction in NMPB/XP S 31-133 depends on the boundary conditions. On sites that do not comply with these boundary conditions, a met-correction is not possible. Similar restrictions do not apply to ISO 9613-2.

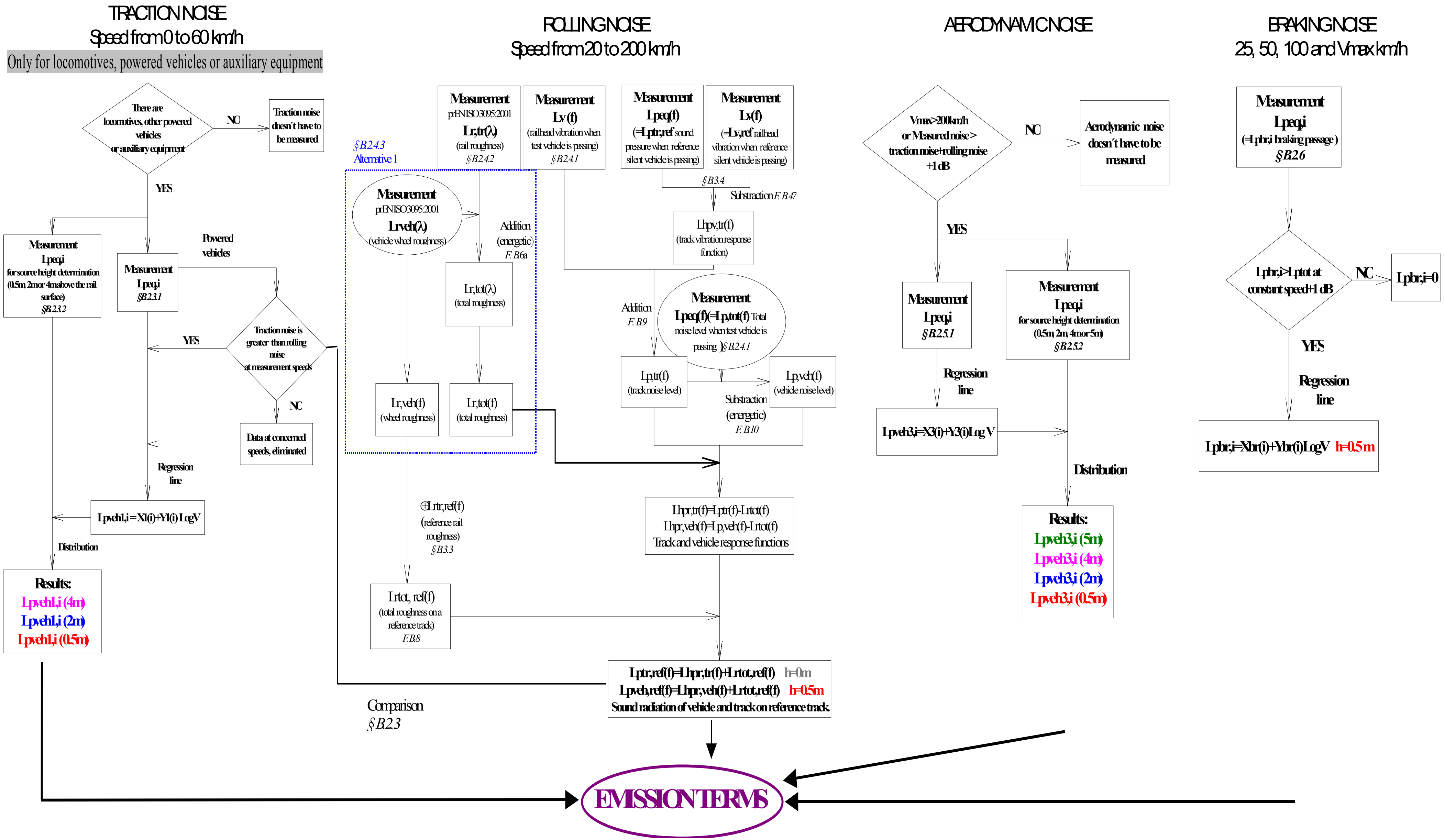
Conclusions

This report has produced evidence of the application of the prevention principle to noise. In addition, further evidence has been produced to justify the application of the precautionary principle with regard to environmental noise. Some indications have been shown of EU M.S. attempting unsuccessfully to draw back from implementing Directives on the grounds that they are restrictive. Finally, technical implications have been illustrated to show that the actual effect of using a simplified approach to account for meteorological correction required to produce the noise indicators defined in the Directive 2002/49/EC as long-term sound levels according to ISO 1996-2:1987 is small.

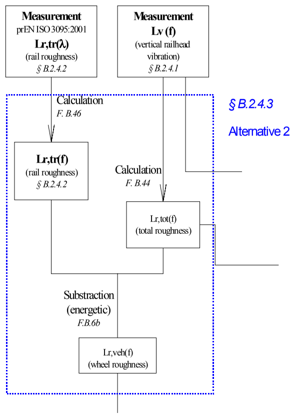
It is therefore concluded that the proposed approach of allowing either the use of elaborate meteorological data properly describing the average year (thus a statistical analysis of at least ten years of local meteorological data) on the site studied, or the use of a simplified met-correction is both sustainable and supported by current EU praxis.

ANNEX II
SRM II – Emission Data
Measurement Method B

FLOWCHART B: CHARACTERISATION OF RAILWAY ROLLING STOCK



ROLLING NOISE (Alternative 2)



EMISSION IN DB(A) on reference track

§ B.2.7.1

Partial contributions are not defined in source heights

Lptotal,i= Lpveh1,i; Lptr,ref,i; Lpveh,ref,i; Lpveh3,i; Lpbr,i

EMISSION IN OCTAVE BANDS at the relevant source heights on reference track.

§ B.2.7.2

h=5 m Lpveh3,i

h=4 m Lpveh1,i; Lpveh3,i

h=2 m Lpveh1,i; Lpveh3,i

h=0.5m Lpveh1,i; Lpveh,ref; Lpveh3,i or

h=0 m Lptr,ref